

# HANDBOOK OF GEOSYNTHETICS



The Geosynthetic Materials Association (GMA) represents all segments of the geosynthetics industry, including manufacturers as well as 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. For additional information please contact GMA, tel: 651/225-6907 or 800/636-5042; e-mail: [amaho@ifai.com](mailto:amaho@ifai.com) or [www.gmanow.com](http://www.gmanow.com).

**Handbook of Geosynthetics**

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## PREFACE

### Dealing with Difficult Sites

In the past, when dealing with difficult sites for construction purposes, the conventional practice was limited to either replacing the unsuitable soils, or bypassing them with costly deep foundations. Additionally, the age-old problem of land scarcity and the need to rebuild aging infrastructure in urban areas, increased realization of seismic hazards, and regulations mandated for various environmental problems, have been the impetus for the evolution of a number of ground improvement techniques during the past 35 years. Innovative ground modification approaches are routinely used now to solve unique soil-related problems, and often are considered to be the most economical means to improve an undesirable site condition.

Geosynthetics have proven to be among the most versatile and cost-effective ground modification materials. Their use has expanded rapidly into nearly all areas of civil, geotechnical, environmental, coastal, and hydraulic engineering.

This handbook 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.

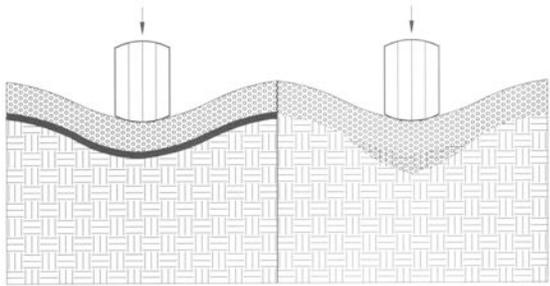
### Geosynthetic Advantages

Geosynthetics, including geotextiles, geomembranes, geonets, geogrids, geocomposites and geosynthetic clay liners, often used in combination with conventional materials, offer the following advantages over traditional materials:

- **Space Savings** - Sheet-like, geosynthetics take up much less space in the landfill than do comparable soil and aggregate layers.
- **Material Quality Control** - Soil and aggregate are generally heterogeneous materials that may vary significantly across a site or borrow area. Geosynthetics on the other hand are relatively homogeneous because they are manufactured under tightly controlled conditions in a factory. They undergo rigorous quality control to minimize material variation.
- **Construction Quality Control** - Geosynthetics are manufactured and often factory “prefabricated” into large sheets. This minimizes the required number of field connections, or seams. Both factory and field seams are made and tested by trained technicians. Conversely, soil and aggregate layers are constructed in place and are subject to variations caused by weather, handling and placement.
- **Cost Savings** - Often geosynthetic materials are less costly to purchase, transport and install than soils and aggregates.
- **Technical Superiority** - Geosynthetics have been engineered for optimal performance, i.e. much lower permeability, drainage efficiency and clogging resistance.
- **Construction Timing** - Geosynthetics can be installed quickly, providing the flexibility to construct during short construction seasons, breaks in inclement weather, or without the need to demobilize and remobilize the earthwork contractor.
- **Material Deployment** - Layers of geosynthetics are deployed sequentially, but with a minimum of stagger between layers, allowing a single crew to efficiently deploy multiple geosynthetic layers.
- **Material Availability** - Numerous suppliers of most geosynthetics and ease of shipping insure competitive pricing and ready availability of materials.

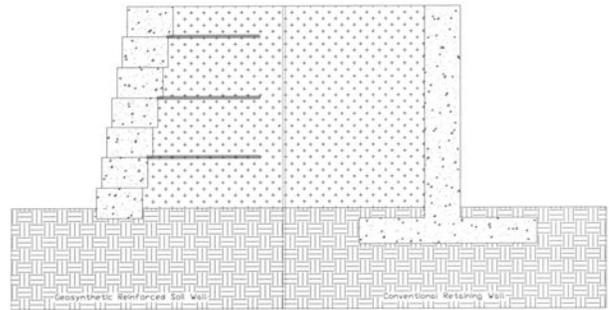
# INTRODUCTION TO GEOSYNTHETICS

## SEPARATION



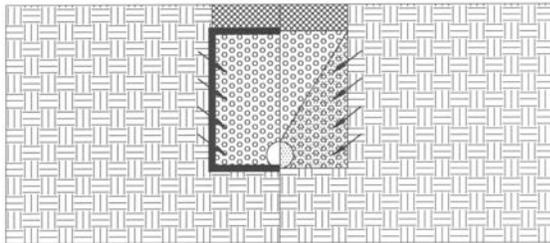
With a Geotextile      Without a Geotextile

## REINFORCEMENT



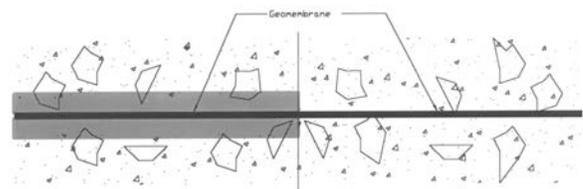
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## FILTRATION



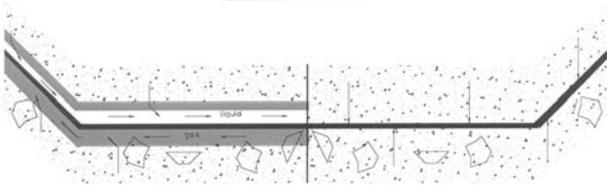
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## PROTECTION/CUSHION



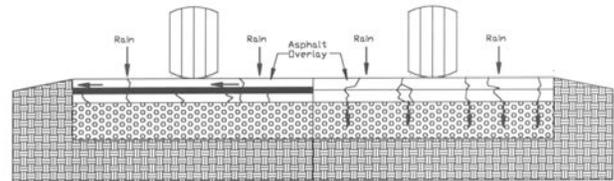
With Geotextiles      Without Geotextiles

## PLANAR FLOW



With Geotextiles      Without Geotextiles

## FLUID BARRIER



With a Paving Fabric      Without a Paving Fabric

## Geosynthetics

Geosynthetics are a rapidly emerging family of geomaterials used in a wide variety of civil engineering applications. Many polymers (plastics) common to everyday life are found in geosynthetics. The most common are polyolefins and polyester; although rubber, fiberglass, and natural materials are sometimes used. Geosynthetics may be used to function as a separator, filter, planar drain, reinforcement, cushion/protection, and/or as a liquid and gas barrier. The various types of geosynthetics available, along with their specific applications, are discussed in subsequent sections.

## Geotextiles

### *Geotextile Polymers*

Almost all geotextiles available in the United States are manufactured from either polyester or polypropylene.

Polypropylene is lighter than water (specific gravity of 0.9) and is strong and durable. Polypropylene filaments and staple fibers are used in manufacturing woven yarns and nonwoven geotextiles.

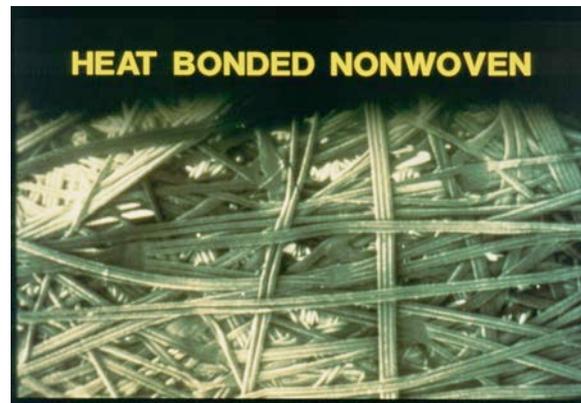
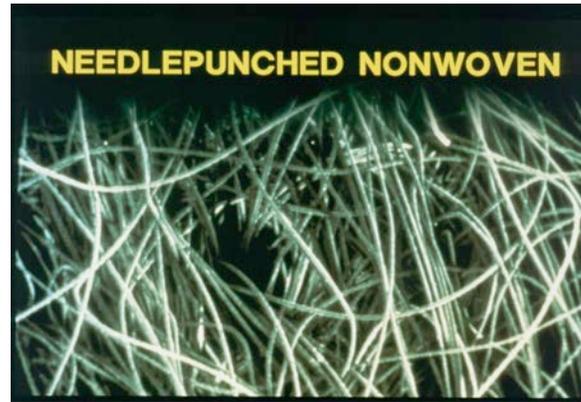
High tenacity polyester fibers and yarns are also used in the manufacturing of geotextiles. Polyester is heavier than water, has excellent strength and creep properties, and is compatible with most common soil environments.

### *Geotextile Structures*

There are two principal geotextile types, or structures: wovens and nonwovens. Other manufacturing techniques, for example knitting and stitch bonding, are occasionally used in the manufacture of specialty products.

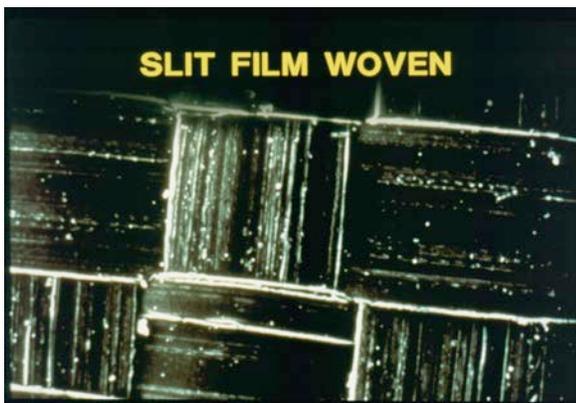
Nonwovens. Nonwoven geotextiles are manufactured from either staple fibers (staple fibers are short, usually 1 to 4 inches in length) or continuous filaments randomly distributed in layers onto a moving belt to form a felt-like "web". The web then passes through a needle loom and/or other bonding machine interlocking the fibers/filaments. Nonwoven geotextiles are highly desirable for subsurface drainage and

erosion control applications as well as for road stabilization over wet moisture sensitive soils.

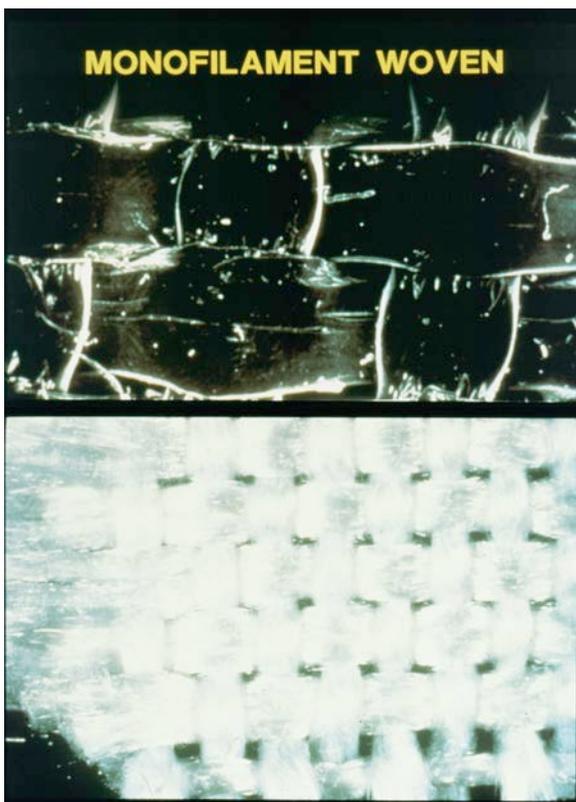


Wovens. Weaving is a process of interlacing yarns to make a fabric. Woven geotextiles are made from weaving monofilament, multifilament, or slit film yarns. Slit film yarns can be further subdivided into flat tapes and fibrillated (or spider web-like) yarns. There are two steps in this process of making a woven geotextile: first, manufacture of the filaments or slitting the film to create yarns; and second, weaving the yarns to form the geotextile.

Slit film fabrics are normally used for sediment control, i.e. silt fence, and road stabilization applications but are poor choices for subsurface drainage and erosion control applications. Due to the structure of the flat tape slit film yarns, these fabrics have relatively poor permeability. However, fabrics made with fibrillated tape yarns are usually stronger and have better permeability than flat tape products.



Monofilament wovens have better permeability and making them suitable for certain drainage and erosion control applications. High strength multifilament wovens are primarily used in reinforcement applications.

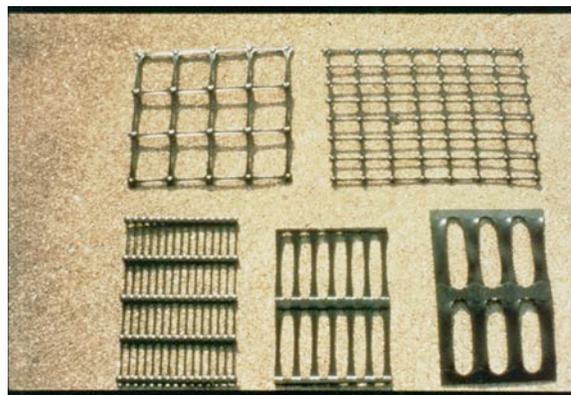


Multifilament Woven

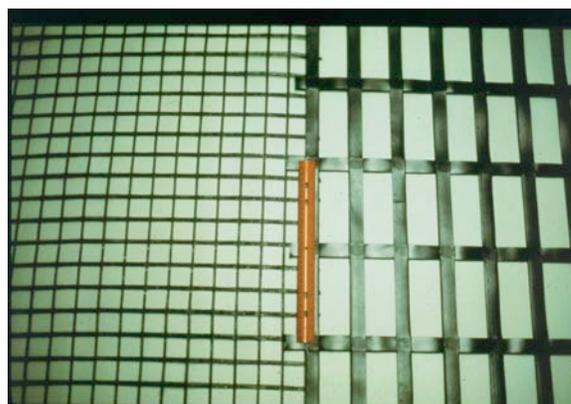
### Geogrids

Geogrids are gridlike polymeric materials usually made from punching holes in and stretching sheets of high-density polyethylene or polypropylene or by weaving or knitting and coating high tenacity polyester yarns. The resulting grid structure possesses large open spaces (called apertures) ranging from 0.5 to 4.0

in. (1 to 10 cm), which enhance interaction with the soil. The high tensile strength and stiffness, or modulus, of geogrids makes them especially appropriate for soil reinforcement.



Punched/Drawn Geogrid



Woven/Coated Geogrid

### Geonets

Geonets are a 3-dimensional matrix of polymer strands utilized for in-plane drainage. Nearly all geonets are made of polyethylene. The molten polymer is extruded through slits in counter-rotating dies, forming a matrix, or “net” of closely spaced “stacked” ribs.



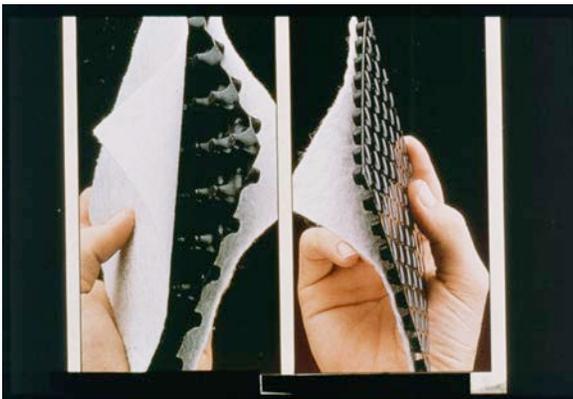
Geonet

**Geocomposites**

The possibility of combining the superior features of various geosynthetics has rendered a host of so called "geocomposite" materials. There is a large number of possibilities in assembling different materials, only limited by one's ingenuity and imagination.

*Drainage Geocomposites*

The most common geocomposite configuration is known as a drainage geocomposite. Drainage geocomposites are composed of a geotextile filter surrounding either a geonet (blanket drain), a thick preformed core (panel or edge drain), or a thin preformed core (wick drain). Some applications of drainage geocomposites are blanket drains, panel drains, edge drains and wick drains.



Double- and single-sided geocomposite drains

*Blanket Drains* – Blanket drains are commonly used as leachate or infiltration collection and removal layers within landfills.



Blanket Drain

*Panel Drains* - Panel drains can be placed adjacent to structures to reduce hydrostatic pressures.



Panel Drain



Edge Drain

*Edge Drains* – Edge drains are often used adjacent to pavement structures to collect and remove lateral seepage from the road base.

*Wick Drains* – Wick drains are pushed deep into the ground, providing drainage paths to expedite the consolidation of saturated soils, significantly decreasing the settlement time of embankments over soft soils.



Wick Drain

*Other Geocomposites* - Many other geocomposite products have been developed. For example, high strength yarns have been knitted into a nonwoven to produce a product that is both strong (via the yarns) and which has controlled permeability characteristics (provided by the non woven).

## Geomembranes

Geomembranes are relatively impermeable sheets of plastic. There are two general categories of geomembranes: calendered and extruded.

### *Calendered Geomembranes*

Calendered geomembranes are formed by working and flattening a molten viscous formulation between counterrotating rollers. Polyvinyl chloride (PVC), chlorosulfonated polyethylene (CSPE), chlorinated polyethylene (CPE), and, more recently, polypropylene (PP) are the most common calendered geomembranes. Specialty ethylene interpolymer alloy (EIA) geomembranes are used for unique applications. In most cases these engineered films are supported by a textile that provides tensile strength and enhances tear and puncture resistance.



Calendered Geomembrane

### *Extruded Geomembranes*

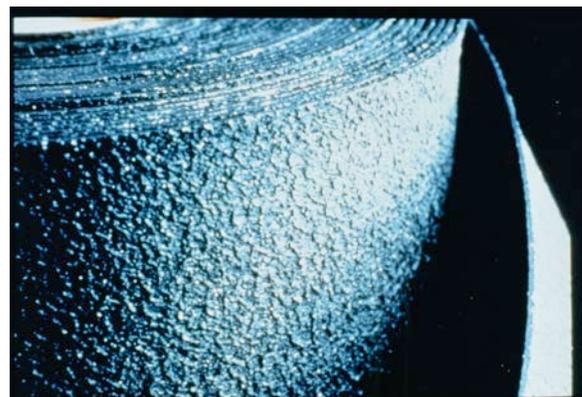
Extruded geomembranes are manufactured by melting polymer resin, or chips, and forcing the

molten polymer through a die using a screw-extruder. The sheet is formed either by a flat horizontal die or through a vertically oriented circular die to form either a flat wide sheet advanced on a conveyor belt, or cylindrical tube of "blown film", filled with air which is collapsed and pulled by nip rollers mounted high above the die. Blown film geomembranes must be slit prior to wind-up. Common extruded geomembranes include high-density polyethylene (HDPE) and various lower density, or very flexible, polyethylenes (VFPE). Polypropylene (PP) is a relatively new type of extruded (as well as calendered) geomembrane.



Extruded Geomembrane

Variations in the manufacturing of geomembranes include texturing to enhance the interface friction between the geomembrane and adjacent soils or other geosynthetics; co-extruding different polymers into a single sheet to provide enhanced durability; and the availability of multiple thicknesses and sheet sizes.



Close-up of texturing



### Geosynthetic Clay Liners (GCLs)

Geosynthetic clay liners (GCLs) are thin layers of finely-ground bentonite clay. When wetted, the clay swells and becomes a very effective hydraulic barrier. GCLs are manufactured by sandwiching the bentonite within or layering it on geotextiles and/or geomembranes, bonding the layers with needling, stitching and/or chemical adhesives. The preferred sodium bentonite clay occurs naturally in Wyoming, North Dakota and Montana in the U.S. GCLs are commonly used to augment or replace compacted clay layers or geomembrane liners.



GCL

### Geopipe

Another significant product which has been “adopted” as a geosynthetic is plastic pipe. The specific polymer resins used in the manufacturing of plastic pipes are: polyvinyl chloride (PVC), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), acrylonitrile butadiene styrene (ABS), and cellulose acetate buytrate (CAB). There is a wide variety of civil engineering applications for these products, including: highway and railway edge drains, interceptor drains, and leachate removal systems.



Geopipe

### Geofoam

A relatively new category of geosynthetic product is geofoam, which is the generic name for any foam material utilized for geotechnical applications. Geofoam is manufactured into large blocks which are stacked to form a light-weight, thermally insulating mass buried within a soil or pavement structure. The most common type of polymer used in manufacturing of geofoam materials is polystyrene. Typical applications of geofoams include: within soil embankments built over soft, weak soils; under roads, airfield pavements and railway track systems subject to excessive freeze-thaw conditions; and beneath on-grade storage tanks containing cold liquids.



Geofoam

**Erosion and Sediment Control Materials**

Geosynthetics are used extensively in erosion and sediment control systems such as:

- Long-term, nondegradable materials to extend the erosion control limits of vegetation, soil, or rock;
- Silt fences and turbidity curtains;

*Erosion Control*

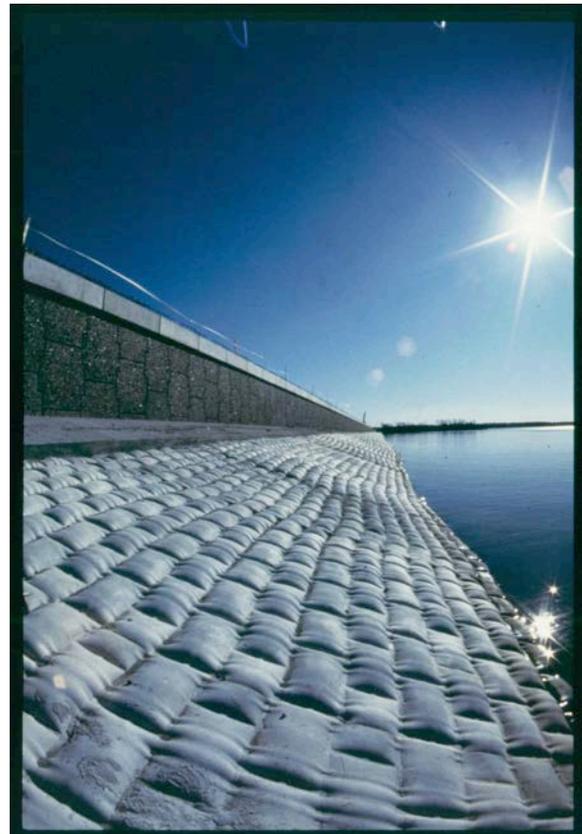
Geosynthetic erosion control materials include turf reinforcement mats (TRM), fabric formed revetments (FFR), and geocellular confinement systems (GCS).

*Turf Reinforcement Mats (TRM)* – Turf reinforcement mats (TRMs) are 3-dimensional structures composed of fused polymer nettings, randomly laid monofilaments, or more recently yarns woven or tufted into an open, dimensionally stable mat. These flexible, synthetic, 3-dimensional mats are designed to be used in conjunction with topsoil and seed or turf to create strong, durable and continuous soil-root-mat matrices which can provide nearly twice the erosion protection of plain grass alone.



Turf Reinforcement Mats (before and after germination)

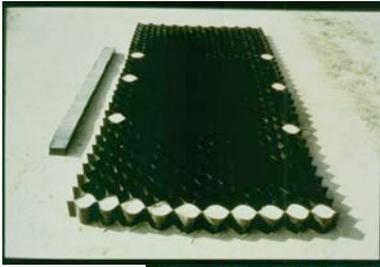
*Fabric Formed Revetments (FFR)* – Fabric formed revetments (FFR) are constructed by pumping a very fluid fine-aggregate grout into a fabric envelope consisting of 2 layers connected by tie-chords or by interweaving. FFRs provide the durability of rigid linings, such as cast-in-place concrete or asphaltic concrete. FFRs can be engineered to perform as barriers or to be highly permeable, and they can be stiff or as flexible as protective rock systems such as riprap or gabions.



Fabric Formed Revetments

*Geocellular Confinement Systems (GCS)* –

Geocellular confinement systems (GCS) are 3-dimensional honeycomb-like structures filled with soil, rock or concrete. The GCS structure, often called a geocell, is made of strips of polymer sheet or geotextile connected at staggered points so that, when the strips are pulled apart, a large honey-comb mat is formed. The GCS provides both a physical containment of a depth of soil and a transfer of load through the GCS.



Geocellular Confinement Systems

### *Sediment Control*

Geosynthetic sediment control materials include silt fences and turbidity curtains.

*Silt Fence* – A well-designed silt fence is made of a durable geotextile attached to support posts with the bottom edge securely buried. It performs as follows:

- It initially screens silt and sand particles from runoff.
- A soil filter is formed adjacent to the silt fence and reduces the ability of water to flow through the fence.
- This leads to the creation of a pond behind the fence, which serves as a sedimentation basin to collect suspended soils from runoff water.



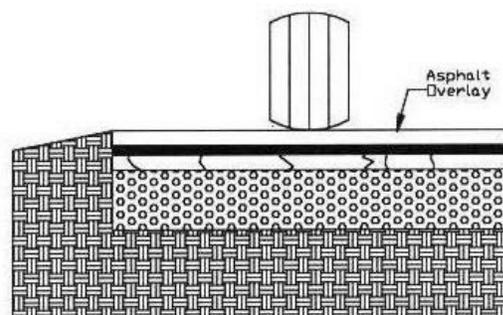
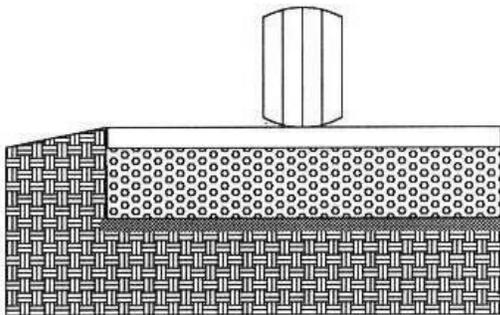
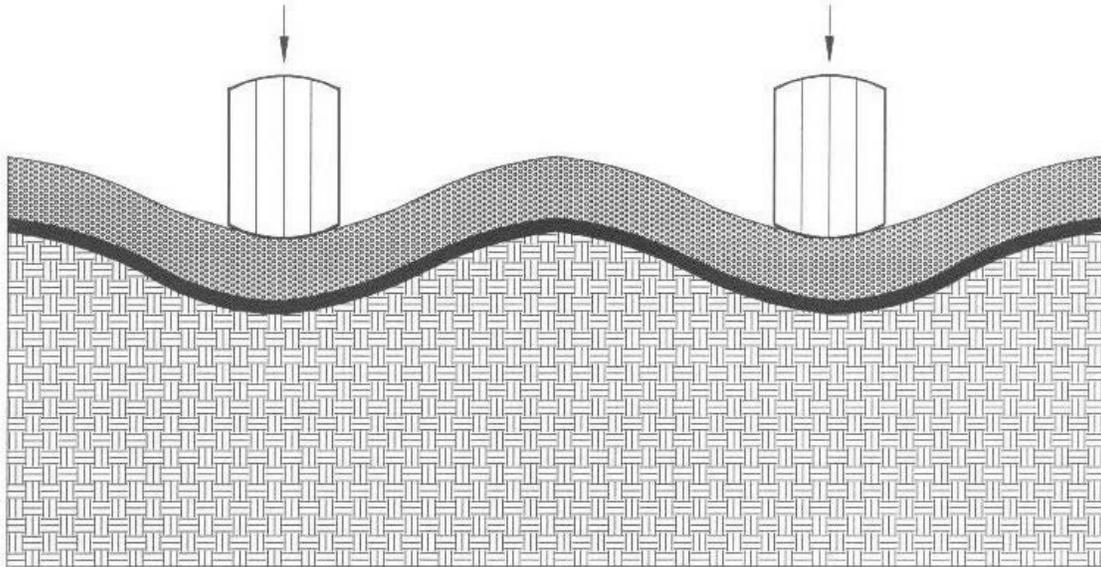
Silt Fence

*Turbidity Curtains* - Turbidity curtains are reusable floating geosynthetic panels that prevent water-polluting sediment from shore-side construction or off-shore filling and dredging operations from moving off-site. The top edge of each curtain contains floats and a cable or chain. Weights are attached to the lower edge of the curtain to keep it vertical in the water. Posts, piling, or anchors hold the curtains in place. Generally, they are intended for use with currents no greater than about 1.5 m/s and to depths of no more than 5 to 8 m.



Turbidity Curtain

# GEOSYNTHETICS IN ROADS AND PAVEMENTS: Subgrade Separation and Stabilization, Base Reinforcement, Overlay Stress Absorption and Reinforcement



## OVERVIEW

A large variety of detrimental factors affect the service life of roads and pavements including environmental factors, subgrade conditions, traffic loading, utility cuts, road widenings, and aging. These factors contribute to an equally wide variety of pavement conditions and problems which must be addressed in the maintenance or rehabilitation of the pavements, if not dealt with during initial construction.

Pavement maintenance treatments are often ineffective and short lived due to their inability to both treat the cause of the problems and renew the existing pavement condition. The main cause of distress in pavements is that they are quite permeable with 30 to 50% of precipitation surface water infiltrating through the pavement, softening and weakening the pavement subgrade and base, accelerating pavement degradation. Existing pavement distress such as surface cracks, rocking joints, and subgrade failures cause the rapid reflection of cracking up through the maintenance treatment.

Therefore, the preferred strategy for long-term road and pavement performance is to build in safeguards during initial construction. These performance safeguards include stabilizing the subgrade against moisture intrusion and associated weakening; strengthening road base aggregate without preventing efficient drainage of infiltrated water; and, as a last resort, enhancing the stress absorption and moisture proofing capabilities of selected maintenance treatments. Geosynthetics have proven to be cost effective tools for safeguarding roads and pavements in these ways.

The four main applications for geosynthetics in roads are subgrade separation and stabilization, base reinforcement, overlay stress absorption, and overlay reinforcement. Subgrade stabilization and base reinforcement involve improving the road structure as it is constructed by inserting an appropriate geosynthetic layer.

Subgrade separation and stabilization applies geosynthetics to unpaved roads although geosynthetics may be used as separators in paved roads as well. Base reinforcement is the use of geosynthetics to improve the structure of a paved road.

Geosynthetics are also helpful in rehabilitating distressed road surfaces. The application of a layer of asphalt called an overlay is often the solution for damaged pavement. Geosynthetics can be used as interlayers by placing them below or within the overlay. Some geosynthetics relieve stress and others are able to reinforce the overlay.

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

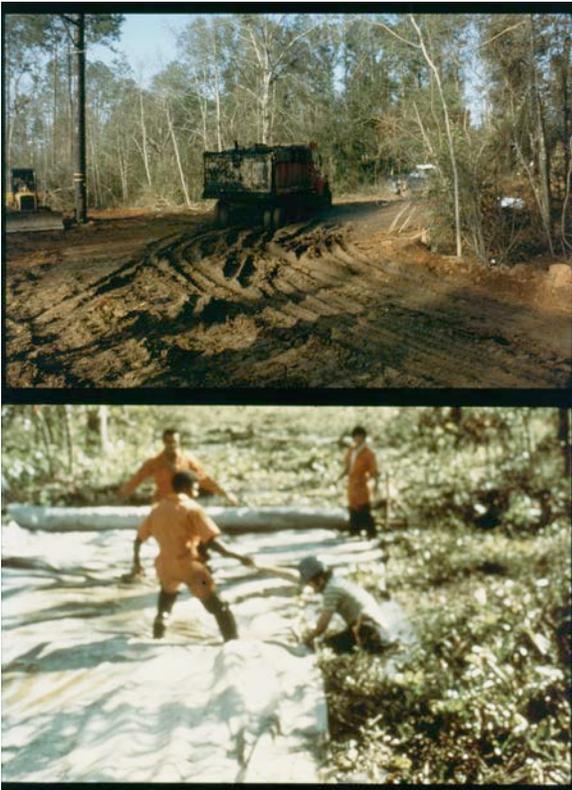


Early Use of Geosynthetics in Road Structures in South Carolina in the 1930's

## SUBGRADE SEPARATION AND STABILIZATION

### Introduction to the Problem

Temporary roads used for hauling and access roads that are subject to low volumes of traffic are often constructed without asphalt or cement concrete surfacing. In these cases, a layer of aggregate is placed on the prepared subgrade of these roads to improve their load carrying capacity. Problems are usually encountered when the subgrade consists of soft clays, silts and organic soils. This type of subgrade is often unable to adequately support traffic loads and must be improved.



Typical poor subgrade conditions

### Typical Solutions

Excavating and replacing unsuitable materials is costly and time consuming. Other methods of subgrade improvement include deep compaction, chemical stabilization and pre-loading.

### The Geosynthetic Solution

Geosynthetics are proving to be a cost effective

alternative to traditional road construction methods. As a result, the application of geosynthetics to the construction of unpaved roads over soft subsoils has become quite popular. Design has focused on the reinforcement of the aggregate and has led to the identification of two important functions: lateral restraint and membrane action. Lateral restraint is the lateral interaction between the aggregate and the geosynthetic. The presence of the geosynthetic creates pressure in the aggregate that improves the strength and stiffness of the road structure. Membrane action is the ability of a geosynthetic material to reduce and spread stress arising from the weak subgrade. Additionally, when a geogrid is involved, a third function can be described: enhanced load distribution within the aggregate.

### Separation

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



GEOSYNTHETICS IN ROADS AND PAVEMENTS:  
Subgrade Separation and Stabilization, Base Reinforcement, Overlay Stress Absorption and Reinforcement

A separation geotextile prevents the engineered fill for this parking area from mixing with the soft subgrade.

### *Stabilization*

For larger rut depths, more strain is induced in the geosynthetic. Thus the stiffness properties of the geosynthetic are essential. A considerable reduction in aggregate thickness is possible by the use of a geosynthetic that has a high modulus in the direction perpendicular to the road centerline; however, the benefits of the geosynthetic are not wholly dependent on the membrane action achieved with a stiff geosynthetic. Lateral restraint produced by the interaction between the geosynthetic and the aggregate is equally important. In general, the following conclusions can be drawn relating to a 12 inch base.

- A reinforcement element that functions primarily as a separator but relatively little as reinforcement will provide a load distribution improvement ratio in the range of 1.1 to 1.4. (separation geotextiles)
- A reinforcement element that functions primarily as a reinforcement but relatively little as separator will provide a load distribution improvement ratio in the range of 1.7 to 2.2. (stabilization geogrids)
- A reinforcement element that functions both as a separator and as reinforcement will provide a load distribution improvement ratio in the range of 2.0 to 2.5. (separation geotextile + stabilization geogrid or stabilization geotextile)



A stabilization geotextile facilitates construction over weak subgrades



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



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

### **Design for Stabilization**

The design of geosynthetic-reinforced unpaved roadways has been simplified into design charts that relate aggregate thickness requirements to a range of subgrade strengths, based on standard highway design loading and various allowable rut depths.

## BASE REINFORCEMENT

### Introduction to the Problem

Permanent roads carry larger traffic volumes and typically have asphalt or cement concrete surfacing over a base layer of aggregate. The combined surface and base layers act together to support and distribute traffic loading to the subgrade. Problems are usually encountered when the subgrade consists of soft clays, silts and organic soils. This type of subgrade is often unable to adequately support traffic loads and must be improved. If unimproved subgrade will worsen as a result of penetration of the aggregate into the subgrade and an increase in the subgrade's moisture content.



Poor roads often result from poor subgrades

Aggregate (SGA) system gains stiffness. The stiffened SGA system is better able to provide the following structural benefits:

- 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



Geogrid base reinforcement stiffens the aggregate base layer providing long-term support for the paved surface.

### Typical Solutions

As with unpaved roads, a problematic subgrade is typically excavated and replaced, or it is improved by the addition of cement, lime, or excess aggregate. In any case, the traditional solution is often costly and always time consuming.

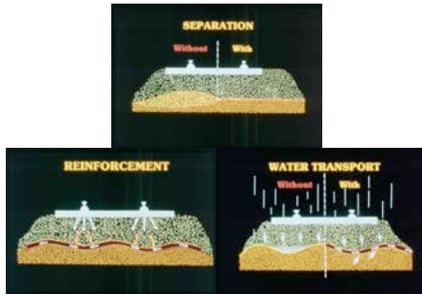
### The Geosynthetic Solution

As was noted earlier, geosynthetics are proving to be a cost effective alternative to traditional road construction methods. In paved roads, lateral restraint also called confinement is considered to be the primary function of the geosynthetic. With the addition of an appropriate geosynthetic, the Soil-Geosynthetic-

### Geosynthetic Benefits

The Geosynthetics Materials Association (GMA) recently commissioned an in-depth review of geosynthetic base reinforcement. The review identified the most common method for quantifying geosynthetic benefits is the determination of a Traffic Benefit Ratio (TBR) as the “measure” of base course reinforcement performance. 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 general, geogrids have been found to provide a TBR in the range of 1.5 to 70 while geotextiles have provided TBRs in the range of 1.5 to 10.

**THE SPECIAL CASE OF RAILROADS –  
Separation + Reinforcement + Planar Flow**



Railroad maintenance operations can include the insertion of a geotextile during undercutting



“stabilized” (upper) vs. “unstabilized” (lower) track



This rail line reconstruction benefited from both a nonwoven geotextile and a reinforcing geogrid



A new rail line in an area of high groundwater is built over a heavy weight nonwoven geotextile

## INSTALLATION OF GEOSYNTHETICS FOR SEPARATION, STABILIZATION, AND BASE REINFORCEMENT

### Site Preparation

Clear and grade the installation area. Remove all sharp objects and large stones. Cut trees and shrubs flush with the subgrade. Removal of topsoil and vegetation mat is not necessary.

Any soft spots or low areas are unsuitable for geosynthetic installation. Excavate these areas, backfill with select material, and compact so that the filled area provides equal stability as adjacent areas. The problem area may be enhanced by using a geosynthetic at the bottom of the excavation prior to backfilling.

### Deployment of the Geosynthetic

Unroll the geosynthetic on the prepared subgrade in the direction of construction traffic. Hold the geosynthetic in place with pins, staples, fill material or rocks. Adjacent rolls should overlap in the direction of the construction. Depending on the strength of the subgrade, the overlaps may have to be sewn.

Overlap Specifications

Soil Strength (CBR)	Overlap Unsewn (in.)	Overlap Sewn (in.)
Less than 1	-	9
1 – 2	38	8
2 – 3	30	3
3 & Above	24	-



Water sensitive subgrades can often be graded when dry



When more challenging subgrades are encountered it is usually more effective to leave vegetation and construction debris in place

### Placement of the Aggregate

Place the aggregate by back dumping on to the geosynthetic or by end dumping onto previously placed aggregate and then spreading it on to the geosynthetic with a motor grader or bulldozer. On subgrades having a CBR < 1, a sufficient layer of aggregate must be maintained beneath all equipment while dumping and spreading to minimize the potential of localized subgrade failure.

Avoid traffic directly on the geosynthetic. When using construction equipment on the aggregate, try to avoid any sudden stops, starts or sharp turns.

Maintain a minimum lift thickness of six inches except in cases of low volume roads. Smooth the aggregate to the specified density using a drum roller. Fill any ruts with additional subbase and compact as specified.



Fabric Rolled Out and Overlapped (or seamed)



Aggregate spreading



If the subgrade is firm and free of debris, run and dump placement of aggregate may be used



Aggregate compaction



When constructing over weak subgrades, back-dumping of the aggregate is required

Normal construction activities, including aggregate spreading and compaction are used. Caution should be used when selecting compaction equipment. When thin lifts are used, vibratory compaction is not recommended. Use of such equipment may result in damage to the geosynthetic.

### Damage Repair

Repair damaged geosynthetics immediately. Clear the damaged area and an additional three feet around it of all fill material. Cover the cleared area with a piece of the geosynthetic extending. The patch should extend three feet beyond the perimeter of damage. Replace the aggregate and compact to the specified density.



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.

## OVERLAY STRESS ABSORPTION AND REINFORCEMENT

### Introduction to the Problem

Road surfaces must be maintained regularly. Commonly a paved road becomes a candidate for maintenance when its surface shows significant cracks and potholes. The rehabilitation of cracked roads by simple overlaying is rarely a durable solution. The cracks under the overlay rapidly propagate through to the new surface. This phenomenon is called reflective cracking.

Cracks in the pavement surface cause numerous problems, including:

- Riding discomfort for the users
- Reduction of safety
- Infiltration of water and subsequent reduction of the bearing capacity of the subgrade
- Pumping of soil particles through the crack
- Progressive degradation of the road structure in the vicinity of the cracks due to stress concentrations



Typical Cracked Pavement

### Typical Solutions

In spite of reflective cracking, overlays are still the only viable option for extending the life of distressed pavement. To lengthen the lifetime of an overlay, special asphalt mixes can be specified. Also, the thicker the overlay the longer it will last. Thick overlays are expensive as are special asphalt mixes, but the alternative is reconstruction. Depending on the cause of the problem, this can involve removing layers of pavement, improving subgrades, and repaving. This is extraordinarily expensive and time consuming.

### The Geosynthetic Solution

A geosynthetic interlayer can be placed over the distressed pavement or within the overlay to create an overlay system. The geosynthetic interlayer can contribute to the life of the overlay via stress relief and/or reinforcement.

A stress relieving interlayer retards the development of reflective cracks by absorbing the stresses that arise from the damaged pavement. It also waterproofs the pavement so that when cracking does occur, water cannot worsen the situation.

Reinforcement occurs when an interlayer is able to contribute significant tensile strength to the pavement system. The reinforcement attempts to prevent the cracked old pavement from moving under traffic loads and thermal stress by holding the cracks together.

Newly manufactured composites can provide both stress relief and reinforcement.

The benefits of geosynthetic interlayers include:

- Saving 1.3 to 2 inches of overlay thickness
- Delaying the appearance of reflective cracks
- Lengthening the useful life of the overlay



Paving Fabric for Stress Absorption



Paving Grid for Overlay Reinforcement

## Geosynthetic Benefits

### *Stress Relief*

Nonwoven geotextiles, a.k.a. paving fabrics, have high elongation and low tensile strength and are commonly used for stress relief. When saturated with asphalt, the flexible interlayer allows considerable movement around a crack but nullifies or at least lessens the effect the movements have on the overlay. This type of interlayer also waterproofs the road structure.

The crucial parameters in a stress relieving overlay system are the overlay thickness and the tack coat application rate. The addition of the interlayer allows the overlay thickness be reduced by as much as 1.3 inches; however, the overlay must be at least 1.5 inches thick. Tack coat application rates vary with temperature and site specific conditions. Too much tack coat can cause the liquid asphalt to bleed up through the overlay; too little will cause the overlay to slip and will not waterproof the structure.

### *Reinforcement*

To reinforce, an interlayer has to hold the crack together and dissipate the crack propagation stress along its length. If the interlayer elongates under stress, it will allow the crack to open. Consequently, the interlayer must have high axial stiffness so that little elongation takes place. When used over a leveling course or a nonwoven paving fabric, the grid can hold the overlay together while allowing the cracked pavement underneath to move independently.



The benefits of paving fabric are important in this overlay of I-70

## THE SPECIAL CASE OF CHIP SEALS Moisture Proofing + Low Cost Resurfacing



As with overlays, paving fabric is installed over the distressed pavement. A typical chip seal is then applied

GEOSYNTHETICS IN ROADS AND PAVEMENTS:  
Subgrade Separation and Stabilization, Base Reinforcement, Overlay Stress Absorption and Reinforcement

over the fabric providing a moisture proofing layer that  
also prevents surface raveling

## INSTALLATION OF INTERLAYERS

The key to the performance of overlay systems is proper installation. There are four steps in the installation of an overlay system with a geosynthetic interlayer. Surface preparation is followed by the application of the tack coat, installation of the geosynthetic, and finally the placement of the asphalt overlay.

### Surface Preparation

Clean the roadway of dirt, water, oil and debris. Smaller cracks should be sealed. Large cracks in excess of 1/8 inch (0.32 cm) and potholes should be filled. Milling of severely cracked pavement may be required, or a thin layer of asphalt called a leveling course may be applied. Sections of broken asphalt that sink when loaded should be removed down to the subgrade and reconstructed. The old surface should be dry and clean at the conclusion of this step.



Sweeping is an important part of surface preparation



Tack Coat Application and Fabric Laydown

### Application of the Tack Coat

Proper installation of the asphalt cement tack coat is crucial; mistakes can lead to early failure of the overlay. Uncut paving grade asphalt cements are recommended with AC-20 and AR-4000 being the most popular. Emulsions can be used successfully, but they must be applied at a higher rate and allowed to cure completely. The proper grade will be chosen with regard to climate, geography and time of year. The grade of the tack coat and the asphalt used in the overlay should match. The maximum temperature of the tack coat is 163°C, and the minimum is between 138-143°C.

The distributor truck must be capable of uniform application of the tack coat. The bar should be adjusted to obtain uniformity and the correct width of spray usually 5.1 to 7.6 cm past the edge of the geosynthetic. The spray of the nozzles should overlap so that uniform double coverage occurs. Heavy spots, streaks, or gaps will cause problems in the system. As spraying begins and ends, care should be taken to avoid dripping and unevenness.

For a typical paving fabric, the application rate is 0.25gal/yd<sup>2</sup> (1.13 L/m<sup>2</sup>). The waterproofing element of a stress absorbing system will not be present unless the fabric absorbs more than 0.68 L/m<sup>2</sup>. The membrane attains optimum impermeability between .73 and .77 L/m<sup>2</sup>. The roughness of the surface, the porosity of the road, and the presence or absence of a leveling course effect the desired application rate. Once in progress, the rate of application should be measured and verified.



Paving Grid Laydown

Geogrid and geocomposite systems vary. Therefore, the manufacturer's recommendations for tack coat, if any, should be followed.

**Deployment of the Geosynthetic**

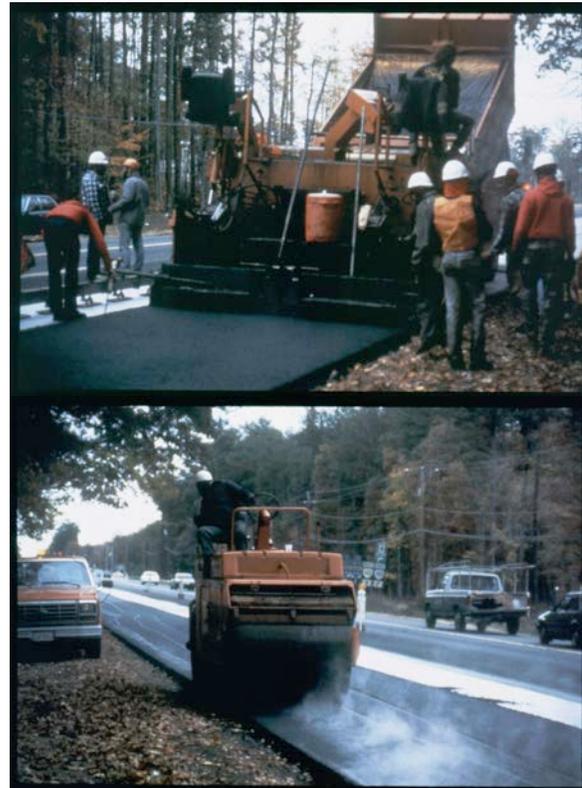
Geosynthetics may be deployed manually or mechanically with equipment designed specifically for this application. In either case, the geosynthetic must not be allowed to wrinkle. The surface temperature of the tack coat should not exceed 164°C when a paving fabric is deployed. In cool weather, the paving fabric needs to be placed as soon after the tack coat as possible. Allowing time for the tack coat to set and become sticky is advisable in hot weather.

The fuzzy side of the paving fabric should be laid down into the tack coat leaving the smooth side up. The fabric should be broomed into the tack coat. In cool weather, rolling may be required to force the fabric to adhere to the surface. When two segments of fabric come together, an overlap of 2.5 to 7.6 cm should be created and treated with extra tack coat. The overlap should be shingled in the direction of the paving operation.

To install a geogrid, the leading edge of the first roll must be attached to the old asphalt using nails about 1-1/2 inches long (40 mm) and flat washers about 1-3/8 inches (36 mm) in diameter. At each roll change, place the leading edge under the preceding roll and secure the lap by nailing to the old asphalt. On roads without curbs, the geogrid must be placed 4 inches (100 mm) from the edge of the roadway. Also, allow a clearance of 4 inches (100 mm) from the edges of obstructions. An overlap up to 6 inches (100 mm) is required at both longitudinal and transverse joints.

In the case of drains, joints, or other irregularities, the geosynthetic should be placed normally and then cut out around the inside of the obstruction. Any wrinkles especially those occurring on sharp curves need to be slit open and treated as overlaps. Caution should be exercised when allowing traffic on the

geosynthetic. Sharp turning and braking will damage the fabric. Sand may be broadcast to reduce the likelihood of skidding.



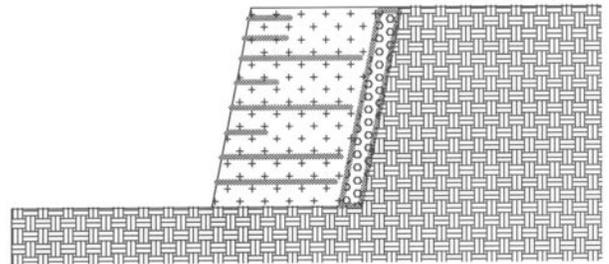
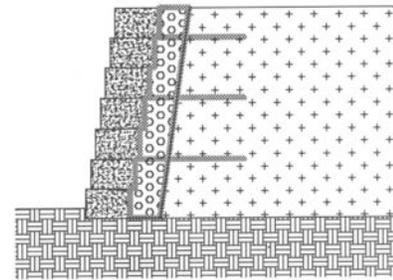
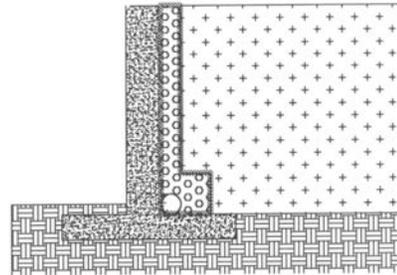
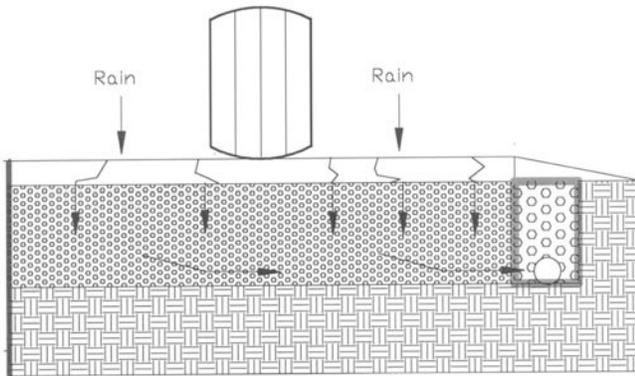
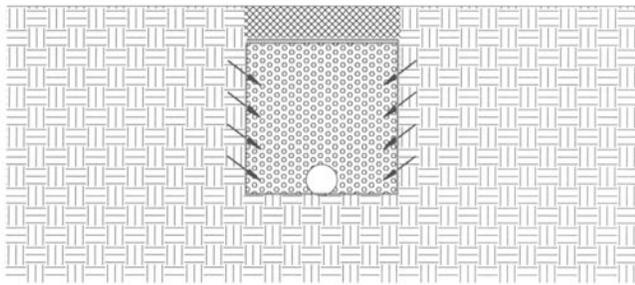
Standard placement and compaction techniques are used

**Installation of the Overlay**

Installation of the geosynthetic and the asphalt concrete overlay should take place on the same day. Paving can commence as soon as the product is laid down. The temperature of the asphalt should not be less than 121°C or exceed 163°C. Grain mix, amount and grade of bitumen, type of filler, aggregate, and additives must all be considered in selecting the kind of asphalt. The minimum compacted thickness of the overlay at its thinnest point is 3.8 cm (1.5 in). This thickness is necessary to produce enough heat to guarantee saturation of the paving fabric or bonding of the geogrid to the lower pavement. In cold weather, a thicker overlay may be necessary to achieve the same objective.

Asphalt can be placed by any conventional means. Compaction should take place immediately after dumping in order to ensure that the different layers are bonded together.

# GEOSYNTHETICS IN SUBSURFACE DRAINAGE: Subgrade Dewatering, Road Base Drainage, and Structure Drainage



## SUBGRADE DEWATERING

### Introduction to the Problem

A high groundwater table can, and often does, interfere with the stability of subgrade soils. For instance, some clay soils can swell or shrink as their water content increases or decreases, respectively. Also, most soils are considerably weaker when they have high water contents or have not been drained prior to loading. This means that weather-related or seasonal fluctuations in groundwater levels can adversely affect permanent structures founded on undrained soils.

Unfortunately, soils will only drain if there is an adjacent soil layer or zone of higher permeability into which the water can escape. The lower the permeability of the subgrade soils, the closer together the drainage layers/zones must be to provide effective dewatering.



High groundwater is a threat to any construction project

### Typical Solutions

The traditional approach to subgrade dewatering is to dig a trench to the depth to which the water table is to be lowered and filling the trench with coarse drainage stone. Sometimes a perforated pipe is placed at the base of the trench to more efficiently transport collected seepage to an outlet. Trenches are spaced to assure drainage of the soil within a desired time period.

Alternatively, in new construction, a coarse aggregate drainage layer or “blanket” can be constructed beneath and before placing the subgrade soil. Similarly, a pipe system is

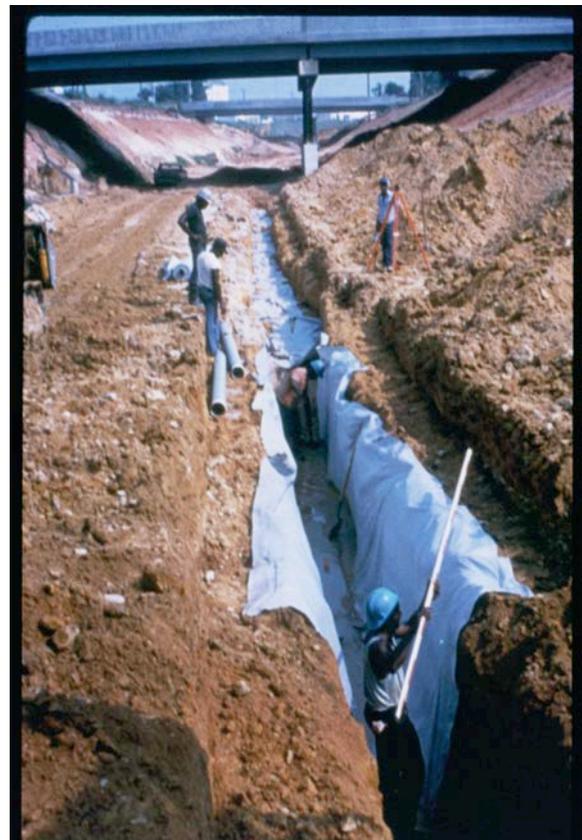
commonly placed within the drainage layer to transport collected seepage.

Since groundwater seeping into a drainage layer can carry subgrade soil particles with it – a phenomenon called “piping” – a layer of fine sand is commonly used as a filter over a drainage layer or in lieu of coarse stone in a trench.

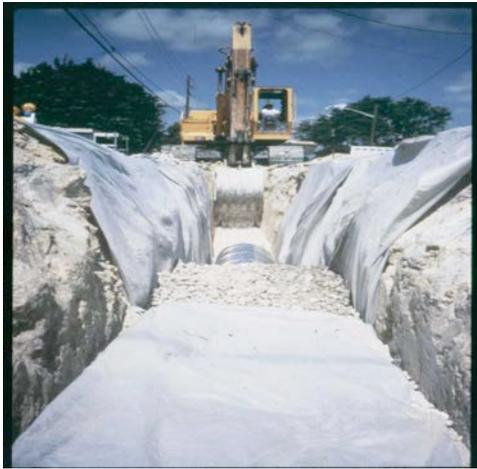
### The Geosynthetic Solution

Effective subgrade dewatering requires a very porous drainage media to accept seepage and a properly graded filter to prevent piping. Coarse aggregate and sand have not proven to be the most desirable drainage and filtration materials.

Geosynthetic materials have become commonplace in subsurface drainage applications. Commonly, geotextiles are being used in lieu of select grades of sand because they are less expensive, provide more consistent properties, and are much easier to install.



Subsurface drains are a common approach to controlling groundwater levels.



Coarse aggregate drains must be protected by a geotextile



A geotextile sandwiched aggregate blanket drain protects this highway fill

The advantages of geotextile filters can be extended to the drainage medium. Where coarse aggregate can be costly, have variable gradations, and be costly and burdensome to install, a geocomposite drain incorporating a 3-dimensional plastic drainage core wrapped with a filtration geotextile overcomes all of these limitations.



Geotextile filter and 3-dimensional plastic drainage core

## INSTALLATION OF GEOSYNTHETICS FOR SUBGRADE DEWATERING

Trench excavation shall be done in accordance with details of the project plans. In all instances excavation shall be done in such a way so as to prevent large voids from occurring in the sides and bottom of the trench. The graded surface shall be smooth and free of debris.

In the placement of the geotextile for drainage applications, the geotextile shall be placed loosely with no wrinkles or folds, and with no void spaces between the geotextile and the ground surface. Successive sheets of geotextiles shall be overlapped a minimum of 300 mm, with the upstream sheet overlapping the downstream sheet.

In trenches equal to or greater than 300 mm in width, after placing the drainage aggregate the geotextile shall be folded over the top of the backfill material in a manner to produce a minimum overlap of 300 mm. In trenches less than 300 mm but greater than 100 mm wide, the overlap shall be equal to the width of the trench. Where the trench is less than 100 mm, the geotextile overlap shall be sewn or otherwise bonded.

Should the geotextile be damaged during installation, or drainage aggregate placement, a geotextile patch shall be placed over the damaged area extending beyond the damaged area a distance of 300 mm, or the specified seam overlap, whichever is greater.

Placement of drainage aggregate should proceed immediately following placement of the geotextile. The geotextile should be covered with a minimum of 300 mm of loosely placed aggregate prior to compaction. If a perforated collector pipe is to be installed in the trench, a bedding layer of drainage aggregate should be placed below the pipe, with the remainder of the aggregate placed to a minimum required construction depth. The aggregate should be

GEOSYNTHETICS IN SUBSURFACE DRAINAGE:  
Subgrade Dewatering, Road Base Drainage, and Structure Drainage

compacted with vibratory equipment unless the trench is required for structural support.



Trench is excavated



Placement of coarse aggregate and pipe



Geotextile filter installed



Completion of drain by wrapping the geotextile. Then backfill to grade.

## ROAD BASE DRAINAGE

### Introduction to the Problem

Designing without positive rapid subsurface drainage costs billions of dollars a year due to increased rates of pavement damage caused by poor drainage. Most road builders recognize the role of water in pavement deterioration. Yet, most emphasize strength and quality of pavement improvement, neglecting improved drainage techniques.

### Typical Solutions

Most traditional positive drainage systems use an open-graded drainage layer under the full width of a roadbed with adequate collector pipes and outlet pipe. Additionally, pavement edge drains can be retrofit to greatly reduce the rate of water-related damage to existing pavements.

### The Geosynthetic Solution

Recent moves toward greater use of subsurface pavement drainage stem from the development of improved and economical drainage materials, along with greater awareness of the nature and extent of the problem.

The introduction of geotextiles into drainage applications has enhanced the economical application of blanket and trench drains under and adjacent to the pavement structure, respectively. The excellent filtration and separation characteristics associated with filtration geotextiles permits the use of a single layer of open-graded base or trench aggregate enveloped in a geotextile. The thin filtration geotextile reduces the required excavation as well as the cost of the drained structural section.

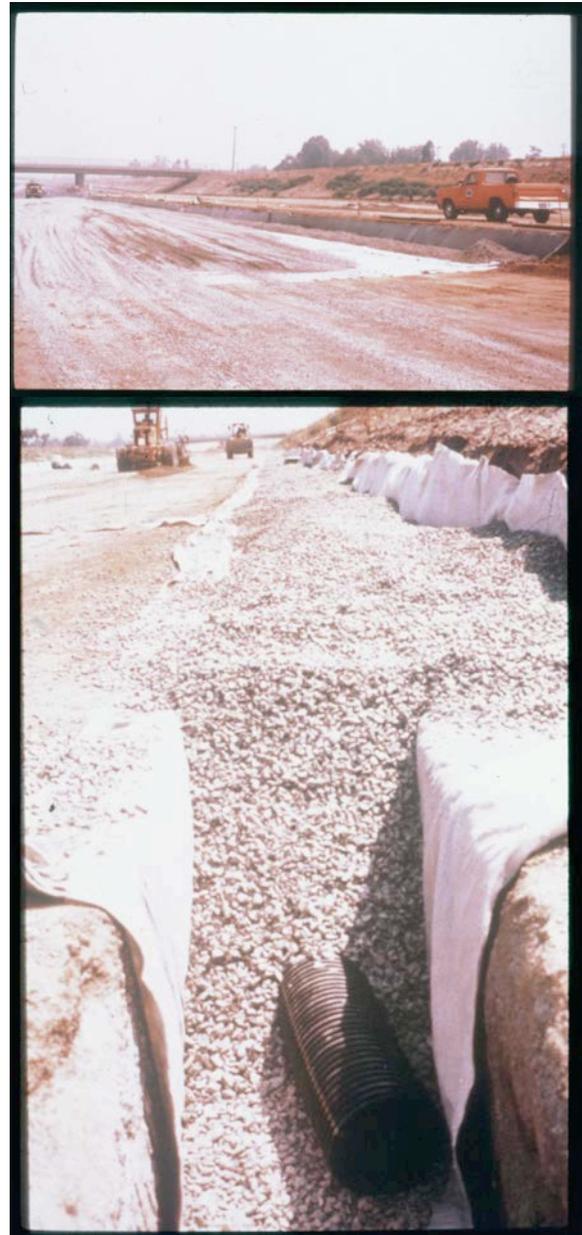
The following enhanced performance has been identified for pavements having an efficient functioning edge drain system:

Flexible Pavements:

25% increase in service life.

Rigid Pavements:

50% increase in service life.



The open-graded base course (above) ties into an edge drain (below). Both are protected by geotextiles.

## INSTALLATION OF GEOSYNTHETICS FOR ROADBASE DRAINAGE

### New Construction

When constructing a new road with an open graded base course designed to also provide blanket drainage, a filtration geotextile is deployed prior to placement of the base course in the same manner as a separation geotextile. Commonly, the base course terminates along the road edges into deepened edge drains. These edge drains should also be wrapped with the

GEOSYNTHETICS IN SUBSURFACE DRAINAGE:  
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geotextile as shown in the above photos.

**Retrofit**

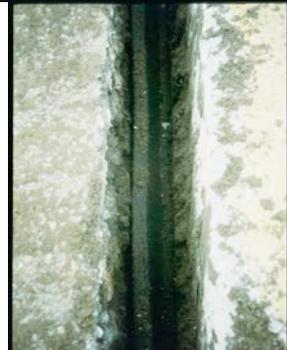
Excavations for retrofit edge drains should be done in such a way so as to prevent large voids from occurring in the sides and bottom of the trench. The edge drain can be an aggregate trench drain with a collector pipe in the bottom.



The trench is "lined" with the filtration geotextile prior to pipe and aggregate placement.

**Geocomposite Edge Drain**

Alternately, a geocomposite edge drain can be used. The excavator, if appropriately equipped, will lay a geocomposite drain into a narrow trench and backfill with sand between the drain and the exposed base course.



The geocomposite drain is "inserted" into the narrow trench in a continuous process. The trench is completed

by backfilling with sand between the geocomposite and the exposed base course.

## STRUCTURE DRAINAGE

### Introduction to the Problem

According to Cedergren, 1989, any well drained structure is inherently safer and more economical than if constructed without drainage. This is because the placement of relatively impermeable structural elements, such as a concrete foundation or retaining walls, against water-bearing earth leads to two damaging conditions:

1. Excess uplifting or overturning pressures caused by trapped water.
2. Channeling of seepage and piping caused by the presence of permeable discontinuities.

Strict adherence to sound drainage principles is probably the most important single aspect of the design of structures constructed adjacent to water-bearing soils. Almost every serious failure of structures of these kinds has been caused by lack of control of groundwater or seepage.

### Typical Solutions

The objective of structural drainage is to control water pressures and seepage forces in the earth adjacent to structures and thus prevent their untimely damage, deterioration, or failure.

It has become customary to place a vertical blanket of “pervious” sand or gravel behind retaining walls for protection against hydrostatic pressures. Yet, it has been demonstrated that even when the back face of a wall is drained with a vertical blanket significant pore pressures can exist in the earth behind the blanket. This leads to increased pressure on the wall. An inclined drainage layer overcomes this deficiency by causing seepage to occur in the vertical direction.

Still, whether vertical or inclined, a drainage layer is difficult to construct using sands and gravels and the drainage layer should be protected by a thin filter layer of carefully

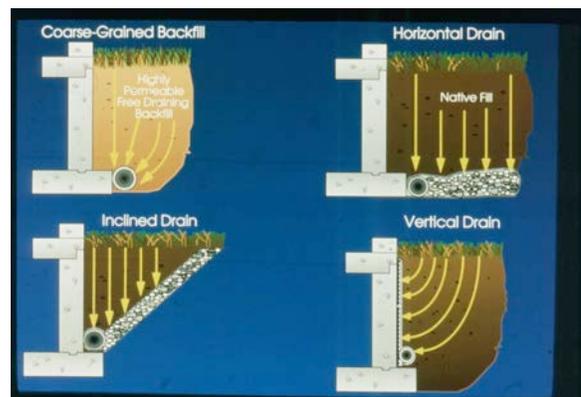
graded sand which is even more difficult, or impossible, to place at a steep angle.

### The Geosynthetic Solution

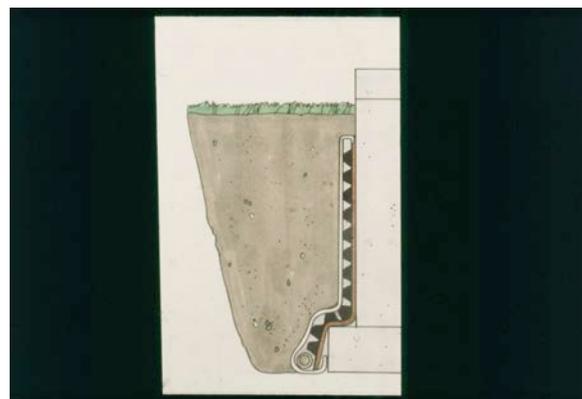
Geosynthetic drainage materials can eliminate the difficulties associated with conventional gravel and sand drains and filters.

One of the best ways to assure effective aggregate drainage is to sandwich an aggregate layer within layers of filtration geotextiles. The inclusion of a perforated drain pipe that collects and discharges seepage will increase the drain’s efficiency. Back fill is placed directly against the drain.

A prefabricated geocomposite drain is an even better alternative. The geocomposite drain replaces the aggregate with 3-dimensional plastic core and comes to the site already covered with the necessary filtration geotextile. This allows the entire drain to be installed in one step.



Wall Drainage Options



The Best Drainage Option: Geocomposite Drain

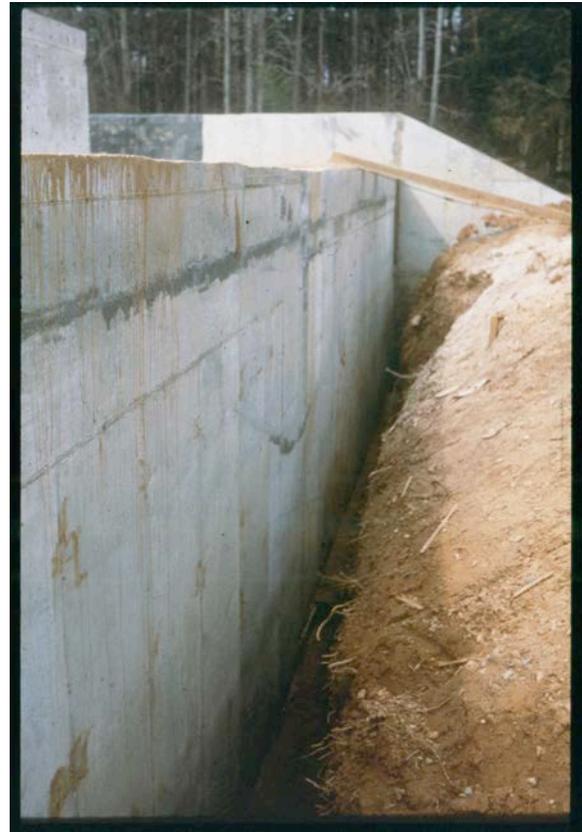
## INSTALLATION OF DRAINS AROUND STRUCTURES

Excavations will be done according to project plans and in such a way so as to prevent large voids from occurring in the sides and bottom of the trench.

To assure an effective aggregate drain, place a filtration geotextile on the excavated stable slope in back of the wall, place a few inches of permeable crushed rock  $\frac{1}{4}$  to 1 inch in size over the geotextile, and cover the rock with another layer of the filtration geotextile.

A prefabricated geocomposite drain may be used in horizontal or vertical applications. In vertical applications, installation begins at the bottom of waterproofed wall where first panel is attached, filter fabric side away from the wall surface. As additional panels are added, insure that the fabric overlay is in optimal position. Overlap panels in the direction of water flow. If a drainpipe discharge system is used, place bottom of drain panel behind geotextile-covered drain pipe and aggregate. Soil should be placed and compacted adjacent to drain.

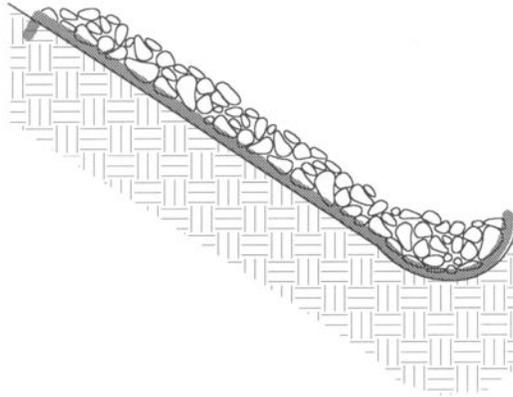
In horizontal applications, such as plaza decks, lay initial panel horizontally, filter fabric side up, at outflow drain and attach panels in like manner insuring that overlapping fabric is properly positioned. Place temporary ballast atop the panels until overlayer is applied.



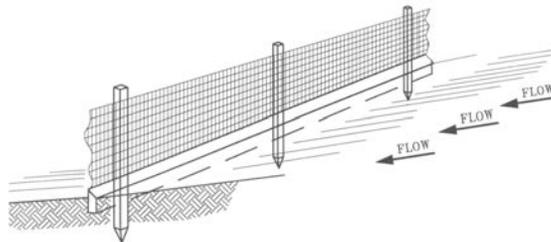
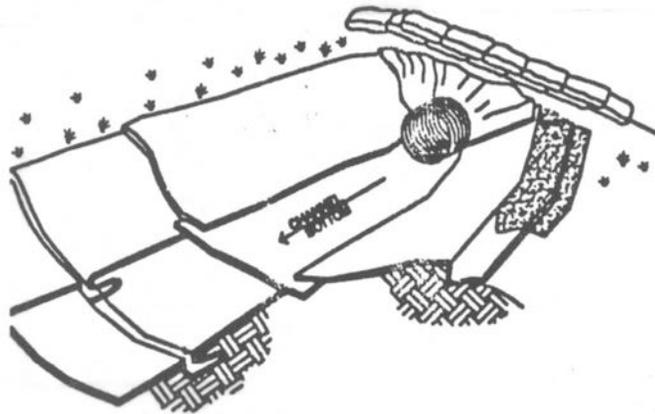
Roof drains enhance the removal of water from around critical structures.

Unlike aggregate, geocomposite drains are easy to install with deep basement walls.

# GEOSYNTHETICS IN EROSION AND SEDIMENT CONTROL: Hard Armor Systems, Rolled Erosion Control Products, Silt Fence



ARMOURED SLOPE



## OVERVIEW

Man-made changes to the environment including unrestricted development, overtaxed resources, removal of surface cover, paving, or simply poor stewardship expose more soil to greater erosive forces and thereby substantially accelerate the rate of erosion.

### Negative Effects of Erosion

- Turbidity caused by eroded soil particles reduces beneficial uses of water by people and can harm aquatic wildlife.
- Eroded sediments carrying chemical molecules have become a major water pollutant.
- As sediments accumulate, they fill up drainage channels and reduce the area available for storm water runoff.
- Flooding occurs when the outlets for storm water are clogged with sediment.

### Erosion vs. Sedimentation

Erosion occurs when soil particles are displaced due to the impact of raindrops, moving water, or wind. Sedimentation occurs when eroded particles (sediments), carried by water or wind, are deposited in another location where they can cause problems. Clearly, sediments (suspended eroded particles) and sedimentation (redeposited soil particles) cause the problems commonly associated with erosion.

Erosion control can prevent problems from ever starting. Sediment control can only attempt to minimize the extent of the problems.

### Erosion Basics

- Raindrops dislodge soil particles and seal the surface. Water cannot infiltrate the sealed surface so overland flow increases.
- Vegetation or any other cover can reduce the momentum or energy of raindrops and prevent sealing of the surface.
- Most construction site erosion results from rainfall impact and overland, or sheet, flows.



Erosion



Sedimentation on Roads and in Channels



Flooding Caused by Sedimentation

## HARD ARMOR SYSTEMS

### Introduction to the Problem

Soil banks or slopes exposed to constant concentrated flows, currents, or waves cannot support vegetation so they must be protected from erosion by hard armor systems. Hard armor systems include fabric formed revetments, geocellular confinement systems, gabions, articulating concrete blocks, and, of course, riprap.

When a hard armor system is in place, water can seep in and out of the bank or slope, but the force of the water is resisted by the armor. As the water seeps, it can gradually carry soil particles with it. The resulting voids cause armor support to be lost over time. This process is called *piping*. Piping can culminate in shifting, rolling, or other instability in the hard armor system.



An Undermined Hard Armor System

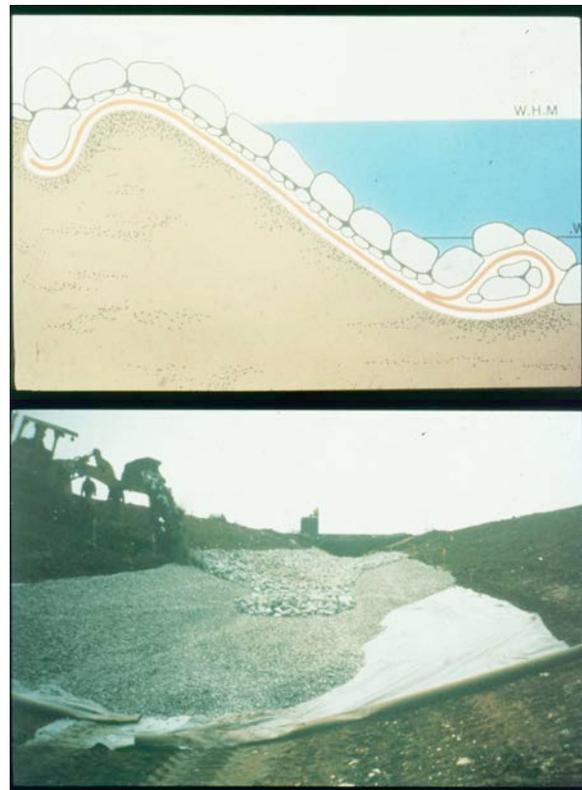
### Typical Solutions

In a properly constructed armor system, a filter layer is placed between the bank soil and the armor to prevent piping. Traditional filter layers have been graded sand and aggregate layers. These graded filters are very costly to construct because they are constructed of select graded materials. Also, the filter layer must be a controlled thickness. On a steep slope, it can be very difficult to properly construct. For these two reasons, filter layers are often – and mistakenly - not included.

### The Geosynthetic Solution

Hard armor systems are quite expensive to construct. Costs can range as high as \$60 per square yard or more. The performance of even the most expensive system can only be assured if it is protected against piping. Consequently, a filter layer should always be used beneath hard armor system in an erosive environment.

Geotextiles have become standard filter layers for hard armor systems because they overcome the drawbacks of graded sand and aggregate filters. First, they are manufactured with specific hydraulic and soil retention properties, which can be easily selected to complement the soil that needs protection. Secondly, they can be installed with ease on slopes – even under water.



A Hard Armor System – Properly Constructed

### Geotextile Properties

Depending on the gradation of the bank soil, either a nonwoven or a woven geotextile can be selected. AASHTO M288 provides guidance on selecting the appropriate geotextile properties.

## INSTALLATION OF GEOTEXTILES UNDER HARD ARMOR

### Site Preparation

The site should be prepared in accordance with good engineering practices. The slope or bank should be graded smoothly and be free from stumps or debris. The surface should be compacted. Any pockets of soft soil should be removed and replaced with compacted earth material to provide a consistently uniform and strong, stable surface.

### Deployment of the Geotextile

Unroll the geotextile on the prepared soil. The geotextile should be placed parallel to small ditch and stream alignments and perpendicular to lake or ocean shores. This arrangement minimizes the exposure of the geotextile to current or wave uplift.

Overlap the geotextile a minimum of 0.5 in order to provide continuous erosion protection. Secure the geotextile in place using pins, staples, fill material or rocks.

### Placement of the Armor Layer

The armor, such as riprap or concrete blocks, should be placed in accordance with accepted practices. The drop height should be held to a minimum, and care must be exercised to avoid damage to the geotextile. If a drop height greater than 3 feet is anticipated, a heavier, more durable geotextile will be required.

### Damage Repair

To repair portions of the geotextile damaged during placement of the armor, clear the damaged area, plus an additional three feet around it, of all armor material. Cover the area with a geotextile patch that extends three feet beyond the perimeter of damage. The patch should be placed beneath the damaged geotextile. Then carefully replace the armor material.



Placing Armor Stone on Woven Geotextle



Placing Armor Stone on Nonwoven Geotextle



Excessive Drop Height / Damage

## ROLLED EROSION CONTROL PRODUCTS ON SLOPES AND IN CHANNELS

### Introduction to the Problem

Straw or hay can be chopped and blown onto a pre-seeded soil bed to provide mulching benefits during seed germination. The straw or hay fragments are secured to the ground surface by crimping, punching, tacking, netting or, in many cases, by nothing at all. Yet, the integrity of these mulches can be severely effected by:

- rain;
- wind;
- overland flow; and
- biological forces.

As a result, conventional mulches provide, at best, only a few weeks or months of protection to the bare soil often making grading and reapplication necessary.

### Typical Solutions

Cellulose-based fibrous mulches can be hydraulically spray-applied with the seed. The fibers are dispersed in a solution that, when sprayed on bare soil, causes the fibers to stick to each other and to the soil. These “spray-on” mulch systems are somewhat more resistant to erosion than are dry-applied systems. Very heavy applications, called bonded fiber matrices, can be more erosion resistant, but are also more costly.

### The Geosynthetic Solution – Green Engineering and RECPs

Erosion is often a problem when there is not enough protective cover on steep slopes or in drainage channels that have been designed to rely on vegetation for long-term erosion control. Vegetation is ideal for erosion control because it is relatively inexpensive to establish and maintain, it poses few safety problems, and it looks natural. Additionally, grasses can filter harmful chemicals out of contaminated water.

The maximum use of vegetation in erosion and sediment control is often referred to as *green*

*engineering* and produces the following long-term benefits:

- modest cost
- improved visual aesthetics
- proven performance
- ease of installation
- enhanced infiltration/groundwater recharge
- reduced flow velocities
- capture of sediments
- hydrostatic pressure relief
- resistance to heaving and differential settlement
- self healing

Rolled erosion control products (RECPs) are designed to encourage and enhance the effectiveness of vegetation as an erosion control material. RECPs were introduced in the late 1960s to remedy the limitations of conventional mulches by dependably meeting the two principal objectives of mulches:

- reducing soil loss
- enhancing site re-vegetation.

Additionally, some RECPs can form a long-term composite layer with the vegetation - tying together the individual plants at the root level - to create “reinforced turf”.

RECPs, used in lieu of or in combination with conventional materials, offer the potential to limit erosion while providing the following advantages over traditional materials:

- RECPs undergo rigorous quality control in a controlled manufacturing environment to minimize material variation.
- Large RECPs rolls can be easily and efficiently deployed.
- RECPs are often less costly to purchase, transport and install than alternative hard systems.
- RECPs are engineered for optimal performance.
- RECPs can be installed quickly.
- RECPs are easily shipped, competitively priced and readily available to any location.
- RECPs performance is not dependent upon weather conditions.

**Temporary, Degradable RECPs for Slopes**

Temporary, degradable materials are used to prevent loss of soil from the seedbed and to enhance the establishment of vegetation where the vegetation alone should provide sufficient site protection once established. Open weave meshes (ECM), and erosion control blankets (ECB) are the most common temporary, degradable RECP systems. Typically natural fibers are used in these RECPs. The fibers are derived from the cultivation of various types of straw/hay or jute, or by the processing of coconut hulls (coir) or wood shavings (excelsior) and photodegradable polypropylene.



Typical Temporary Degradable RECP

**Long-Term, Non-Degradable RECPs**

Long-term, non-degradable RECPs, often called turf reinforcement mats (TRMs), furnish erosion protection and extend the erosion control limits of vegetation, soil, rock and other materials. These materials retain seeds and soil, stimulate seed germination, accelerate seedling development, and most importantly synergistically mesh with developing plant roots and shoots.

TRMs are composed solely of UV stabilized, non-degradable, polymeric fibers, nettings and/or filaments processed into three dimensional reinforcement matrices where design discharges exert velocities and shear stresses that exceed the limits of mature, natural vegetation. TRMs provide sufficient thickness, strength and void space to permit soil filling and/or retention and the development of vegetation within the matrix.

These materials may be installed at 1/3 to 1/2 the cost of hard armor techniques such as rock riprap and concrete. TRMs have been documented to withstand hydraulic shear stresses of up to 8 psf (400 kPa) and velocities of 20 ft/sec (6 m/sec). Newer generation high performance TRMs will resist shear stresses of up to 11 psf (550 kPa) and velocities of 25 ft/sec (8 m/sec). These levels of performance, combined with their cost effectiveness, improved aesthetics, and positive environmental attributes have lead to their endorsement by the EPA in a Storm Water Technology Fact Sheet-”Turf Reinforcement Mats” (EPA 832-F-99-002).



Typical Non-degradable RECPs (TRMs)

## INSTALLING RECPS ON SLOPES AND IN CHANNELS

### Site Preparation

Grade the surface of installation areas so that the ground is smooth and compact. When seeding prior to installation, prepare for seeding by loosening the top 2" to 3" of soil. All gullies, rills, and any other disturbed areas must be fine graded prior to installation. Spread seed before or after mat installation as directed. (Important: Remove all large rocks, dirt clods, stumps, roots grass clumps, trash and other obstructions from the soil surface to allow for intimate contact between the soil surface and the mat.)

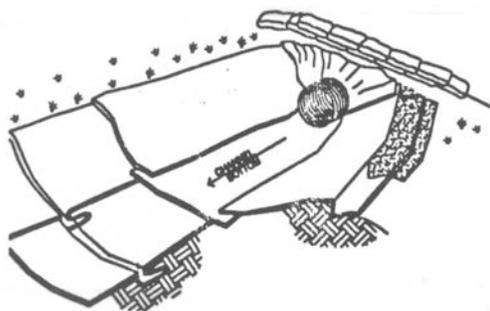
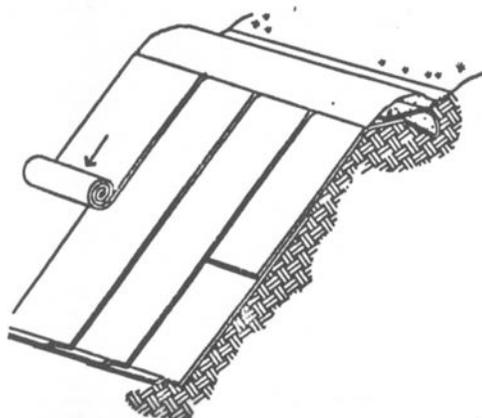
Terminal anchor trenches are required at mat ends and intermittent trenches must be constructed across channels at 25' intervals. Terminal anchor trenches should be a minimum of 12" in depth and 6" in width, while intermittent trenches need be only 6" deep and 6" wide.

### Installation on Slopes

Place the mat 2 to 3' over the top of the slope and into an excavate end trench measuring approximately 12" deep by 6" wide. Pin the mat at 1' intervals along the bottom of the trench, backfill and compact. (See note above for details of mat placement in trench.) Unroll the mat down (or along) the slope maintaining intimate contact between the soil and the mat. Overlap adjacent rolls a minimum of 3". Pin the mat to the ground using staples or pins in a 3' center-to-center pattern. Less frequent stapling/pinning is acceptable on moderate slopes.

### Installation in Channels

Excavate terminal trenches (12" deep and 6" wide) across the channel at the upper and lower end of the lined channel sections. At 25' intervals along the channel, anchor the mat across the channel either in 6"x 6" trenches or by installing two closely spaced rows of anchors. Excavate longitudinal trenches 6" deep and wide along channel edges (above water line) in which to bury the outside mat edges.



RECPS are anchored in trenches at their ends and edges and overlapped downslope and in the direction of flow

Place the first mat at the downstream end of the channel. Place the end of the first mat in the terminal trench and pin it at 1' intervals along the bottom of the trench. The RECP should be placed upside down in the trench with the roll on the downstream side of the trench. Once pinned and backfilled, the mat is deployed by wrapping it over the top of the trench and unrolling it upstream. If the channel is wider than the provided rolls, place ends of adjacent rolls in the terminal trench, overlapping the adjacent rolls a minimum of 3'. Pin at 1' intervals, backfill and compact. Unroll the RECP in the upstream direction until reaching the first intermittent trench. Fold the mat back over itself, positioning the roll on the downstream side of the trench, and allowing the mat to conform to the trench. Then pin the mat (two layers) to the bottom of the trench, backfill and compact.

Continue up the channel (wrapping over the top of the intermittent trench) repeating this step at other intermittent trenches, until reaching the upper terminal trench. At the upper terminal trench, allow the mat to conform to the trench and secure with pins or staples. Backfill, compact, and then bring the mat back over the top of the trench and onto the existing mat (2' to 3' overlap in the downstream direction). Finally pin at 1' intervals across the mat.

When starting installation of a new roll, begin in a trench or shingle-lap ends of rolls a minimum of 1' with upstream mat on top to prevent uplifting. Place the outside edges of the mat(s) in longitudinal trenches, pin, backfill and compact.

#### Anchoring Devices

Eleven (11) gauge, at least 6" L x 1" W staples, 18" pins with 1.5" diameter washers, wooden stakes, or 12"-30" J-shaped pins (or bent rebar) having at least 1/4" diameter, are recommended for anchoring the RECP to the ground. Drive staples or pins so that the top of the staple or pin is flush with the ground surface. Anchor each mat every 3' along its center. Longitudinal overlaps must be sufficient to accommodate a row of anchors and uniform along the entire length of overlap and anchored every 3' along the overlap length. Roll ends may be spliced by overlapping 1' (in the direction of water flow), with the upstream/upslope mat placed on top of the downstream/downslope mat. This overlap should be anchored at 1' spacing across the mat. When installing multiple width mats heat seamed in the factory, all factory seams and field overlaps should be similarly anchored.



Channel installation includes: fine grading and seeding; RECP deployment and pinning; and backfilling and compacting. The resulting channel provides all the benefits of vegetation.

## SILT FENCE

### Introduction to the Problem

Because accelerated erosion can result from denuded areas during construction, sediment control measures are needed to prevent construction-generated silt from being carried into nearby waterways or onto adjoining properties. Various types of sediment control measures are used to impede the flow of sediment-laden waters and to filter out sediment.

### Typical Solutions

Sediment control structures composed of permeable material are placed so as to intercept sheet flow and low level channel flow from denuded areas. These barriers serve (1) to decrease the velocity of moving water, and (2) to trap suspended sediment. Traditional measures include barriers made of straw, gravel or crushed stone, and brush.

Improper use of filter barriers has been a major problem. For instance, straw barriers have been used in streams and drainage ways where high water velocities and volumes have destroyed or impaired their effectiveness. Another major problem has been that improper placement of the barriers has allowed undercutting and end flow, which have actually resulted in additions to rather than removal of sediment from runoff waters. Finally, inadequate maintenance and cleaning efforts have tended to greatly lower the effectiveness of the barriers.

Because of the problems noted above, straw barriers have generally shown low trapping efficiencies and high failure rates.



### Typical straw bale installation (failure)

### The Geosynthetic Solution – Silt Fence

Faced with the ineffectiveness of straw barriers, a second type of filter barrier, the silt fence, has emerged. Silt fences are composed of tough, durable, commercially available geotextiles attached to support posts. Silt fences can trap a much higher percentage of the suspended sediments than can straw bales. When properly performing, a well designed silt fence will:

- initially screen silt and sand particles from runoff.
- form a soil filter adjacent to the silt fence, reducing the flow of water through the fence.
- create a pond behind the fence which serves as a sedimentation basin to collect suspended soils from runoff water.

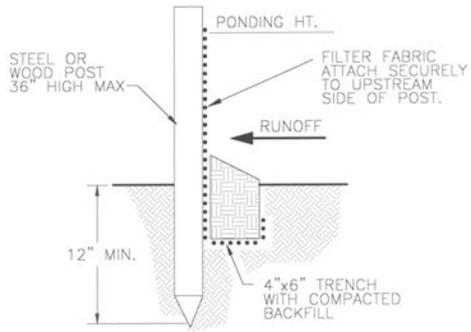


Silt fence retaining sediment laden runoff.

Over 20 million square yards of silt fence are used annually providing the following benefits over traditional sediment control structures:

- Minimal labor required to install;
- Low cost;
- Highly efficient in removing sediment;
- Very durable and sometimes reusable.

GEOSYNTHETICS IN REINFORCED SOIL SYSTEMS:  
Emankments over Soft Foundations, Reinforced Steepened Slopes, Mechanically Stabilized Earth Walls



SILT FENCE DETAIL

## SILT FENCE INSTALLATION

Proper installation of sediment control structures is critical to their proper functioning. For example, it is not uncommon to observe a silt fence around a construction site that is not toed in. In these cases, runoff will be allowed to run under the fence and cause off-site migration of sediments. Following are some generally accepted installation guidelines for silt fences.

There are important details associated with proper installation of silt fence. The keys to performance are installation details, location, and maintenance.



Silt fence installed in trench, backfilled and compacted; posts installed, and fabric tied to posts.

### Installation Details

1. Dig a minimum 150 mm x 150 mm (6 in. deep x 4 in. wide) trench where the silt fence will be installed.
2. Unroll the fence and position it in the down-slope side of the trench. Place about 150 mm (6 in) of the fabric below ground level. For greater effectiveness, lay this portion of fabric along the bottom of the trench.
3. Backfill and compact soil in the trench to prevent runoff from getting underneath the fence. Fill the trench with soil and tamp by foot or with equipment.
4. Place posts on the down-slope side of the fabric (the side away from the expected runoff flow) and drive them into the ground.
5. Attach fabric and mesh reinforcement to the up-slope side of the posts.

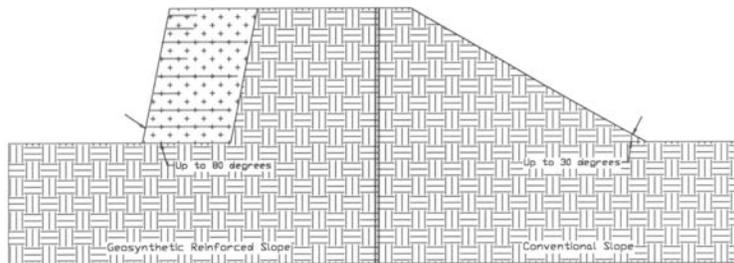
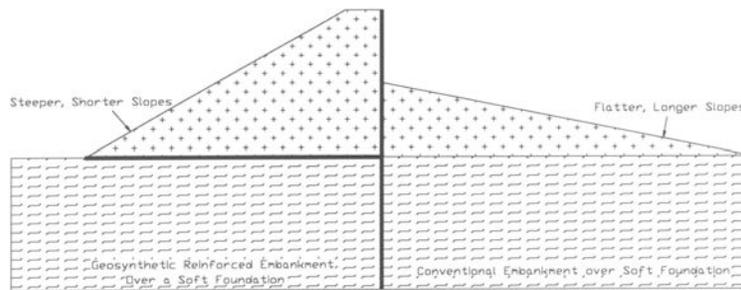
### Location

Unless otherwise specified, silt fence should be placed where it will intercept all runoff from the site. Extend the fence far enough uphill to prevent runoff from escaping around the ends. When continuing the fence line with a new roll of fencing, install the new fence to prevent silt from passing between the end of the existing fence and the beginning of the new.

### Silt Fence Maintenance

Over the time required for any given Construction project, the control of erosion and sedimentation will be no better than the quality of the maintenance effort. The value of careful and prompt attention to maintenance cannot be overemphasized. Routine maintenance should be performed on all silt fencing. The fence line should be inspected after each significant rain event as well as at specified intervals. If silt buildup is discovered, it should be cleaned from the fabric either by sweeping or by hand shoveling. When fabric begins deteriorating either because of U.V. exposure or vandalism/debris, it should be replaced or a new fence line should be established adjacent to the old.

# GEOSYNTHETICS IN REINFORCED SOIL SYSTEMS: Emankments over Soft Foundations, Reinforced Steepened Slopes, Mechanically Stabilized Earth Walls



## OVERVIEW

Though the use of tensile inclusions in soil structures dates back several thousand years to the construction of religious structures in ancient Babylonia, it was only three decades ago that 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.

Beginning in the early 1970's, experimentation using geotextiles as soil reinforcement was conducted in Europe and the United States. The U.S. Forest Service constructed full-scale wrapped-face walls using geotextiles in 1974 and 1975 and 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. These successes attracted other candidate forms of plastic inclusions such as geogrids manufactured of polyethylene and coated polyester.

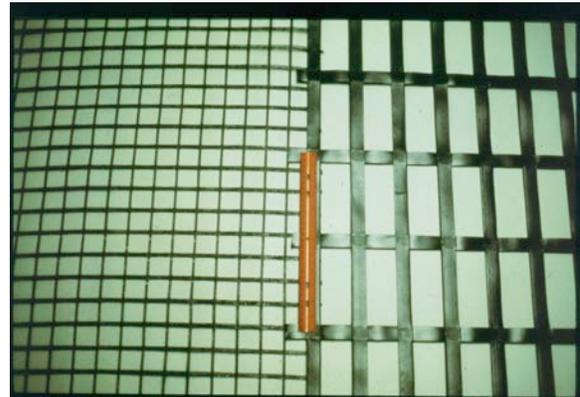
These and other reinforced soil systems have become known as mechanically stabilized earth (MSE) and their use has significantly increased. The primary types of MSE systems which have emerged include: mechanically stabilized earth walls (MSEW); reinforced soil slopes (RSS); reinforced embankments over soft foundations (RESF). MSEW and RSS have become especially important in highway construction as their use reduces the required width of new right-of-way and facilitates construction within existing limited right-of-way. RESF are recognized as a cost-effective alternative to traditional techniques for constructing earthen embankments over low strength foundations.

Geosynthetic reinforced soil systems include:

- Engineered soil fill
- Geosynthetic reinforcement
- Facing or slope protection system



Engineered Soil Fill



Geosynthetic Reinforcement



GEOSYNTHETICS IN SEEPAGE CONTROL SYSTEMS:  
Structure Waterproofing, Water Supply Preservation, Environmental Protection

Facing

## EMBANKMENT OVER SOFT SOILS

### Introduction to the Problem

Historically, 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.



Soft foundation soils pose real construction challenges

### Typical Solutions

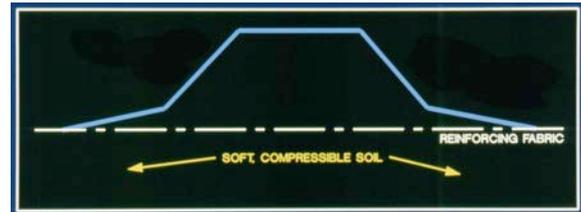
Several methods of treatment are available to reduce the problems associated with soft foundations. These methods include:

- 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.
- Deposit improvement using admixtures (e.g. soil, cement, lime) or injections
- Reinforcement of the soil matrix using a structural element.

### Geosynthetic Solutions

Geosynthetic solutions include geotextiles, geogrids and combinations of geotextiles and geogrids. While a wide variety of site improvement methods have been used during the past decade, soil reinforcement has emerged as an efficient, economical and effective solution to the problem of constructing embankments over soft soils.



Reinforced Embankment Concept

### Geotextiles

For many years very strong fabrics have been employed in constructing embankments over soft ground. Very strong fabrics, with tensile strengths ranging from 1000 lb/in to 4500 lb/in, are placed over a prepared working table and earthen embankments are erected using a system of controlled height lifts to maintain uniform pressure on the subgrade.

### Geogrids

Smaller embankments may also be designed and constructed using single or multiple layers of high strength, high modulus reinforcing geogrids at the base. The geogrid(s) reduce lateral displacement and improve the overall stability of the soil embankment.

### Combination systems

Geogrids are limited in ultimate strength by structure and polymer properties. In a combined system, a geogrid can be employed to facilitate the development of a working platform which is subsequently covered with the very strong

GEOSYNTHETICS IN SEEPAGE CONTROL SYSTEMS:  
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(>2000 lb/in) geotextile. The embankment is then constructed on the geotextile.



Large factory-fabricated panels are deployed on the jobsite.



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



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



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



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



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

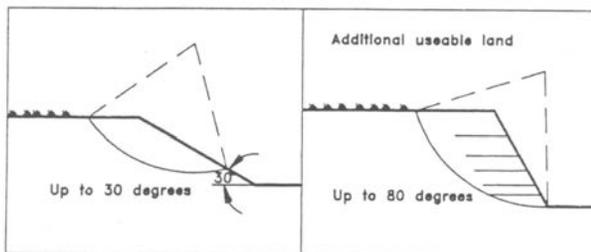
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## REINFORCED STEEPENED SLOPE (RSS)

### Advantages Of RSS Systems

Slopes are common geographic features and can be found everywhere with steepness ranging from gentle swales to ultra steep mountain sides. The full range of these terrain features is commonly found adjacent to transportation rights of way and building sites. The economics associated with a particular highway alignment or with the development of a parcel of land may be determined by the ability to create sufficient flat, or level, land to satisfy space, safety, or access requirements. On highway and building projects relatively flat areas are preferred. These areas must be constructed by excavation or filling in the existing terrain, often leaving significant grade changes at the edges of the excavation.

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



Conventional vs. Steepened Slopes

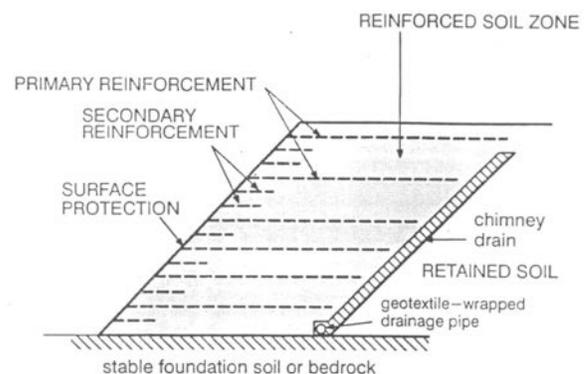
Geosynthetic reinforced steepened slopes are soil structures constructed with a slope face angle up to as high as 80 degrees from the horizontal. Typical unreinforced soil slopes are limited to a slope face angle of approximately 30 degrees, or less, depending on the angle of repose of the slope soil. The additional steepness provided by reinforced slopes minimizes the extent to which grade change structures, i.e. slopes, must encroach into highway right-of-way or onto building sites.

### Details of RSS Systems

Like conventional soil slopes, reinforced slopes are constructed by compacting soil in layers

while stepping the face of the slope back at an angle. Subsequently, the face is protected from erosion by vegetation or other protective systems ranging from concrete slabs to geocell walls and including a wide variety of systems. Additional geosynthetic elements are incorporated into reinforced steepened slopes to facilitate drainage, minimize ground water seepage and to assure the stability of the steepened slope and the erosion resistance of the facing. Following are the detailed components of a geosynthetic reinforced steepened slope system:

- Foundation - Stable soil or bedrock upon which the slope is constructed. Stability in the foundation is assumed.
- Retained Soil - The soil which remains in place beyond the limits of the excavation.
- Subsurface Drainage - Geosynthetic drainage medium installed at the limits of the reinforced soil zone to control and collect ground water seepage.
- Reinforced Soil - The soil which is placed in lifts adjacent to the retained soil and incorporates horizontal layers of reinforcing to create the sloped structure.
- Reinforcement - Geosynthetic, either geogrid or geotextile with sufficient strength and soil compatible modulus, placed horizontally within the slope to provide tensile forces to resist instability.
- Surface Protection - The erosion resistant covering of the finished slope surface.



Components of a

## Reinforced Steepened Slope System



An RSS is used to raise this site out of the flood plain.



The finished project includes important structures.

A slope repair that must support a roadway.



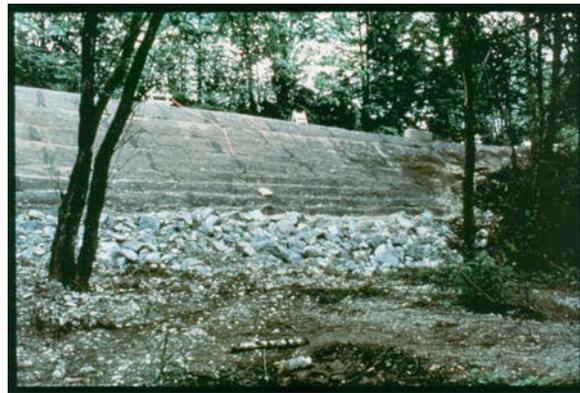
Alternating layers of geosynthetic and compacted soil.



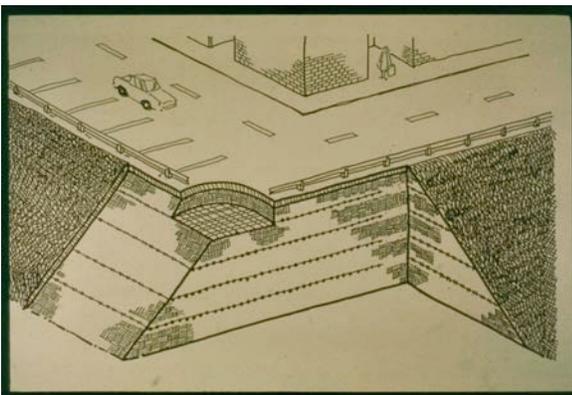
An RSS is constructed using conventional equipment.



The steepened face must be protected from erosion.



The RSS with protected face and toe.

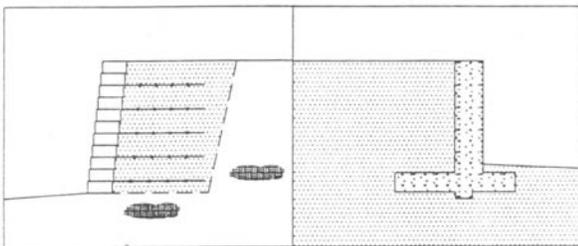


The RSS supports a public roadway.

## MECHANICALLY STABILIZED EARTH (MSE) WALLS

### Advantages of MSE Wall Systems

The economics associated with a particular highway alignment or with the development of a parcel of land may be determined by the ability to create sufficient flat, or level, land to satisfy space, safety, or access requirements. Retaining walls are a common structural feature located adjacent to highways and building sites in many areas of the country. Retaining walls are popular because their vertical or near vertical faces increase the width of the relatively flat areas which are preferred for both highways and building sites. These areas must be excavated out of the existing terrain often requiring significant grade changes at the edges of the excavation. Though there are many types of retaining walls, geosynthetic reinforced (MSE) soil walls provide vertical grade changes at significantly less cost than conventional retaining walls.



Reinforced Soil vs. Conventional Walls

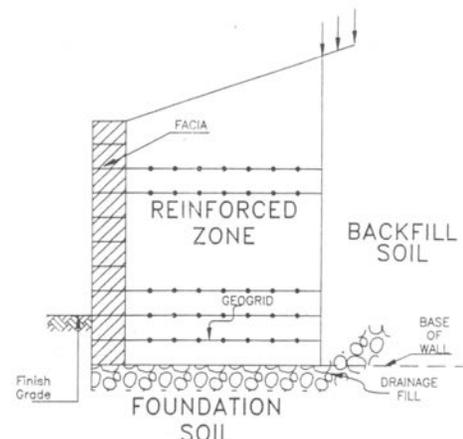
Geosynthetic reinforced soil walls are soil structures constructed with the face at an angle of close to 90 degrees from the horizontal. Conventional retaining walls are gravity structures which must be massive enough to resist the destabilizing forces of the retained fill. Reinforced soil walls create gravity retaining structures out of the fill itself by incorporating geosynthetic reinforcement into the design.

### Details of an MSE Wall System

Unlike conventional retaining walls, reinforced soil walls are constructed by compacting fill soil in layers between intermittent horizontal

geogrid layers. These geosynthetic elements are incorporated into fill soil to assure the stability of the entire soil/facing system. Following are the detailed components of a geosynthetic reinforced soil wall system:

- Foundation - Stable soil or bedrock upon which the slope is constructed. Stability in the foundation is assumed.
- Retained/Backfill Soil - The soil which remains in place beyond the limits of the excavation or is placed behind the reinforced zone.
- Subsurface Drainage - Geosynthetic drainage medium installed at the base and back of the reinforced soil zone to control and collect ground water seepage.
- Reinforced Soil - The soil which is placed in lifts between the facia and the retained soil and which incorporates horizontal layers of reinforcing to create the gravity wall structure.
- Reinforcement - A geogrid or geotextile with sufficient strength and soil compatible modulus, placed horizontally within the soil 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 positive connection must be provided between the facia and the geogrid reinforcement.





The first MSE walls used “wrap-around” techniques.



Backfill placed over reinforcement layer.



The wrapped face was protected with shot-crete



One of numerous, attractive MBU facing options.



More recent walls commonly use masonry block units.



Geocellular confinement system faced MSE wall.



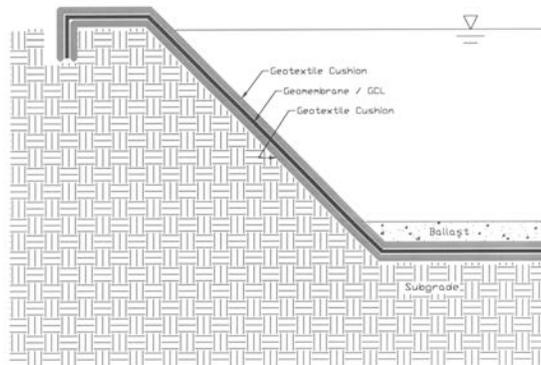
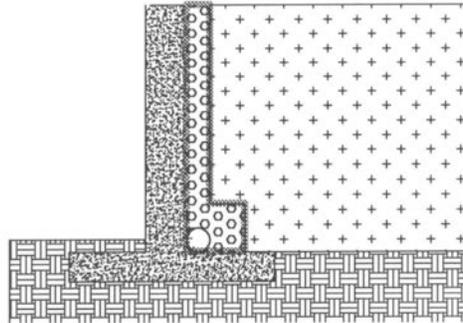
MSE walls have geosynthetic reinforcement layers.



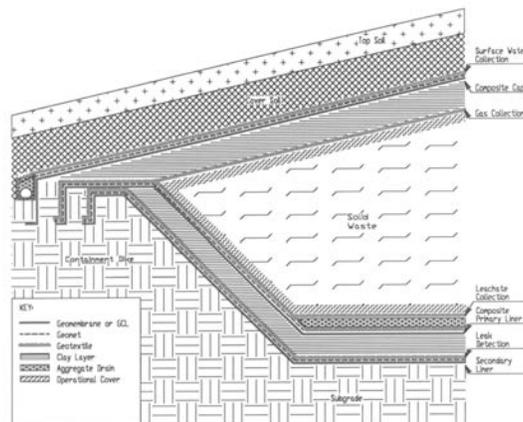
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Structure Waterproofing, Water Supply Preservation, Environmental Protection

MSE wall with timber facing.

# GEOSYNTHETICS IN SEEPAGE CONTROL SYSTEMS: Structure Waterproofing, Water Supply Preservation, Environmental Protection



SURFACE IMPONDMENT



## OVERVIEW

Geosynthetics have been utilized in numerous civil and environmental engineering applications worldwide for more than 20 years to prevent seepage of liquids. Such seepage control applications as water containment and conveyance, structure waterproofing, and environmental protection make extensive use of geomembranes and geosynthetic clay liners (GCLs) along with other geosynthetics.

The materials used for seepage control may be exposed, as with pond linings, or buried, as with landfill linings. They may be subject to significant stresses, as with a pond cover, or exposed to very aggressive environments, as with a chemical tank lining.

The wide variety of potential exposure conditions is why there is such a wide variety of geosynthetic barrier materials. Material selection and installation details are, therefore, project specific.



Lined Architectural Pond



Pond Cover



Tank Lining



Landfill Lining



Spray-applied lining



Landfill Cap

## STRUCTURE WATERPROOFING

### Introduction to the Problem

The protection of structures (even soil and rock structures) from the effects of seeping water is a common need. As noted in Chapter 3, this need is typically addressed with a drainage layer, often accompanied by a waterproofing layer.

### Typical Solutions

Conventional soil barrier layers silts and clays attempt to minimize liquid migration. Where readily available, clay can be compacted in multiple layers to achieve a durable, low permeability barrier, although placement against a vertical structure can be difficult, costly or impossible. Additionally, the integrity of clay barriers is adversely effected by:

- variations in texture (i.e. presence of clods),
- fluctuating moisture content and compaction effort,
- extreme temperature exposure, and
- exposure to certain chemicals.

Gravel and sand layers, if locally available, can be cost-effectively engineered into systems to collect and remove liquids and gasses. Additionally, assuring proper gradations, facilitating vertical placement on slopes, and obtaining uniform layer thickness often requires large construction tolerances and numerous duplicate inspections.

### The Geosynthetic Solution

Since geomembranes and GCLs can be easily deployed in horizontal, vertical or even overhead configurations, they are especially useful for waterproofing tunnel linings as well as foundation and basement walls and other wall structures such as bridge abutments.

Taking advantage of their “sheet-like” nature, geomembranes and GCLs can be used to isolate or encapsulate water-sensitive roadway soils and subgrades in order to maintain the soils at their desired water content. They are also quickly and easily deployed as protective covers over material stockpiles to prevent wetting and erosion.

Geosynthetics, specifically geomembranes and GCLs, can offer a more economical, less installation-intensive alternative to clay barriers. In areas where naturally occurring clays and silts are scarce, GCLs can provide the impermeability required to protect structures. In addition, it is not always possible to place and compact natural clay in non-planar forms as in a tunnel lining or wall. GCLs also take up less space and are somewhat resistant to freeze/thaw and wet/dry cycles.

Geomembranes can be effectively incorporated in the construction of earthen and earth/rock dams which require an impervious core. These structures are traditionally constructed with silts and clays. In addition, concrete dams must be protected from seepage into the structure. Geomembranes are often used to cover the upstream sides of these dams.



Effective waterproofing includes drainage.



Tunnels require sophisticated waterproofing and drainage systems – made easier with geosynthetics

## WATER SUPPLY PRESERVATION

### Introduction to the Problem

#### *Water Containment Systems*

The containment and protection of important water supplies is a challenge to public works agencies as well as to industry. Effective lining of potable water reservoirs can conserve millions of gallons of water by preventing seepage losses. Additionally, covers can prevent contamination, control evaporation and prevent chlorine loss. Similar containment and protection is needed in waste water treatment facilities, though the purpose is to prevent leakage of untreated liquids and to collect biodegradation gases such as methane.

#### *Water Conveyance Systems*

The prevention of seepage from lined and relined canals is critical in arid regions.

Similarly, storm water retention and detention facilities are lined with a geomembrane or GCL to prevent excess wetness or instability of surrounding property resulting from seepage of contained runoff.

### Typical Solutions

Most water reservoirs, because of their magnitude, are often lined with low permeability soil and left uncovered. This often results in high water treatment costs and potentially serious contamination.

Clay or concrete linings have commonly been used for water and wastewater conveyance.

### The Geosynthetic Solution

Geomembranes serve as effective protection against evaporation and contamination and can prevent seepage losses when used as liners and floating covers. Though generally used in more “highly engineered” installations, their low cost, wide spread availability, and relative ease of installation make geomembranes and GCLs more and more popular for lining architectural ponds, recreational ponds, and fire fighting ponds as well as for facing dams.

Geomembrane and GCL barrier systems provide flexibility and ease of installation which is especially beneficial when lining and relining is done over existing rigid linings of clay, asphalt, or concrete.



Installation of Cushion Geotextile



Geomembrane Placed Over Cushion



Pond Complete with Geosynthetic Lining

## ENVIRONMENTAL PROTECTION SYSTEMS

### Introduction to the Problem

The increase in environmental sensitivity of the last two decades has led to important regulations requiring “de minimus” leakage of contamination to the environment from landfills and other waste deposits. Additionally, as soon as a landfill reaches capacity, it must be capped to minimize future leachate generation

### Typical Solutions

**Conventional Systems.** Conventional capping and lining systems have incorporated very low permeability soil barrier layers such as thick layers of silts and clays, along with drainage layers of coarse uniformly graded sands or gravels and specially graded sand filters in an attempt to minimize liquid migration.

Where readily available, clay can be compacted in multiple layers to achieve a durable, very low permeability barrier. Yet, the integrity of clay barriers is adversely effected by:

- variations in texture (i.e. presence of clods),
- fluctuating moisture content and compaction effort,
- extreme temperature exposure, and
- exposure to certain chemicals.

Gravel and sand layers, if locally available, can be cost-effectively engineered into systems to collect and remove liquids and gasses. Yet, assuring proper gradations, facilitating placement on slopes, and obtaining uniform layer thickness often requires large construction tolerances and numerous duplicate inspections.

### The Geosynthetic Solution

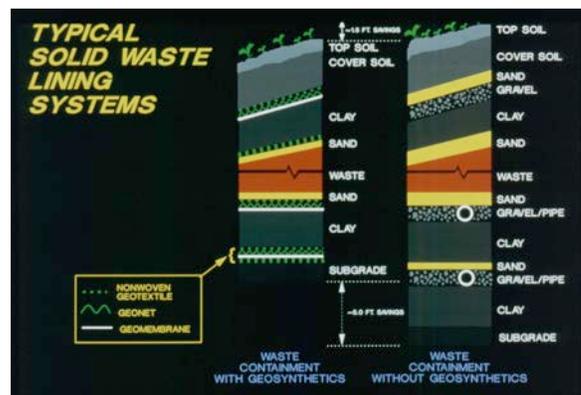
The chemical resistance and flexibility of geomembranes and GCLs makes them technically superior to any other alternative for providing a positive barrier to the movement of fluids and gases. In the case of environmental protection, that movement usually includes containment of contaminated liquids and gases

while keeping clean water, in the form of rain or runoff, from becoming contaminated.



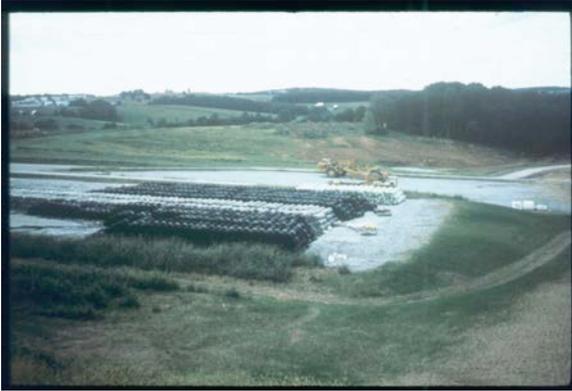
There are many ways that geomembranes and GCLs have been incorporated into environmental protection barrier systems, including:

- final covers over waste materials,
- liners for solid, hazardous and monofill waste landfills,
- liners for lagoons and other surface impoundments such as geothermal, aquaculture, solar, or specific chemical ponds.
- secondary containment for underground storage tanks,
- vertical barriers to contain subsurface contaminant plumes,
- horizontal and vertical barriers to radon and methane emissions,
- pit liners for the collection and recycling of leached solutions from ore piles or even manure piles.



Typical Geosynthetic vs. Conventional Lining Systems

GEOSYNTHETICS IN SEEPAGE CONTROL SYSTEMS:  
Structure Waterproofing, Water Supply Preservation, Environmental Protection



Landfill lining projects use many geosynthetics.

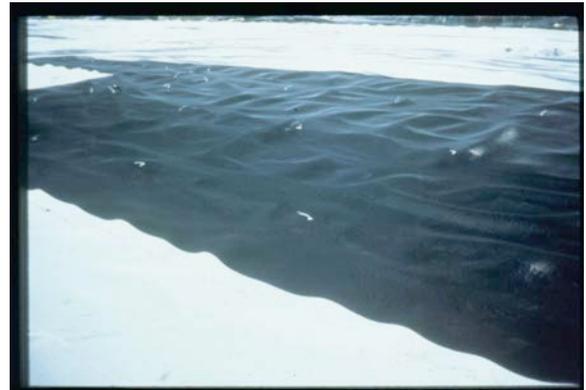


Geosynthetic installation proceeds in multiple layers.

Composite liners include both clay and geomembrane.



Geonet composite drains for leachate collection.



Geonet and geotextile are sometimes placed separately.



Sand operational cover layer protects liner system.



The leachate collection system drains to a lined sump.



Clay (and then a geomembrane) is placed over a leak

detection system in a double composite liner system.

## GEOSYNTHETIC SUPPORT SYSTEMS: Prefabricated Systems, On-site Fabrication, Testing and Specifying

## OVERVIEW

Innovation is a tradition in the geosynthetics industry. In partnership with contractors, engineers are constantly developing cost-effective installation techniques, advanced new products and specially fabricated systems. Such innovations include prefabricated soil containment systems and preassembled fences and specially developed installation equipment and techniques for on-site fabrication. Additionally, the industry has developed an extensive array of tests for establishing the quality of geosynthetics and facilitating their specification.



Specialty Installation Equipment

## PREFABRICATED SYSTEMS

Factory fabrication is an effective way of minimizing field operations. Fabricated geosynthetic products lead to faster, easier and more accurate installation, plus significant cost savings. Many geosynthetic suppliers offer factory fabrication capabilities including seaming of extra wide panels, joining multiple rolls and re-rolling them onto pipe cores, or specialty folding and bundling to facilitate field installation. Common prefabricated systems include:

- Geotextile socks for perforated pipe
- Reinforced selveges and grommets for silt (turbidity) curtains and geomembrane covers.
- Special widths, lengths or shapes of geosynthetic panels for installation in curves, on slopes or in other irregular configurations.

Some prefabricated “systems” mentioned earlier in this handbook include:

- Dredged Soil Containment System
- Barge-Placed Soil Containment System
- Sandbags
- Silt Fences and Turbidity Curtains
- Safety Fences

### *Dredged Soil Containment System*

Geotextile tube systems use a woven geotextile that is formed into a tube. The tube's diameter and length is determined by project requirements. The tube is filled by a hydraulic piping system conveying dredged material. Designed with appropriately sized openings, the geotextile tube retains fill material while allowing water to permeate out through the tube wall. Geotextile tubes permanently trap granular material in both dry and underwater construction.



Dredged Soil Containment System

### *Barge-Placed Soil Containment System*

Geotextile containers are constructed of woven geotextiles using special seaming techniques to contain available granular fill material. Sunk accurately into position by barge, geotextile containers are designed to provide a desirable alternative to loose soil placement. Geotextile containers can be used for preventing erosion around piers and revetments, protecting and ballasting pipelines, and constructing groins, breakwaters, embankment cores and breach repairs.

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Barge-Placed Soil Containment System

Large sandbags can be fabricated to the size and material specifications of each customer. Bags are positioned and filled by hand. Ends are closed using a hand-held sewing machine.



Sand Containers – Custom Fabricated

*Sand Containers - Pre-Fabricated*

Geotextile sandbags provide incomparable convenience to contractors needing fast, easy access to sand-filled bags. Geotextile sandbags are perfect for weighing down sign bases, anchoring plastic sheets or redirecting storm runoff.



Sandbags

*Turbidity Curtains*

Turbidity curtains are reusable floating geotextile or reinforced geomembrane panels that prevent water-polluting sediment from shore-side construction or off-shore filling and dredging operations from moving off-site. The top edge of each curtain contains floats and a cable or chain. Weights are attached to the lower edge of the curtain to keep it vertical in the water. Posts, piling, or anchors hold the curtains in place.

*Sand Containers – Custom Fabricated*

Sandbags can also be custom engineered. Facing storm-induced erosion, large bags offer a flexible, stable armoring system that can be quickly installed to protect against storm induced erosive forces. Multiple bags can be stacked as required to create larger erosion protection structures.



Typical Turbidity Curtain

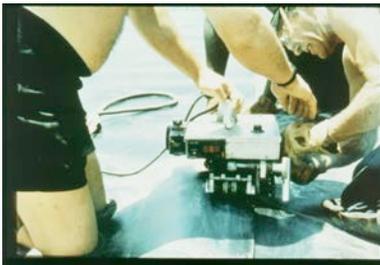
## ON-SITE FABRICATED SYSTEMS

Installation of a geosynthetic is only a small part of many projects. But if there are installation delays, work schedules and budgets can be drastically effected. By subcontracting geosynthetic installation including field seaming, project delays and overruns are avoided. Experienced installers work closely with contractors assuring timely deliveries and proper installation.

When time and quality matter, an experienced fabricator/installer with specialty equipment and know-how makes the ideal partner on projects involving field seaming of geosynthetics.



Geomembrane Deployment



Geomembrane Seaming: Wedge & Extrusion Welding

APPENDIX 2  
**GMA Member Products and Services**



GCL Deployment



GCL Seaming



High Strength Geotextile Seaming



High Strength Geotextile Deployment

## GEOSYNTHETIC TESTING AND SPECIFYING

### Testing

Most specifiers and users of geosynthetics establish required physical property values for the geosynthetics to be utilized in their project based on standard tests. This practice is common for most engineering materials and is certainly recommended for geosynthetics.

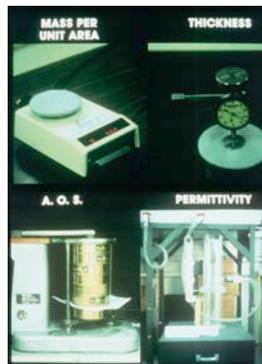
National standards bodies, such as the American Society for Testing and Materials (ASTM) have established standard tests for geosynthetics. These standard tests can be used to compare specific properties of different geosynthetics.

Geosynthetics test procedures can generally be placed in two categories: index tests and design tests. These two categories tend to overlap at times, and this distinction is not always clear.

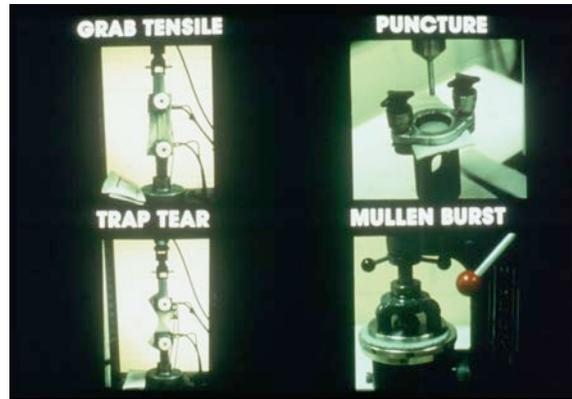
Index tests are those tests a specifier or user can use to compare different geosynthetics. They do not, generally, provide a designer with "hard numbers" to use in his design, but they do allow for a quantitative comparison of physical property data. Most standard geosynthetics testing methods fall into this category.

Index tests are further divided by geosynthetics manufacturers into quality control tests and performance tests. Quality control tests are run routinely by the manufacturer in their labs and are used as a means of insuring product quality. Performance index tests are run at regular intervals (sometimes by an independent lab) in order to provide necessary test results for the manufacturer's products.

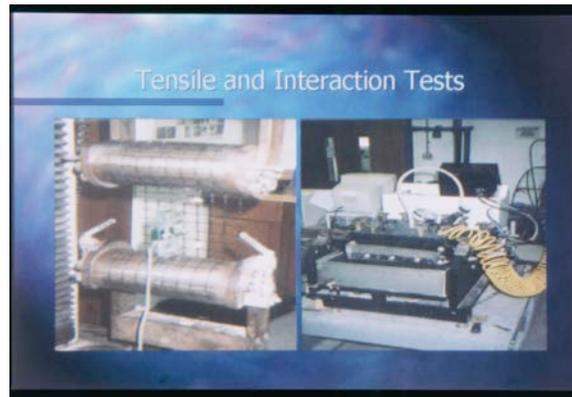
Design tests, as the term implies, provide a designer with additional performance values he can use in his calculations. An index test may be converted to a design test by changing boundary conditions, soil types, etc. The basic premise of a design test is that the test set-up accurately models field conditions.



APPENDIX 2  
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Typical QC Index Tests



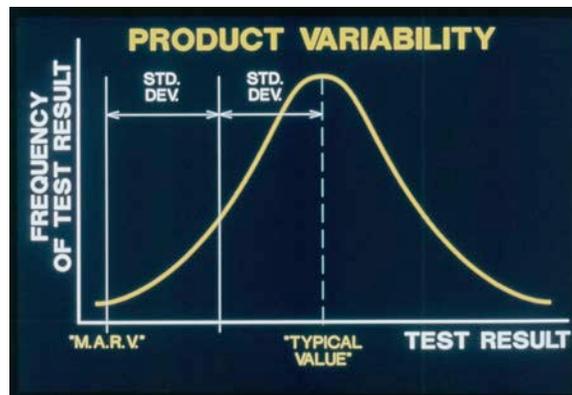
Typical Performance Index Tests

### **Specifying Geosynthetics**

For all applications, four selection criteria should be considered.

Quality Control - Geosynthetics must be tested to insure they meet the specification. Most manufacturers test their geosynthetics and will supply certificates of compliance to the specification. However, on critical applications, additional testing should be performed by the user or an independent lab to guarantee that the geosynthetic complies with the specification.

Geosynthetics are commonly specified using Minimum Average Roll Values which statistically assures the contractor that the material purchased will consistently meet specs.



Minimum Average Roll Values (MARVs) assure that nearly all material exceeds specification requirements

APPENDIX 1  
Geotextile Material Specifications

Survivability - Geosynthetics must be able to withstand installation stresses. Often these stresses are significantly more severe than application stresses.



Installation damage testing determines how much the tensile strength of a product should be reduced to account for damage during construction

Long-term Design - Geosynthetics must be able to function as designed over the life of the project. Most specifications include properties related to long-term performance.



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Transmissivity and Creep Testing are examples of commonly run design tests.

**Durability** - Geosynthetics must be able to function in the application's environment over the design life of the project. Durability considerations are particularly critical for waste facilities and chemical storage areas, but should be examined whenever acidic or alkaline soils are present or unusual geosynthetic design conditions are known, (e.g. prolonged exposure to sunlight. etc.)



Environmental Stress Crack Resistance testing is a common durability test run on geomembranes

**Specifications**

The link below are to generic material specifications for common geotextile applications. The specification of other geosynthetic applications will generally require the input of a qualified engineering professional.

STANDARD SPECIFICATION FOR CONSTRUCTION OF ROADS AND BRIDGES ON FEDERAL HIGHWAY PROJECT FP03 – [can be found by searching this link](#)

AASHTO M288 can be found at this link [M288-06-UL - Standard Specification for Geotextile Specification for Highway Applications](#)

