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18.1 OVERVIEW

This chapter addresses the design of geosynthetics in the following applications:

- Bedding
- Separation
- Drainage
- Slope Protection
- Stabilization
- Turbidity Curtain
- Silt Fence
- Geomembranes
- Prefabricated Composite Structural Drains
- Prefabricated Composite Integral Abutment Drains
- Geogrids
- Geocells
- Geosynthetic Fibers

Investigation and design of Geosynthetically Reinforced Soil System (GRSS) walls and slopes are addressed in NYSDOT GDM Chapter 17.

Investigation and design of embankment base reinforcement using geosynthetics is addressed in NYSDOT GDM Chapter 12.

This chapter does not address applications where geosynthetics are used to help establish vegetation through temporary prevention of erosion (vegetation mats).

18.1.1 Definitions

The following definitions are provided by ASTM D4439:

- Apparent Opening Size (AOS), \( \theta_{95} \): for a geotextile, a property which indicates the approximate largest particle that would effectively pass through the geotextile.
- Breaking Load: the maximum force applied to a specimen in a tensile test carried to rupture.
- Clogging: for a geotextile, the condition where soil particles move into and are retained in the openings of the fabric, thus reducing hydraulic conductivity.
- Cross-Machine Direction: the direction in the plane of the fabric perpendicular to the direction of manufacture.
- Elongation at Break: the elongation corresponding to the breaking load, that is, the maximum load.
- Geogrid: a reinforcing geosynthetic comprised of integrally connected tensile elements.
- Geonet: a geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets a various angles for planar drainage of liquids or gases.
• Geomembrane: an essentially impermeable geosynthetic composed of one or more synthetic sheets.
• Geosynthetic: a planar product manufactured from polymeric material used with soil, rock, earth, or geotechnical engineering related material as an integral part of a man-made project, structure, or system.
• Geotextile: a permeable geosynthetic comprised solely of textiles.
• Hydraulic Transmissivity: for a geotextile or related product, the volumetric flow rate of water per unit width of specimen per unit gradient in a direction parallel to the plane of the specimen.
• Machine Direction: the direction in the plane of the fabric parallel to the direction of manufacture.
• Permittivity (Ψ, T⁻¹) of Geotextiles: the volumetric flow rate of water per unit cross sectional area per unit head under laminar flow conditions, in the normal direction through a geotextile.
• Sample: (1) a portion of material which is taken for testing or for record purposes, (2) a group of specimens used, or of observations made, which provide information that can be used for making statistical inferences about the population(s) from which the specimens are drawn.
• Specimen: a specific portion of a material or laboratory sample upon which a test is performed or which is taken for that purpose.
• Tearing Strength: the force required either (1) to start or (2) to continue to propagate a tear in a fabric under specified conditions.
• Tensile Strength: for geotextiles, the maximum resistance to deformation developed for a specific material when subjected to tension by an external force.
• Tensile Test: in textiles, a test in which a textile material is stretched in one direction to determine the force-elongation characteristics, the breaking force, or the breaking elongation.
• Wide-Width Strip Tensile Test: for geotextiles, a uniaxial tensile test in which the entire width of an 8 in. wide specimen is gripped in the clamps, and the gauge length is 4 in.

18.2 DEVELOPMENT OF DESIGN PARAMETERS FOR GEOSYNTHETIC APPLICATION

For underground drainage design, information regarding the gradation and density of the soil in the vicinity of the geosynthetic drain, as well as details regarding the likely sources of water to the drain, including groundwater, is needed. For shallow systems, hand holes will be adequate for this assessment. For drainage systems behind retaining walls, test holes may be needed. In general, the geotechnical site investigation conducted for the structure itself will be adequate for the drainage design.

In general for soil stabilization and separation, hand holes coupled with Falling Weight Deflectometer (FWD) test results will be adequate for design purposes. For extremely soft subgrade soils, subgrade shear strength data may be needed to allow a subgrade reinforcement design to be conducted.
Investigation for silt fences can generally be done by inspection, as silt fence design is, in general, standardized.

Investigation for base reinforcement of embankments over soft ground is addressed in NYSDOT GDM Chapter 12.

For geomembrane design, groundwater information and soil gradation information is usually needed. If the geomembrane is to be placed on a slope, the geotechnical data needed to investigate slope stability will need to be obtained (see NYSDOT GDM chapters 10, 12, and 13).

18.3 GEOSYNTHETICS

The accepted American Society for Testing and Materials (ASTM) definition of geosynthetic is: “A planar product manufactured from polymeric material used with foundation soil, rock, earth, or other geotechnical engineering material, as an integral part of a man-made structure of system.”

Within this classification fall many types of geosynthetics. They include geotextiles, geomembranes, geogrids, and geocomposites such as prefabricated edge drains, prefabricated vertical drains (wick drains), prefabricated structural drains.

A geotextile is defined as a permeable geosynthetic comprised solely of textiles, geomembrane as an essentially impermeable geosynthetic composed of one or more synthetic sheets; geocomposite as a product fabricated from any combination of geosynthetics with geotechnical materials, or other synthetics, which is used in a geotechnical application; geogrid as a reinforcing geosynthetic comprised of integrally connected tensile elements.

The Department currently uses an Approved List of materials in the selection of a geosynthetic for use on its projects. The Approved List is developed from a set of basic minimum material properties aimed at assuring satisfactory performance of the geosynthetic in non-critical, non-severe applications, and to reduce installation damage. The criteria for critical/severe projects are provided in Table 18-1. In instances of non-severe, non-critical applications, a geotextile may be selected directly from the Approved list for the intended application. See NYSDOT GDM Section 18.4 Approval Process.
### A. Critical Nature of Project

<table>
<thead>
<tr>
<th>Item</th>
<th>Critical</th>
<th>Less Critical</th>
</tr>
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<tbody>
<tr>
<td>Risk of loss of life and/or structural damage due to drain failure.</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Repair cost versus installation costs of drain</td>
<td>&gt;&gt;&gt;&gt;&gt;</td>
<td>= or &lt;</td>
</tr>
<tr>
<td>Evidence of drain clogging before potential catastrophic failure</td>
<td>None</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### B. Severity of Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Severe</th>
<th>Less Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil to be drained</td>
<td>Gap-graded, pipable, or dispersible</td>
<td>Well-graded or uniform</td>
</tr>
<tr>
<td>Hydraulic gradient</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Flow conditions</td>
<td>Dynamic, cyclic, or pulsating</td>
<td>Steady state</td>
</tr>
</tbody>
</table>

**Table 18-1 Guidelines for Evaluating Critical/Severe Nature**
(adopted from Holtz et al., 1995)

If a failure of the installation is determined to be severe and critical, then the Approved List is only a starting point. A detailed design process should be undertaken to reduce the potential for a catastrophic failure of the installation.

#### 18.3.1 Geosynthetic Types and Characteristics

Terms used in the past for geosynthetic construction materials include fabrics, filter fabric, or filter cloth, which are for the most part synonymous with the newer term geotextile.

Geotextiles are made from one or more of the following polymers:
- polyester,
- polypropylene,
- polyethylene, or
- polyamide.

The polymers are formed into one of the three basic fiber types:
- filaments,
- staple fibers,
- slit films.
A filament is a long continuous yarn that, along with many filaments is woven or formed into a geotextile. A staple fiber is a filament that has been cut into a short fiber (2 in. – 3 in.). A slit film is a yarn formed by taking a flat polymer sheet and using sharp cutting blades to cut the sheet into long flat yarns.

The yarns are formed into woven, non-woven, or a combination of woven and non-woven geotextiles.

1. Woven Geotextiles
   A woven geotextile is formed by weaving parallel sets of either single filaments (monofilament), or two or more filaments twisted together (multifilament), or slit films perpendicular (or at a skew to each other) simply woven into a mat. Woven geotextiles generally have relatively high strength and stiffness and, except for the monofilament wovens, relatively poor drainage characteristics.

2. Nonwoven Geotextiles
   A non-woven geotextile consists of a random arrangement of either filaments or staple fibers bonded together through a mechanical, chemical, and/or thermal process. The bonding process plays a major part in determining the physical properties of the end product. Depending on the intended use and critical material property requirements of the geotextile, a composite geotextile may be formed by a combination of a woven and non-woven geotextile. Nonwoven geotextiles tend to have low-to-medium strength and stiffness with high elongation at failure and relatively good drainage characteristics. The high elongation characteristic gives them superior ability to deform around stones and sticks.

A chemical bond consists of a resin material that joins the fibers together at their points of contact. A thermal bond is formed when the fibers are heated to a high enough temperature to cause them to melt together at their points of contact. One form of mechanical bonding is called needle punched. This bond is formed by "punching" many thin, barbed needles through the geotextile. When the needles are withdrawn, the fibers become intertwined together forming the bond.

The type of geotextile used on a particular project will depend on its intended primary function in the installation, and thus its critical properties.
a. Slit Film Woven
b. Monofilament Woven
c. Combination Monofilament/ Fibrillated Yarn Woven
d. Needle Punched NonWoven
e. Heatbonded NonWoven

Figure 18-1 Geotextiles
Other geosynthetic types and characteristics include:

1. Geogrids
   A polymer grid mat constructed either of coated yarns or a punched and stretched polymer sheet. Geogrids usually have high strength and stiffness and are used primarily for soil reinforcement.

   a. Extruded Uniaxial
   b. Extruded Biaxial
   c. PVC Coated Woven Biaxial

Figure 18-2 Geogrids
2. Geonets
   Similar to geogrids, but typically lighter weight and weaker, with smaller mesh openings. Geonets are used in light reinforcement applications or are combined with drainage geotextiles to form a drainage structure.

3. Geomembranes
   Impervious polymer sheets that are typically used to line ponds or landfills. In some cases, geomembranes are placed over moisture-sensitive swelling clays to control moisture.

![PVC Extruded Geomembrane](image1.png) ![PVC Textured Geomembrane](image2.png)

**Figure 18-3 Geomembranes**

4. Geocomposites
   Prefabricated composite edge drains (PCEDs), prefabricated composite structure drains (PCSDs)/prefabricated composite integral abutment drains (PCIADs) (i.e. wall drains), and sheet drains that typically consist of a cusped or dimpled polyethylene drainage core wrapped in a geotextile. The geotextile wrap keeps the core clean so that water can freely flow through the drainage core, which acts as a conduit. Prefabricated composite edge drains are used in place of shallow geotextile-wrapped trench drains at the edges of the roadway to provide subgrade and base drainage. PCSDs or PCIADs are typically placed between the back of an abutment and the soil to drain the retained soil.
18.3.2 Geosynthetic Function Definitions and Applications

The function of the geosynthetic varies with the application. The geosynthetic must be designed with its application function(s) in mind. Typical geosynthetic functions include filtration, drainage, separation, reinforcement, and erosion control.

Definitions of these functions and examples of their dominant applications are as follows:

(a) Geosynthetic Filtration
   The passage of water through the geosynthetic relatively unimpeded (permeability or permittivity) without allowing passage of soil through the geosynthetic (retention). This is the primary function of geotextiles in underground drainage applications.

(b) Drainage
   The carrying of water in the plane of the geosynthetic as a conduit (transmissivity) is a primary function of geocomposite drains. In some cases, the function includes thick, nonwoven needle-punched geotextiles placed in underground drainage applications where water must be transported away from a given location by the geosynthetic itself.

(c) Separation
   The prevention of the mixing of two dissimilar materials. This is a primary function of geotextiles placed between a fine-grained subgrade and a granular base course beneath a roadway.

(d) Reinforcement
   The strengthening of a soil mass by the inclusion of elements (geosynthetics) that have tensile strength. This is the primary function of high-strength geotextiles and geogrids in geosynthetic reinforced wall or slope applications, or in roadways placed over very soft
subgrade soils that are inadequate to support the weight of the construction equipment or even the embankment itself.

(e) Geosynthetic Erosion Control
The minimizing of surficial soil particle movement due to the flow of water over the surface of bare soil or due to the disturbance of soil caused by construction activities under or near bodies of water. This is the primary function of geotextiles used as silt fences or placed beneath riprap or other stones on soil slopes. Silt fences keep eroded soil particles on the construction site, whereas geotextiles placed beneath riprap or other stones on soil slopes prevent erosion from taking place at all. In general, the permanent erosion control methods described in this chapter are only used where more natural means (like the use of biodegradable vegetation mats to establish vegetation to prevent erosion) are not feasible.

These functions control some of the geosynthetic properties, such as apparent opening size (AOS) and permittivity, and in some cases load-strain characteristics.

The application will also affect the geosynthetic installation conditions. These installation conditions influence the remaining geosynthetic properties needed, based on the survivability level required.

(f) Geosynthetic Survivability
The ability of the geosynthetic to resist installation conditions without significant damage, such that the geosynthetic can function as intended. Survivability affects the strength properties of the geosynthetic required.

18.4 APPROVAL PROCESS

18.4.1 Geotextiles, Geocomposites and Geomembranes

18.4.1.1 Approved List

The NYSDOT maintains an Approved List of materials for the subfamilies of geosynthetics including geotextiles, geocomposites, and geomembranes. All of these geosynthetics, including those sold under a private label agreement, shall be submitted for testing and approval through the American Association of State Highway and Transportation Officials (AASHTO) National Transportation Product Evaluation Program (NTPEP). The program has a rolling submission cycle. Information regarding submittal is available at the address shown below:

AASHTO-NTPEP Coordinator
444 N. Capitol St., NW, Suite 249
Washington, DC 20001
www.ntpep.org

The requirements of the NYSDOT Standard Specifications are based on the most current version of the AASHTO M-288 Specification for Geotextiles. The results of the NTPEP testing are the basis for the NYSDOT Approved List.
The strength, permeability and filtration characteristics of most of the manufactured geotextiles have been determined by extensive testing. Based upon the strength testing, the NYSDOT has divided the geotextiles into three strength classes: Class 1 being the strongest class, Class 2 of lesser strength and Class 3, the least strong.

Figure 18-5 Geotextile Strength Testing
The permeability and filtration characteristics have been grouped to be compatible with the soil material being drained. These are grouped according to apparent opening size (AOS) class as follows:

Class A is compatible with coarse material (0%-15% passing No. 200 sieve).
Class B, with average material (15%-50% passing No. 200 sieve).
Class C, with fine soil (greater than 50% passing No. 200 sieve).

Figure 18-6 Geotextile Permeability and Filtration Testing
18.4.1.1.1 Approved List – Quality Assurance

The purpose for sampling and testing construction materials is to verify the physical properties. For geosynthetics, the Contractor shall furnish material with a brand name and style appearing on the Approved List for the intended application and a material certification with the geotextile stating that the material conforms to the specification.

Ideally, geosynthetics are controlled during manufacturing by a quality control (QC) program. However, the Department’s level of confidence in the supplied geotextiles is low if there is no exchange of information regarding operations, no ability to control and/or monitor processing improvements and/or QC sampling intervals, or no guarantee in the labeling of the specifically processed geotextile.

Additional steps are required to boost the level of confidence. Quality Assurance (QA) is defined by the American Association of State Highway and Transportation Officials (AASHTO) as all those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service.

Quality assurance refers to the overall system for ensuring project quality and is discussed in NYSDOT GDM Chapter 7. The NYSDOT has established a QA Program in accordance with 23 CFR 637 to ensure the materials incorporated into each Department project are in conformity with the approved plans and specifications.

QA of geotextiles involves collecting samples and performing testing to compare its properties to those properties determined at the time of the product's initial approval, which may indicate a change has occurred in the manufacturing process or QC process.

The following scenarios may develop as a result of the QA testing.

1. The properties are shown to be comparable to those originally determined, within the statistical validity of the test. No action will be taken.
2. The properties are shown to be significantly different than originally determined.
   a. If the results are within the acceptable minimum for approval, contact with the manufacturer will be made by the Geotechnical Engineering Bureau to determine what has changed.
   b. If the results are below the minimum acceptable for approval, the product’s status on the Approved List will be re-evaluated. The manufacturer will be notified of the review.

The Geotechnical Engineering Bureau continues to assess and revise the QA program as needed.

18.4.1.1.1.1 Approved List Quality Assurance – Method of Sampling

The Department reserves the right to sample and test material delivered to the contract site in order to be confident that the material being used meets those properties established at the time of the product's initial approval and therefore, meets specification requirements.
SiteManager will submit to the Regional Geotechnical Engineer, at the beginning of each calendar year and the beginning of each month thereafter, a list of contracts that contain the planned use of geosynthetic material. The list will include a notification that designates the quantity of samples for each application type.

It is the Regional Geotechnical Engineers responsibility to determine which contracts to visit throughout the construction season to obtain the necessary geosynthetic QA samples. The Regional Geotechnical Engineers QA sampling protocol should include sufficient flexibility to obtain samples from various manufactures for the different application types.

The Regional Geotechnical Engineer will take the QA samples in accordance with the instructions contained in Section 737, log them into SiteManager, and submit them to the Geotechnical Engineering Bureau for testing and evaluation.

18.4.2 Geogrids

The NYSDOT accepts independent laboratory test data for the subfamily of geosynthetics that are geogrids. Geogrid reinforcing shall be tested and certified to meet the minimum requirements for geosynthetic products in accordance with AASHTO Specifications for Highway Bridges, *Geosynthetic Reinforcement*.

The certification of material specification is identified in catalog cut sheets presenting the independent laboratory test results. The certification submitted with the geogrid shall identify the following:

- The geogrid manufacturer’s name,
- The geogrid name,
- The test lot number,
- The minimum average roll value (MARV) for Ultimate Tensile Strength (ASTM 6637),
- The long-term design tensile strength, and
- The reduction factors used to calculate the long-term design tensile strength (including supporting laboratory test data).

The Regional Geotechnical Engineer will review the material for acceptance based on the Ultimate Tensile Strength, the Long-Term Design Tensile Strength, and the reduction factors.

1. Reduction Factors: The Geotechnical Engineering Bureau has examined the standard backfill items and construction practices and has assigned the minimum reduction factor values for durability and installation damage as follows:
   - \( RF_{ID} \). Reduction Factor For Installation Damage (GRI:GG4, ASTM D 5818, and ASTM D 6637) - The minimum tested \( RF_{ID} \) value permitted is 1.1.
   - \( RF_{DU} \). Reduction Factor for Durability - The minimum tested \( RF_{DU} \) value permitted is 1.1.
   - \( RF_{CR} \). Reduction Factor for Creep Deformation – The specification identifies the design life and ASTM test to determine the creep factor. The geogrid
manufacture shall provide test data to verify their $R_{FCR}$ (AASHTO PP 66, ASTM D 5262, and ASTM D 6992).

Based on the appropriate reduction factors (either submitted or superseding minimum values), the Regional Geotechnical Engineer will review and accept or reject the material based on the information provided in the contract documents and the following equations:

**Equation 18-1**

$$ RF = R_{FCR} \times R_{FD} \times R_{FDU} $$

Where:
- $RF$ = Total Reduction Factor
- $R_{FCR}$ = Reduction Factor for Creep Deformation
- $R_{FD}$ = Reduction Factor For Installation Damage
- $R_{FDU}$ = Reduction Factor for Durability

**Equation 18-2**

$$ T_D = \frac{T_{ULT}}{RF} $$

Where:
- $T_D$ = Long Term Design Tensile Strength
- $T_{ULT}$ = Ultimate Tensile Strength
- $RF$ = Total Reduction Factor

18.4.3 Geocells

The NYSDOT accepts independent laboratory test data for the subfamily of geosynthetics that are geocells. Geocells consist of High Density Polyethylene (HDPE) and are to conform to the size(s) and dimensions shown in the contract documents.

The certification of material specification is identified in catalog cut sheets presenting the independent laboratory test results. The certification submitted with the geocells shall identify the following:

- The geocell manufacturer’s name,
- The geocell name,
- The test lot number,
- The minimum thickness (ASTM D 5199),
- The cell seam peel strength (Per U.S. Army Corps of Engineers, Technical Report GL-86-19, Appendix A),
- The ultraviolet stability (ASTM D 1603 or ASTM D 4218), and
- The environmental stress crack resistance (ASTM D 1693).
18.4.4 Geosynthetic Fibers

The NYSDOT accepts independent laboratory test data for the subfamily of geosynthetics that are geofibers. Geosynthetic fibers consist of fibrillated polypropylene strands.

The certification of material specification is identified in catalog cut sheets presenting the independent laboratory test results. The certification submitted with the geosynthetic fibers shall identify the following:

- The geosynthetic fiber manufacturer’s name,
- The geosynthetic fiber name,
- The test lot number,
- The polypropylene percentage (ASTM D4101, Group I/Class I/Grade 2),
- The fiber length (measured),
- The specific gravity (ASTM D792),
- The carbon black content (ASTM D1603),
- The tensile strength (ASTM D2256),
- The tensile elongation (ASTM D2256), and
- Young’s modulus (ASTM D2101).
Figure 18-8 Geosynthetic Fibers
The Regional Geotechnical Engineer will review the material for acceptance.

18.5 DESIGN REQUIREMENTS

18.5.1 Geotextiles, Geocomposites and Geomembranes

For situations where a site specific geosynthetic design is required, FHWA manual No. FHWA NHI-95-038 “Geosynthetic Design and Construction Guidelines – Participant Notebook” (Holtz, et al., 1995) shall be used.

The following questions must be answered to complete a geosynthetic design:

- Is a geosynthetic really needed?
- What geosynthetic properties will ensure the geosynthetic functions as intended?
- Where should the geosynthetic be located?
- Will maintenance or replacement of the geosynthetic, or the structure of which it is a part, be needed? If so, how soon and how will it be maintained or replaced?

The site conditions and purpose for the geotextile are reviewed to determine whether or not a geotextile is needed.

- For most drainage, separation, soil stabilization, permanent erosion control, and silt fence applications, if a geotextile is needed, the geotextile properties in the Standard Specifications can be used.
- In some situations where soil conditions are especially troublesome or in critical or high-risk applications, a project-specific design may be needed.
- The location of the geosynthetic will depend on how it is intended to function.
- Consider the flow path of any groundwater or surface water when locating and selecting the geotextile to be used. For example, in permanent erosion control applications, water may flow to the geotextile from the existing ground as well as from the surface through wave action, stream flow, or overland sheet flow. For saturated fine sandy or silty subgrades, water must be able to flow from the subgrade through the geotextile soil stabilization layer during the pumping action caused by traffic loads.

Background information and the answers to each of these questions, or at least guidance to obtaining the answers to these questions, are provided for each of the following Standard Specifications applications:

18.5.1.1 Geotextile Drainage

In a drainage installation, the geotextile lines a stone filled trench adjacent to a highway pavement. See Figure 18-9. The function of the drainage system is to collect free water from underground sources, rainfall runoff, spring melt, etc. The free water enters the trench through the geotextile, travelling to regularly spaced outlets. The primary function of the geotextile is to act as a filter, retaining in-situ soil particles while allowing water to pass through. The geotextile thus prevents the drainage system from becoming plugged with in-situ soil, which otherwise would be transported into it by the flowing water.
The NYSDOT allows only non-woven geotextiles to be used in this application. The non-wovens provide better soil retention characteristics than do other types.

Figure 18-9 Geotextile Wrapped Longitudinal Underdrain

Figure 18-10 Geotextile Wrapped Longitudinal Dry Swale

Geotextiles used for underground drainage must provide filtration to allow water to reach the wrapped drain aggregate without allowing the aggregate to be contaminated by finer soil particles. The designer should be aware that as the geotextile performs filtration, over time the collected fines will form a coating, or filter cake, on the surface of the geotextile. This coating
CHAPTER 18
Geosynthetic Design

will, at some point in time, develop to a thickness that will significantly reduce the permittivity of the geotextile. For this reason, some designers will place the geotextile on top of a 3” to 4” bed of underdrain filter aggregate to slow down the development of the filter cake at the base of the geotextile wrap, or will utilize geotextiles for drainage filtering only on temporary applications, or in locations where the geotextile can be easily replaced every 7 to 10 years, or less.

Geotextile filtration properties are a function of the soil type. For underground drainage applications, if the subgrade soil is relatively clean gravel or coarse sand, a geotextile is probably not required. At issue is whether or not there are enough fines in the surrounding soil to eventually clog the drain rock or drain pipe if unrestricted flow toward the drain is allowed.

In the drainage installation the critical properties are pore size opening of the geotextile structure, and its water flow capacity. At the present time the pore size opening of a geotextile is expressed in terms of its Apparent Opening Size (AOS), and its water flow capacity in terms of its Permittivity.

Caution should be exercised in attempting to equate the apparent opening size of a geotextile to the ability of the geotextile to act as a filter. The AOS is a measure of a particular opening size of the material, and not the pore size distribution. Just as the grain size distribution of a soil needs to be considered in designing its use as a filter, the pore size distribution of a geotextile is important in the design of its use as a filter. However, at the present time there are no accepted standard methods for determining the distribution. In the interim design methodologies exist that incorporate AOS in them. For one design approach incorporating AOS refer to Chapter 2 of the National Highway Institute's May 1995 Publication No. FHWA HI - 95-038, "Geosynthetic Design and Construction Guidelines Participant Notebook."

In designing for permittivity requirements there are differing views on which property to use, once the permittivity of the geotextile is known. There are designs methods which, using the nominal thickness of the geotextile, convert the geotextile permittivity to permeability. This is then compared to the permeability of the soil. The NH1 Notebook calls for $k_{\text{geotextile}} > k_{\text{soil}}$ in non-critical, non-severe applications. For critical, severe applications $k_{\text{geotextile}} > 10k_{\text{soil}}$, is required.

There are also design methods which convert the soil coefficient of permeability to permittivity by taking into account the length of the flow path the water will travel through the soil. Since the volumetric flow rate of water through the geotextile compared to the volumetric flow of water through the soil is what is critical, it is recommended that when performing a drainage design permittivity be used. The 3rd Edition of "Designing with Geosynthetics" by Dr. Robert Koerner uses the permittivity approach when discussing drainage designs with geotextiles.

The strength requirements for approval for use in the drainage application are minimal requirements that will allow the geotextile to survive installation stresses. These requirements are based on materials that have demonstrated sufficient strength properties in the past. If there is the potential that the geotextile will be exposed to chemical or biological activity that will drastically reduce the strength properties of it over its life expectancy, factors of safety need to be
incorporated into the design. There are ASTM Standards which evaluate the potential of the geotextile to be damaged by chemical and/or biological activity.

The minimum requirements for a geotextile to be included in the drainage category are provided in the Standard Specifications. The permeability and filtration characteristics have been grouped to be compatible with the soil material being drained. These are grouped according to apparent opening size (AOS) class as follows:

<table>
<thead>
<tr>
<th>Geotextile Class</th>
<th>Compatible Soil</th>
<th>Percent Passing No. 200 Sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Coarse material</td>
<td>Less than 15%</td>
</tr>
<tr>
<td>B</td>
<td>Average material</td>
<td>15% to 50%</td>
</tr>
<tr>
<td>C</td>
<td>Fine material</td>
<td>Greater than 50%</td>
</tr>
</tbody>
</table>

Table 18-2 Selection Criteria for Geotextile Flow Capacity and Soil Retention Class

18.5.1.1.1 Design Methods

The installation is evaluated to determine whether it is a non-critical/non-severe or critical/severe installation. In non-critical/non-severe installations, any of the geotextiles listed in the Drainage category of the Approved List may be used. In critical/severe installations, follow the design process outlined here and detailed in the NHI notebook:

1. Obtain soil samples from the site.
   a. Perform grain size analyses.
   b. Perform laboratory permeability tests or field percolation tests.
   c. Select drainage aggregate.
2. Calculate anticipated flow into and through the drainage system.
3. Determine geotextile requirements.
   a. Soil retention criteria.
   b. Permittivity/Permeability requirements.
   c. Clogging criteria, if appropriate.
   d. Survivability
4. Estimate costs.
5. Select materials from the Approved List that meet the design requirements as determined above.
6. Prepare specifications, if material property requirements are more stringent than those for original approval.
7. Obtain samples of the selected drainage aggregate and geotextile before final acceptance on the project.
8. Monitor installation during and after storm events.
   a. When necessary perform maintenance operations, including outlet cleaning.
18.5.1.1.2 Installation Procedures

Once the geotextile has been selected, extreme care must be exercised in the installation process to ensure satisfactory performance of the drainage system. The basic installation process is as follows:

1. In the Department underdrain installations using geotextiles, the geotextile wrapped trench is used.
2. When preparing the site for this type of installation, caution and attention needs to be paid to the excavation of the trench. In order to prevent piping of the soil and eventual clogging of the geotextile, the walls of the trench should be free from large voids. Such voids will allow migration of fines towards the surface of the geotextile. This will cause the geotextile to become clogged and not perform as intended.
3. When installing the geotextile in the trench, care needs to be taken to ensure intimate contact of the geotextile and surrounding soil. Should there not be this contact, it will have the same effect on performance as having large voids mentioned above in the side walls of the trench.
4. The trench shall have no large protruding stones or objects in the trench that can puncture the geotextile, thus negating the ability to retain soil. In the same light, care must be taken when installing the fabric not to overstress it causing tears.
5. Should damage occur to the geotextile during installation, the damaged area has to be repaired by either cutting out of the damaged section and replacement with undamaged material, or the placement of a "geotextile patch" over the damaged section.

As indicated above, once the system has been installed, there must be regular, routine maintenance performed in order to maintain the effectiveness of the system. First and foremost in this process is the maintaining of open outlets to allow the water to flow from the system.

18.5.1.2 Geotextile Separation

In separation applications, the geotextile is used to prevent the inter-mixing of the subgrade and the subbase soils to prevent contamination, and thus reduction in the permeability, of the subbase soil. If the application is strictly one of separation, the minimum properties for acceptance in this category are sufficient.

In separation the critical function of the geotextile is to prevent migration of the subgrade soil into the subbase material. There is a two-fold reason for preventing migration of the subgrade soil. First is to prevent contamination of the subbase material, thus reducing the permeability of it such that the water infiltrating in could not drain out in an appropriate length of time. The second is to maintain the design thickness of the roadway. Migration of subgrade into the subbase can lead to a reduction in the overall thickness.

The secondary property of importance is the permittivity of the geotextile. It must allow water to flow through in order to dissipate any pore pressure build-up that may occur in the subgrade. If the soil retention of the geotextile is sufficient as mentioned above, pore pressure build-up in the
subbase because of contamination from subgrade material should not occur as it (subbase) should have sufficient permeability to dissipate any pore pressures. Excess pore pressure in either the subgrade or subbase will cause failure of a pavement system. The designer should be aware that as the geotextile performs filtration, over time the collected fines will form a coating, or filter cake, on the surface of the geotextile. This coating will, at some point in time, develop to a thickness that will significantly reduce the permittivity of the geotextile which can then lead to a build up of pore pressure at the subgrade surface. To prevent the development of this condition, some designers will place a thin layer of subbase below the separation geotextile or the geotextile is placed at a depth that greatly minimizes pumping of the subgrade from traffic loads.

The minimum requirements for a geotextile to be included in the separation category are provided in the Standard Specifications.
Figure 18-11 Geotextile Separation
18.5.1.3 Geotextile Stabilization

Geotextile used for soil stabilization must function as a separator, a filtration layer, and (to a minor extent) a reinforcement layer. This application is similar to the separation application, except the subgrade is anticipated to be softer and wetter than in the separation application.

Soil stabilization geotextile is used in roadway applications if the subgrade is too soft and wet to be prepared and compacted as required in the Standard Specifications. Soil stabilization geotextile is placed directly on the soft subgrade material, even if some overexcavation of the subgrade is performed. The designer should be aware that as the geotextile performs filtration, over time the collected fines will form a coating, or filter cake, on the surface of the geotextile. This coating will, at some point in time, develop to a thickness that will significantly reduce the permittivity of the geotextile which can then lead to a build up of pore pressure at the subgrade surface as pumping from traffic loads occurs. To prevent the development of this condition, some designers will place a thin layer of subbase below the stabilization geotextile or the geotextile is placed at a depth that greatly minimizes pumping of the subgrade from traffic loads.

In non-critical/non-severe installations, any of the geotextiles listed in the Stabilization category of the Approved List may be used. In critical/severe installations, a detailed design must be carried out to ensure that the proper geotextile tensile strength is selected for use.

Consider the flow path of any groundwater or surface water when locating the soil stabilization geotextile and when selecting the geotextile type to be used. For saturated fine sandy or silty subgrades, water must be able to flow from the subgrade through the geotextile soil stabilization layer during the pumping action caused by traffic loads.

Even if the subgrade is not anticipated to be saturated based on available data, if the subgrade is silty or clayey and it is anticipated that the geotextile will be installed during prolonged wet weather, a soil stabilization geotextile may still be needed.

Soil stabilization geotextile should not be used for roadway fills greater than 5 ft. high or when extremely soft and wet silt, clay, or peat is anticipated at the subgrade level (for example, the deposits encountered in wetlands). In such cases, the reinforcement function becomes more dominant, requiring a site-specific design.
Figure 18-12 Geotextile Stabilization
18.5.1.3.1 Design Methods

It is not the practice of the NYSDOT to consider the reinforcing effect of the geotextile in pavement design. Generally, a geogrid is used for this purpose. The geotextile, if used, is assumed to act purely as a separator.

As stated above, when the geotextile is expected to perform as stabilization in critical/severe applications, a detailed design of the system needs to be done. As outlined in the NH1 Notebook, there are eight basic steps, some requiring additional work, to be followed in designing for stabilization.

The design process consists of the following:
1. Determine the need for a stabilization fabric.
2. The roadway should be designed for structural support using normal pavement design methods, making no allowance for the geotextile.
3. If additional subbase is required for structural support as a result of the susceptibility of soils to pumping and subbase intrusion, reduce the additional subbase by 50% and include a geotextile in the design at the subgrade/subbase interface.
4. Determine if additional subbase is required for stabilization of the subgrade during construction activities using a 3 in. rutting criteria for construction equipment. The design procedures for this are outlined in Section 5.8 of the NHI Notebook.
5. Compare the subbase geotextile system determined in Step 4 to that in Step 3, and use the greatest thickness.
6. Check the geotextile strength requirements for survivability as detail in Section 5.5 of the NHI Notebook.
7. Check the geotextile filtration requirement as outlined in Chapter 2 on Drainage in the NHI Notebook.

Once the design has been completed, and the geotextile requirements are known, refer to the Approved List of Geotextiles under Stabilization category and select the appropriate material from the list.

18.5.1.3.2 Installation Procedures

The basic installation procedures include the following:

1. The site should be cleared, grubbed, excavated, or filled to the design grade.
2. The geotextile should be laid smooth without wrinkles or folds on the prepared subgrade. On curves, the geotextile may be folded or cut to conform to the curves. The reason for insuring smooth placement is to keep the geotextile in intimate contact with the subgrade to avoid creating the potential for migration of the subgrade soil. The aim is to prevent plugging or clogging of the geotextile that would reduce its drainage capability.
3. Prior to covering, the geotextile should be inspected for any installation damage to this point. Damaged geotextiles should be repaired/replaced immediately.
4. The subbase should be placed by end dumping onto the geotextile from the edge of the geotextile, or over previously placed subbase material.
5. Fill any ruts that occur during construction. Compact the filled ruts to the specified density.
6. If subbase placement causes any damage to the geotextile, the damaged area is to be repaired/replaced. In this stabilization installation, vibratory compaction equipment is not to be used.
7. At no time during the installation process is construction equipment to be allowed directly on the geotextile. Were this to be allowed, the geotextile might be damaged, necessitating repair or replacement.

18.5.1.4 Geotextile Slope Protection

In the Department's use of geotextiles, erosion control use is covered under three categories, with slope protection being one. The geotextile acts as a separator under stone slope protection on highway slopes. Free drainage of groundwater occurs, while the underlying soil is held in place. See Figure 18-14.

In the slope protection category, only needle punched non-woven geotextiles are allowed. This style provides better frictional resistance between the geotextile, the stone fill, and the soil than the others. Where slopes are steeper than 1V on 1.75H, a non-heat bonded requirement should also be added to the type of geotextile used since this provides an even higher frictional resistance, or the geotextile should only be placed at the upper and lower ends of the stone fill layer and over locations with heavy seepage.

The critical material property is the permittivity of the geotextile. As indicated, the purpose of the geotextile is to allow drainage of water from the slope, while retaining soil. Allowing drainage to occur dissipates the build-up of pore pressure in the slope, thus reducing the potential for the occurrence of a slope failure.

The minimum material properties for non-severe, non-critical installations in the slope protection category are provided in the Standard Specifications. The permeability and filtration characteristics have been grouped to be compatible with the soil material being drained. These are grouped according to apparent opening size (AOS) class as identified in Table 18-2.
Figure 18-13 Geotextile Slope Protection

Figure 18-14 Method of Placing Geotextile for Slope Protection of Cut and Fill Slopes
18.5.1.4.1 Design Methods

The installation is evaluated to determine whether it is a non-critical/non-severe or critical/severe installation. In non-critical/non-severe installation, any of the geotextiles listed in the Slope Protection category of the Approved List may be used. In critical/severe installations, follow the design process outlined here and detailed in the NHI Notebook:

1. Evaluation of the application has determined that it is a critical and/or severe installation.
2. Perform grain size analysis and permeability testing on soil obtained from the site.
3. Determine the size, type and placement techniques of the stone slope protection to be placed on top of the geotextile.
4. Determine the anticipated flow through the erosion control system.
5. Determine the geotextile requirements for the following:
   a. Soil retention criteria,
   b. Permeability criteria,
   c. Clogging criteria,
   d. Survivability.
6. Estimate the cost of the erosion control system including the stone slope protection, the geotextile, and any additional materials.
7. Prepare the project specific specification using the Approved List as a source of material meeting the above determined requirements.
8. Obtain samples of the geotextile before acceptance for use on the project.
9. Monitor the installation during construction for proper installation procedures, and damage to the geotextile resulting from installation. Continue monitoring of the site after installation for proper performance.

18.5.1.4.2 Installation Procedures

Refer to Construction Appendix of the AASHTO Specification for Geotextiles for detailed construction guidelines. The basic construction procedure is as follows:

1. The geotextile is to be placed in intimate contact with the soils without wrinkles or folds. The geotextile should be placed such that placement of the overlying material not excessively stretch the geotextile causing tears.
2. In the slope protection application, the geotextile shall be placed with the machine direction of the geotextile parallel to the flow of water, which is normally parallel to the dip of the slope. Successive sheets of geotextiles shall be placed up slope over down slope. See Figure 18-14.
3. Extreme care should be taken to avoid damage of the geotextile during installation. Repairs should be as per the Construction Appendix.
4. Following laydown of the geotextile, it should be covered within 14 days to minimize damage potential due to ultraviolet exposure.
5. Placement of the stone slope protection shall begin at the toe of slope and proceed up the slope. Heavy stone should not be dropped from a height greater than 1 ft.
6. Lighter stone should not be dropped from a height greater than 3 ft.
7. All void spaces in the stone protection should be filled to avoid deterioration due to ultraviolet exposure over the life of the installation.
8. If grading of the slope results in stone movement directly above the geotextile, grading should cease.
9. The site should be monitored for the occurrence of geotextile damage during installation. Damaged geotextile should be replaced.

Following installation the site should be periodically inspected for the following:
1. To ensure that the geotextile has not become clogged, allowing pore pressure build-up behind it leading to a "blow-out" of the geotextile. This should not happen if the geotextile has been placed in intimate contact with the slope during installation.
2. That the stone protection has not slid on the geotextile either abrading, or tearing the geotextile. Should this occur, the erosion control function is lost.

Should either of the above occur, it will be necessary to repair the installation for continued erosion control.

**18.5.1.5 Geotextile Bedding**

Bedding is one of the three categories of erosion control geotextile use. In this application the geotextile is placed without of a layer of granular material under stone fill armoring, which protects the face of a slope or the backfill around a structure that is located in or near moving water. See Figures 18-3 & 18-4. The geotextile prevents the erosion of the underlying soil due to the eddy action of moving water.
The NYSDOT only allows the use of monofilament woven geotextiles for this application. The other types of materials tended to float in the water rather than sink and line the channel.
For bedding, the critical material property is soil retention, as expressed by apparent opening size. This is followed by sufficient permittivity to allow dissipation of any hydrostatic pressure which may build-up behind the geotextile. The retention of the soil prevents erosion of the channel, and dissipation of hydrostatic pressures prevents a "blow-out" of the geotextile from occurring.

The minimum material properties for inclusion on the Approved List in the bedding application for non-critical, non-severe applications are provided in the Standard Specifications. The permeability and filtration characteristics have been grouped to be compatible with the soil material being drained. These are grouped according to apparent opening size (AOS) class as identified in Table 18-2. The tensile strength characteristics have been grouped according to a few tests as follows:

<table>
<thead>
<tr>
<th>Geotextile Class</th>
<th>Percent Elongation (%)</th>
<th>Grab Strength (lbf)</th>
<th>Tear Strength (lbf)</th>
<th>Puncture Strength (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 50%</td>
<td>315</td>
<td>112</td>
<td>618</td>
</tr>
<tr>
<td></td>
<td>≥ 50%</td>
<td>202</td>
<td>79</td>
<td>433</td>
</tr>
<tr>
<td>2</td>
<td>&lt; 50%</td>
<td>247</td>
<td>56</td>
<td>495</td>
</tr>
<tr>
<td></td>
<td>≥ 50%</td>
<td>157</td>
<td>56</td>
<td>309</td>
</tr>
</tbody>
</table>

Table 18-3 Selection Criteria for Geotextile Tensile Strength Class

18.5.1.5.1 Design Methods

The installation is evaluated to determine whether it is a non-critical/non-severe or critical/severe installation. In non-critical/non-severe installations, any of the geotextiles listed in the Bedding Category of the Approved List may be used. In critical/severe installations, follow the design process outlined here and detailed in the NHI Notebook:

1. Evaluation of the application has determined that it is a critical and/or severe installation.
2. Perform grain size analysis and permeability testing on soil obtained from the site.
3. Determine the size, type and placement techniques of the stone filling to be placed on top of the geotextile.
4. Determine the anticipated flow through the erosion control system.
5. Determine the geotextile requirements taking into account the information determined from the previous steps. This includes soil retention criteria, permeability criteria, clogging criteria, and survivability.
6. Estimate the cost of the erosion control system including the stone filling, the geotextile, and additional materials.
7. Prepare the project specific specification using the Approved List as a source of material meeting the above determined requirements.
8. Obtain samples of the geotextile before acceptance for use on the project.
9. Monitor the installation during construction for proper installation procedures, and
damage to the geotextile resulting from installation. Continue monitoring of the site
after installation for proper performance.

18.5.1.5.2 Installation Procedures

Refer to the Construction Appendix of AASHTO Specification for Geotextiles for detailed
construction guidelines. The basic procedure is as follows:

1. The geotextile is to be placed in intimate contact with the soils without wrinkles or folds.
The geotextile should be placed such that placement of the overlying material not
ever stretch the geotextile causing tears.

2. In the bedding application the geotextile should be placed with the machine direction of the
gotextile parallel to the stream or channel. Successive sheets of geotextiles should be
placed upstream over downstream. See Figure 18-16.

3. Extreme care should be taken to avoid damage of the geotextile during installation.
Repairs should be as per the Construction Appendix.

4. Following lay down of the geotextile, it should be covered within 14 days to minimize
potential damage due to ultraviolet exposure.

5. Placement of the stone filling should begin at the toe of slope and proceed up the slope.
Heavy stone should not be dropped from a height greater than 1 ft. or directly onto the
gotextile. A layer of aggregate material should separate the geotextile from the base of
the heavy stone material.

6. Lighter stone should not be dropped from a height greater than 3 ft.

7. If grading of the slope results in stone movement directly above the geotextile, grading
shall cease.

8. The site should be monitored for the occurrence of geotextile damage during installation.
Damaged geotextile should be replaced.

Following installation, the site should be periodically inspected for the following:

1. To ensure that the geotextile has not become clogged, allowing pore pressure buildup
behind it leading to a “blow-out” of the geotextile. This should not happen if the
geotextile has been placed in intimate contact with the slope during installation.

2. That the stone filling has not slid on the geotextile, either abrading or tearing the
geotextile. Should this occur, the erosion control function is lost.

Should either of the above occur, it will be necessary to repair the installation for continued
erosion control.

18.5.1.6 Silt Fence

The silt fence application is one of three erosion control applications. In the silt fence
application, the geotextile is used as a temporary structure to remove suspended particles from
runoff water from construction sites. See Figure 18-17. The primary function of geotextile used
in a temporary silt fence is to prevent eroded material from being transported away from the
construction site by runoff water. The silt fence acts primarily as a temporary dam and
secondarily as a filter.

In some cases, depending on the topography, the silt fence may also function as a barrier to direct flow to low areas at the bottom of swales where the water can be collected and temporarily ponded. It is desirable to avoid the barrier function as much as possible, as silt fences are best suited to intercepting sheet flow rather than the concentrated flows that would occur in swales or intermittent drainage channels.

To function as intended, the silt fence should have a low enough permeability to allow the water to be temporarily retained behind the fence, allowing suspended soil particles in the water to settle to the ground. If the retention time is too long, or if the flow rate of water is too high, the silt fence could be overtopped, thus allowing silt-laden water to escape. Therefore, a minimal amount of water must be able to flow through the fence at all times.

Temporary water ponding is considered the primary method of silt removal and the filtration capabilities of the fence are the second line of defense. However, removal of silt-sized particles from the water directly by the geotextile creates severe filtration conditions for the geotextile, forcing the geotextile to either blind or allow the fines to pipe through the geotextile. (Blinding is the coating of the geotextile surface with soil particles such that the openings are effectively plugged.)

The source of load on the geotextile is from silt buildup at the fence and water ponding. The amount of strength required to resist this load depends on whether or not the geotextile is supported with a wire or polymer grid mesh between the fence posts. Obviously, unsupported geotextile must have greater strength than supported geotextile. If the strength of the geotextile or its support system is inadequate, the silt fence could fail. Furthermore, unsupported geotextile must have enough stiffness that it does not deform excessively and allow silt-laden water to go over the top of the fence.

For silt fence, either woven or non-woven geotextiles may be used. The fences may either wire-supported, or self-supported fences. The wire supported fences have either a metal or plastic wire mesh attached to the support posts and/or geotextile. The self-supported fences have no mesh. Self supported fence geotextiles must not exhibit greater than 50% elongation at 50% of the minimum required grab tensile strength referred to below.

In the silt fence installation, two, perhaps contradictory, conditions have to be maximized. The attempt is being made to maximize flow of water through the geotextile, while retaining the maximum amount of sediment. However, as the sediment is filtered from the runoff, the geotextile will become clogged or plugged, thus reducing the flow of water through it.

The minimum material properties for inclusion on the Approved List in the silt fence application for non-critical, non-severe applications are provided in the Standard Specifications. The tensile strength characteristics determine the required post spacing and whether or not additional support (backing) is necessary as follows:
### Table 18-4 Selection Criteria for Geotextile Post Spacing and Support Requirements

<table>
<thead>
<tr>
<th>Max. Post Spacing (ft.)</th>
<th>Percent Elongation (%)</th>
<th>Grab Strength (lbf)</th>
<th>Orientation</th>
<th>Fence Between Posts</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>NA</td>
<td>90</td>
<td>MD</td>
<td>Supported</td>
<td>s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XD</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>≥ 50%</td>
<td>123</td>
<td>MD</td>
<td>Unsupported</td>
<td>us 4.0</td>
</tr>
<tr>
<td></td>
<td></td>
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Figure 18-17 Typical Silt Fence Detail
18.5.1.6.1 Design Methods

The installation is evaluated to determine whether it is a non-critical/non-severe or critical/severe installation. In non-critical/non-severe installations, any of the geotextiles listed in the Silt Fence Category of the Approved List may be used. In critical/severe installations, follow the design process outlined here and detailed in the NHI Notebook:

1. Determine the grain size distribution of the soil to be filtered.
2. Estimate the volume of soil expected to be eroded during construction. This will allow determination of the number of silt fences needed.
3. Determine the anticipated runoff conditions of the site.
4. Determine the expected environmental conditions, such as anticipated length of exposure to sunlight.

One approach to designing for critical, and/or severe conditions is similar to the procedure used for designing drainage systems, as outlined in the Geotextile Drainage section. A second approach is to perform laboratory model flow studies, using the ASTM Standard D 5141 for determining filtration efficiency of geotextiles. This procedure requires large amounts of water and sediment, and space to perform the test. The Soil Mechanics Laboratory of the Geotechnical Engineering Bureau currently does not have the facilities, or equipment to perform this test.

Based on using the underdrain filter design approach, the following criteria, as discussed in Section 4.2 of the NHI Notebook, may be applied when selecting a silt fence for a critical, and/or severe installation.

1. Soil Retention Criteria
   a. For woven geotextiles, an AOS = D_{85} of the soil passing the No. 10 US Standard Sieve.
   b. For non-woven geotextiles, an AOS = 1.8D_{85} of the soil passing the No. 10 US Standard Sieve.
2. Flow Capacity Criteria (Expressed as liters per time)
   a. Permittivity = 10 (runoff volumetric flow rate)/cross sectional area of the area served by the fence.
3. Clogging Resistance
   a. Use the largest AOS requirement from No. 1.

In determining the AOS above, the No. 10 US Standard Sieve is used, as larger particles are not likely to be transported by the runoff water.

While construction of silt fences is rather simple, care must be taken to ensure desired performance. Support posts may be of wood, steel, or synthetic material. They are to be of sufficient strength to withstand damage during installation, and to support the applied loads due to sediment build-up behind the silt fence. If supporting mesh is used, it should be strong enough to support the applied loads.
18.5.1.6.2 Installation Procedures

As detailed in the NYSDOT Standard Specifications, basic construction guidelines are as follows:

1. Excavate at proposed location of silt fence.
2. Posts shall be driven into the ground.
3. Geotextile and any mesh support (if applicable) shall be placed on the upstream side of the posts. Mesh shall be placed between the geotextile and the post.
4. The geotextile shall be fastened to each post in no less than 4 locations with approved fasteners.
5. The mesh support shall be fastened to each post at the top, bottom, and two additional evenly spaced locations, or by a continuous corded attachment along the top of the assembly.
6. Any geotextile or mesh splices necessary for fence erection shall be continuous between two post sections.
7. Geotextile at the bottom of the fence shall be buried in a trench to a depth of 6 in. The trench shall be back filled with the excavated soil and the soil compacted by tamping.

Following installation, there should be a concerted maintenance routine followed. The basics are as follows (Details are found in the AASHTO Specification for Geotextiles Appendix):

1. The silt fence should be inspected immediately after each storm event, and at least daily during any prolonged storm event. Deficiencies should be corrected immediately.
2. If construction has altered the contours, daily review should be made to ensure proper location of the silt fence. Deficiencies should be corrected immediately.
3. Damaged, and/or ineffective silt fences should be replaced or repaired promptly.
4. If sediment deposits reach half the height of the fence, they should be removed, or a second fence installed.

18.5.1.7 Turbidity Curtain

As a turbidity curtain, the geotextile acts as a barrier in streams, lakes, etc. to prevent the pollution of the main body of water by fine soils which have been disturbed by construction activities in the water. Water is allowed to slowly pass through the geotextile, while the fine soils are retained.

In the turbidity curtain application either woven or non-woven geotextiles may be used. The geotextile must have sufficient permittivity to allow passage of water, an AOS that will retain the desired soils, and sufficient strength to withstand the stresses of installation, and those due to water and sediment loads.

The minimum material properties for inclusion on the Approved List in the turbidity curtain application for non-critical, non-severe applications are provided in the Standard Specifications.
18.5.1.7.1 Design Methods

The installation is evaluated to determine whether it is a non-critical/non-severe or critical/severe installation. In non-critical/non-severe installations, any of the geotextiles listed in the Turbidity Curtain Category of the Approved List may be used. In critical/severe installations, follow the design process outlined here and detailed in the NHI Notebook:

1. Determine the grain size distribution of the soil to be filtered.
2. Evaluate the expected environmental conditions, such as anticipated length of exposure to sunlight.
3. Determine the current velocity, direction, and discharge volume of water.
4. Estimate the depth of water, and levels of turbidity.
5. Evaluate the effects of wave action due to waterway traffic.
6. Determine the nature of the bottom sediment and vegetation.
7. Evaluate wind conditions.
The following criteria needs to be evaluated in selecting the geotextile for installation as a turbidity curtain:

1. Soil Retention Criteria:
   a. For woven geotextiles, an AOS = D_{25} of the site soil
   b. For non-woven geotextiles, an AOS = 1.8D_{85} of the site soil
   c. The D_{85} should be determined from soil passing the No. 10 US Standard Sieve.

2. Flow Capacity Criteria (Expressed as liters per time)
   a. Permittivity = 10( volumetric flow rate of water )/cross sectional area of turbidity curtain

3. Clogging Resistance
   a. Use the larger AOS requirements from No. 1.

In constructing a turbidity curtain, some form of floatation material (e.g., styrofoam collars, etc.) is attached to the top of the turbidity curtain, and some form of ballast (e.g., heavy chain) attached to the bottom. Both serve to hold the curtain in place.

The U.S. Army Corps of Engineers recommends that turbidity curtains not be used in the following conditions:

1. Operations in the open ocean.
2. Operations where the currents exceed 1.1 mph.
3. In areas frequently exposed to high winds, and large breaking waves.
4. In areas where frequent curtain movement may be necessary

18.5.1.8 Drainage Geocomposites

As used by the NYSDOT, drainage geocomposites consist of three types of geosynthetic products. They include prefabricated vertical drains, prefabricated composite structural drains, and prefabricated composite edge drains.

The prefabricated vertical drain is used in place of the conventional sand drains for the purpose of increasing the rate of consolidation of a foundation soil. The prefabricated composite structural drain is used in place of the conventional graded aggregate filter behind such structures as bridge abutments and retaining walls. The prefabricated composite edge drain, by its name, is self explanatory.

In all three types of drains, the structure of the drain is a polymeric core of some configuration wrapped with a geotextile. One configuration is one of several forms of cuspates, such as egg crate style, or posts. The core may have cuspates on one or both sides, it may have holes in the core such that water may pass through the core. Another core configuration may be in the form of a geonet. A geonet is defined as a geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets a various angles for planar drainage of liquids or gases.
In all three types of drains the geotextile is required to have been, or to become approved for use as geotextile drainage. Based on the type of drain it is, there are further requirements for testing which must be met also.

As described in NYSDOT GDM Section 18.5.1, the geotextile property requirements are minimal properties which perform in non-critical, non-severe installations. If the site design is determined to be of a critical, severe nature, the geotextile needs to be designed as described in this Chapter.

**18.5.1.8.1 Prefabricated Vertical Drains (Wick Drains)**

Prefabricated vertical drains (PVDs) are approximately ¼ in. in thickness, and approximately 4 in. in width. Because wick drains are smaller than sand drains they require closer spacing, and thus more drains than sand drains to achieve the same end-result. Nevertheless, wick drains are often an economically attractive alternative.

In addition to the geotextile material requirements, the wick drain must meet further requirements in the form of minimum equivalent sand drain diameter, and minimum net core flow capacity, both as determined by NYSDOT Standard Test Methods as shown in Geotechnical Test Procedure (GTP-6) Soil Mechanics Laboratory Test Procedures. The two test methods are for equivalent sand drain diameter, and for flow capacity under all-around lateral pressure.

The minimum requirements for inclusion on the Approved List are provided in the Standard Specifications.

See NYSDOT GDM Chapter 14 for details in designing PVDs. The design process determines drain spacing and layout pattern.

Installation of the wick drains is done by placing the drain through a diamond shaped mandrel which is crane mounted, and pushing the mandrel through the foundation soils using high pressure. In those instances where obstacles are encountered, or the foundation soil is too firm to allow pushing of the mandrel through it, the holes may be pre-augered, and then the drain installed. Following installation of the drains, the area is covered with a drainage blanket to allow drainage of the water which is forced out by the consolidation process.
Figure 18-19 PVD Product Sample
Figure 18-20 Prefabricated Vertical Drain
18.5.1.8.2 Prefabricated Composite Structural Drains

Prefabricated composite structural drains are also referred to as wall drains or sheet drains. This type of drain is generally a flat sheet ranging in width from 1 ft. to 3 ft., and supplied in various lengths.

The geotextile is generally adhered to the core with an adhesive that allows it to be peeled away to allow successive cores to be interlocked with one another, and still maintain the continuity of the geotextile. The drain may be double sided with cuspates on each side of the core. The core is either permeable or impermeable with a geotextile attached to each side. It may be a single sided core, with a geotextile on only one side. A single sided core is one with cuspates on only one side of it. Physical requirements of the drain structure depend on the type of core as described above. For some prefabricated composite structural drains, the adhesive is heavily applied on one side of the core, resulting in a loss of permeable area. Installation of the composite drain must ensure that the more permeable side is placed towards the direction of any water flow.

In addition to the geotextile property requirements, the drain structure must meet minimum flow capacity under a compressive load as tested by ASTM Standard D4716, Hydraulic Transmissivity. Hydraulic transmissivity of a geosynthetic is defined as the volumetric flow rate per unit width of specimen per unit gradient in a direction parallel to the plane of the specimen.

The requirements for hydraulic transmissivity in non-critical, and/or non-severe conditions are as follows:
1. For an impermeable core where flow is allowed on both sides of the core, the minimum hydraulic transmissivity is 4.0 gal./min./ft. of width under 1500 psf and a hydraulic gradient of 0.1. This is a total flow using both sides of the core.
2. For permeable cores, or one sided flow impermeable cores, the minimum hydraulic transmissivity is 2.0 gal./min./ft. of width under 1500 psf and a hydraulic gradient of 0.1. Where concrete is to be poured against the drain, only drains with impermeable cores will be allowed.

If it is determined that the installation is a critical and/or severe installation, the drainage design procedure described in NYSDOT GDM Section 18.5.1 should be followed.

Care needs to be exercised when installing the structural drains so as not to puncture the geotextile when backfilling against it and negating the filtering effect of the geotextile. When pouring concrete against it, care needs to be taken so as not to plug or clog the side of the drain which will face the area to be drained. That is the reason for allowing only drains with impermeable cores to be used when placing concrete against them.

The drains may be attached to the face of an existing abutment or wall by use of a simple adhesive material.
Figure 18-21 Prefabricated Composite Structural Drain

Figure 18-22 Prefabricated Composite Integral Abutment Drain
18.5.1.8.3 Prefabricated Composite Edge Drains (PCED)

The PCED’s generally range in thickness from 1 in. to 1.5 in., from 12 in. to 18 in. in width, and are supplied in various roll lengths.

The core configurations for the PCED’s vary. They come in a single or double sided egg crate type configuration, several post type configurations, and one type that is a flattened plastic pipe with holes in the sides of the pipe to allow the water to enter the core.

The geotextile cover may be adhered to the core with an adhesive material, or tightly wrapped around it. If the drain is supplied with a wrapped geotextile, the geotextile must not intrude the core under a compressive load such that is will reduce the flow capacity of the drain. Specific requirements are given below.

Besides the underdrain geotextile requirements, the PCED must meet minimum hydraulic transmissivity, compressive strength of the core, and fabric intrusion under load into the core requirements. The hydraulic transmissivity is determined by ASTM Standard D4716. The core compressive strength is determined by ASTM Standard D1621. The fabric intrusion is determined by the NYSDOT Intrusion Test.

The minimum requirements for inclusion on the Approved List for non-critical and/or non-severe conditions are provided in the Standard Specifications.

In excavating for the installation of the PCED, a narrow trench (4 in. to 6 in.) is excavated. The walls of the trench must be free from large voids which would promote the piping of fines and eventual clogging of the geotextile.

The PCED is fed through a "boot" which places it in a vertical position, against the pavement side of the trench. Attention needs to be paid to the condition of the PCED in the trench following placement. There are PCED’s whose core configuration may have sharp edges running parallel to the direction of the drain. In some instances these sharp edges have sliced the geotextile covering as the drain was running through the boot into the trench. These slices will allow soil to enter the core, and thus reduce its flow capacity.

Care also has to be taken to avoid "C-ing", or "J-ing" of the drain as it is placed in the trench. "C-ing" means that the drain has been placed in the trench in a curved position. "J-ing" means that the bottom part of the drain has been placed in the trench in a curved position. The effects of both of these are the same. It is extremely critical in placing the PCED to ensure that it intercepts the interface between the pavement and the subbase in order to allow drainage of water from this area. If the drain is curved, it most likely will not intercept this interface, and removal of the water will not take place.

In replacing the excavated soil, care must be taken not to allow large stones, or sharp objects to be returned to the trench. These may cause puncturing of the geotextile, allowing soils to enter the core and reduce the flow capacity of the drain. Compaction of the backfill is accomplished by
the use of a narrow vibratory ski type apparatus. Proper compaction will prevent migration of fines through the backfill. This will prevent blinding and/or clogging of the geotextile from taking place. It will also prevent settlement of the trench from taking place.

Following installation proper maintenance of the system will ensure continued performance of the system. As with all underdrains, maintaining clear outlets to allow flow is the essential.

See NYSDOT GDM Chapter 20 for additional information on PCEDs.

### 18.5.1.9 Geomembranes

Geomembranes are used as easily installed barriers to liquid or gaseous flow through soils. They are often used in environmentally sensitive areas to prevent contamination of the in situ soils by environmentally detrimental materials such as chemicals, salt, etc. They may also be used as barriers to the flow of water into or out of canals and reservoirs or the backfill near critical structures.

In the use of geomembranes, many sites should be considered as critical as having severe implications after failure. Therefore a detailed design may be required. The 3rd edition of "Designing with Geosynthetics," by Dr. Robert Koerner details design procedures.

For the inclusion of a geomembrane on the Department's Geosynthetic Approved List, the properties of concern are ultimate grab tensile strength and elongation, as determined by ASTM D4632; trapezoid tear strength, as determined by ASTM D4535; puncture resistance, as determined by ASTM D4833. The minimum strength requirements for inclusion on the List are provided in the Standard Specifications.

In a design incorporating the use of a geomembrane, knowledge of the environment which the material will be exposed to is critical. Certification of the chemical compatibility of the geomembrane to the environment, as determined by ASTM D5322, Immersion Procedures for Evaluating Chemical Resistance of Geosynthetics to Liquids may be required.

If the geomembrane is to be installed on a slope, consideration needs to be given to the use of a textured surface or a high friction, coarse sand layer to provide frictional resistance between the surface of the geomembrane and the adjacent soils. This frictional resistance necessary can be determined by ASTM D5321, Determining the Soil and Geosynthetic, or Geosynthetic and Geosynthetic Friction by the Direct Shear Method. The procedure calls for a large scale shear box, minimum size of 1 ft. x 1 ft. for a square box, and a minimum dept of 2 in.

The material placed below and over the geomembrane is to be free of protrusions, very large or very coarse aggregates, or sharp objects which may puncture it. Very often, a sand soil layer is placed adjacent to the geomembrane to protect it from accidental puncture. Installation should be progressed in a manner so that localized stresses should cause no damage to the geomembrane. Damaged areas shall be replaced or repaired to ensure complete impermeability. Seams shall be inspected to ensure impermeable continuity so as to prevent leakage.
Figure 18-23 Geomembrane in Overflow Structure Detail
18.5.2 Geogrids

A geogrid is a polymer grid mat constructed either of coated yarns or a punched and stretched polymer sheet. Geogrids usually have high strength and stiffness and are used primarily for soil reinforcement.

Figure 18-24 Geogrid Reinforcement

See NYSDOT GDM Chapter 17 for information regarding the design of geogrid structures (see geosynthetically reinforced soil system (GRSS) walls and slopes).

See NYSDOT GDM Chapter 12 for information regarding the design of geogrid structures (see design of embankment base reinforcement using geosynthetics).
18.5.3 Geocells

A geocell is a three-dimensional, permeable polymeric honeycomb or web structure of expandable panels used to confine fill materials to create structural stability. Geocells are manufactured from High Density Polyethylene (HDPE). When expanded during installation, the interconnected strips form the walls of a flexible, three-dimensional cellular structure into which specified infill materials are placed and compacted.

![Geocell Expanded Honeycomb Features](image)

![Figure 18-25 Geocell Expanded Honeycomb Features](image)

See NYSDOT GDM Chapter 17 for information regarding the design of geocell structures.

18.5.4 Geosynthetic Fibers

Geosynthetic fibers are expandable polypropylene strands used to stabilize soils. It should be noted that, to date, the NYSDOT has limited experience with geosynthetic fibers. The Department Geotechnical Engineer should be consulted regarding the use of geosynthetic fiber reinforced soil.

Geosynthetic fibers may be used address the following situations:

1. Erosion Gulley Repair – In situations where water has been channelized and inadvertently directed over an existing reinforced, oversteepened slope causing erosion, the corrective measure must not only address the replacement of material but also consider long-term stability due to the extreme slope grade. The inclusion of discrete fibers in select granular fill increases both the apparent cohesion and the angle of internal friction of the replacement soil.

   A mixer capable of mixing and sufficiently supplying the required geofiber-fill ratio is used to prepare the material. The material is mixed and hand-tamped into the void areas to fill slope to finished grade.
2. Bearing Capacity Improvement – Studies (Maheshwari et al., 2011) have shown an increase in bearing capacity of compressible clayey soils with the inclusion of polyester fibers. This lends promise to developing another alternative in subgrade improvement in situations where replacement of the existing material is deemed too expensive.

Geosynthetic fibers are placed on the upper surface of each lift in the specific pattern determined by the geosynthetic fiber-fill ratio. The geosynthetic fibers are spread uniformly over the lift, mixed into the soil with a machine capable of processing the soil, and compacted.
18.6 REFERENCES


American Association of State and Highway Transportation Officials (AASHTO), Standard Practice for Determination of Long-Term Strength for Geosynthetic Reinforcement, AASHTO PP 66, Washington, D.C.


ASTM International, American Society for Testing and Materials (ASTM), D5818, *Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics*, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959.


