Technical Supplement 14D

Geosynthetics in Stream Restoration

Issued August 2007

Cover photo: Inert or manmade materials can be used in restoration designs where immediate stability is required and can be used in concert with vegetation.

Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

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Geosynthetics in Stream Restoration

Purpose

A variety of geosynthetic materials may be used for various functions and applications in stream restoration and stabilization projects. This technical supplement is intended to provide field staffs an understanding of some of the basic principles and applications of geosynthetic materials.

Introduction

A geosyntethic material is defined as a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as part of a manmade project, structure, or system (American Society for Testing and Materials International (ASTM) D4439). Geosynthetics used in stream restoration and stabilization include geotextiles, geogrids, geonets, geocells, and rolled erosion control products.

Materials

Selection of a geosynthetic material appropriate for a project requires an understanding of the different types that are available, as well as their performance criteria and range of applications. Five types of geosynthetic materials are described here.

Geotextile

A geotextile is defined as a permeable geosynthetic comprised solely of textiles (ASTM D4439). A geotextile may be woven or nonwoven and may be composed of monofilament yarns or monofilament plastic (fig. TS14D–1). A nonwoven geotextile may be needle-punched (fig. TS14D–2), heat bonded (fig. TS14D–3), or resin bonded.

Geogrid

A geogrid is defined as a geosynthetic formed by a regular network of integrally connected elements with apertures greater than a fourth inch to allow interlocking with surrounding soil, rock, earth, and other sur-

Figure TS14D–1 Monofilament woven geotextile

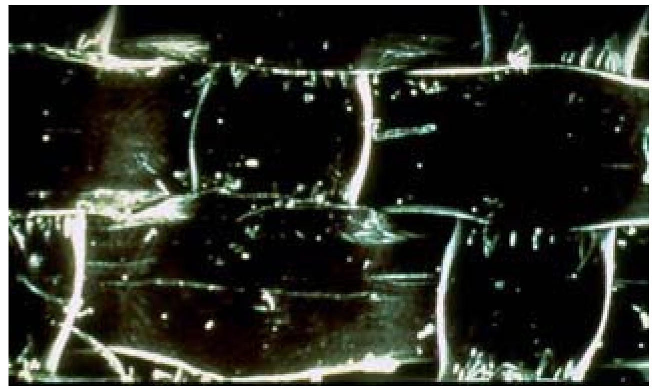


Figure TS14D–2 Needle-punched nonwoven geotextile

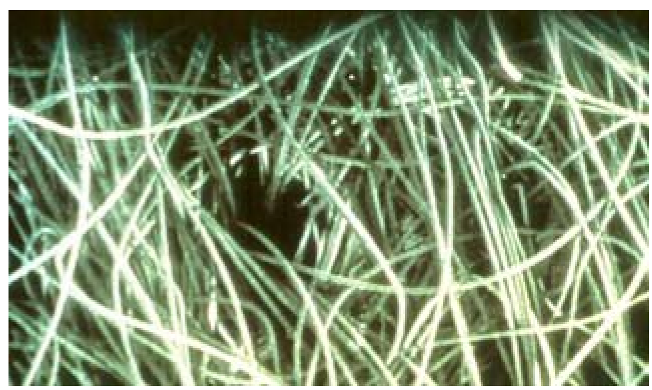


Figure TS14D–3 Heat-bonded nonwoven geotextile

rounding materials to function primarily as reinforcement (ASTM D4439). A geogrid may be biaxial (fig. TS14D–4), or uniaxial (fig. TS14D–5).

Geonet

A geonet is defined as a geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for planar drainage of liquids and gases (ASTM D4439). A typical geonet is shown in figure TS14D–6.

Geocell

A geocell is defined as a product composed of polyethylene strips, connected by a series of offset, full-depth welds to form a three-dimensional honeycomb system (ASTM D4439). Geocells (fig. TS14D–7) are available in a variety of depths from 4 inches to 9 inches.

Figure TS14D–4 Biaxial geogrid

Figure TS14D–5 Uniaxial geogrid

Figure TS14D–6 Geonet

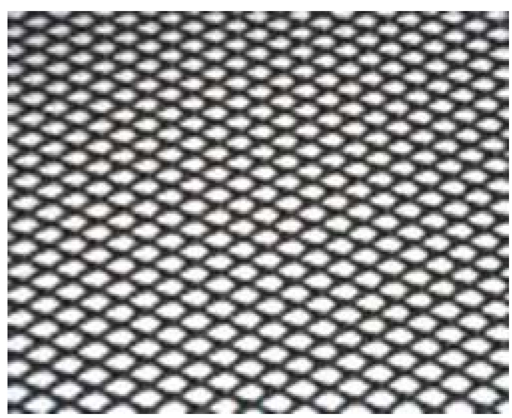


Figure TS14D–7 Geocell

Rolled erosion control products

Rolled erosion control products consist of both erosion control blankets (ECB) used for temporary erosion protection and turf reinforcement mats (TRM) for more permanent erosion protection. An ECB is shown in figure TS14D–8 and two TRMs are shown in figure TS14D–9.

Functions

Geosynthetics may provide one or more of the following functions on a stream restoration or stabilization project.

Drainage

Geosynthetics used for drainage are intended to act as a conduit for fluid (typically water) within the plane of the fabric. Nonwoven geotextiles, geonets, or a composite of geotextiles and geonets are often used for this function.

Filtration

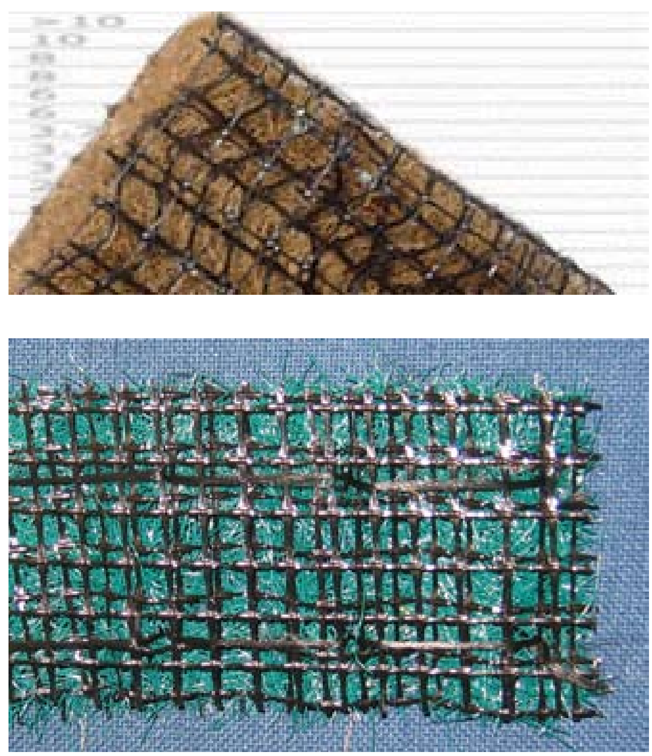
Filtration is the most common use of geosynthetics in stream restoration and stabilization projects. A geosynthetic used for filtration is intended to retain the particles of the filtered (protected) soil, while allowing a fluid to flow through the plane of the fabric. Woven and nonwoven needle-punched geotextiles are used for this function.

Separation

The objective of geosynthetics used for the separation function is to prevent two different materials from mixing and compromising the performance of one or both of these materials. Woven and nonwoven geotextiles may both be used for this function. Heat-bonded nonwoven geotextiles offer an economical geosynthetic separator.

Figure TS14D–8 Erosion control blanket

Figure TS14D–9 Turf reinforcement mats



Reinforcement

Geosynthetics used as reinforcement strengthen the soil mass by interaction with soil, creating frictional or adhesion forces. The geosynthetic reinforcement provides resistance to tensile forces which cannot be otherwise carried by an unreinforced soil mass. High-strength woven geotextiles and geogrids are used for this function.

Erosion control

In erosion control, geosynthetics protect the soil surface from the tractive forces of moving water. They may also provide additional strength to the root system of vegetation. Geotextiles, ECBs, and TRMs may be used for this function.

Applications

Geosynthetics may be used in a variety of applications for streambank restoration and stabilization.

- separation and/or filtration beneath erosion protection materials (fig. TS14D–10)
- reinforcement of steep streambank slopes (fig. TS14D–11)
- mechanically stabilized earth walls (fig. TS14D–12)
- earth retaining structures (fig. TS14D–13)
- erosion protection (fig. TS14D–14)

Geotextile filter

Nonwoven needle-punched geotextiles are typically less costly than woven geotextiles. Nonwoven geotextiles have typically been used by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) beneath erosion protection materials to serve either filtration or separation functions. The U.S. Army Corps of Engineers (USACE) has traditionally used woven geotextiles for these functions. A heat-bonded or resin-bonded nonwoven geotextile should not be used for geotextiles serving as a filter. The permeability of heat-bonded and resin-bonded geotextiles is too low to allow adequate seepage and dissipation of hydrostatic pressure.

A woven geotextile is recommended when water will frequently flow through the geotextile and the retained soil particles have the potential to move within the soil structure towards the geotextile. In this condition, a nonwoven geotextile has a greater potential for clogging since it will allow very few particles to filter through the geotextile. If soil particles have the potential to move within the soil structure, a woven geotextile will often allow fine sand and silt particles to pass through the geotextile until a natural graded filter is developed within the soil structure behind the geotextile. To retain fine sand and silt soil particles, a granular filter of ASTM C33 sand overlain by a properly sized geotextile is often used.

Recommended geotextile properties for geotextiles providing filtration are provided in the Guide for the Use of Geotextile (USDA Soil Conservation Service (SCS) 1991). Recommended geotextile properties for geotextiles providing drainage, separation, and filtration beneath erosion protection are provided in Geotextile Specification for Highway Applications (American Association of State Highway Transportation Officials (AASHTO) 2000). An example design of a geotextile providing filtration beneath rock riprap is provided later in this technical supplement.

It is important to note that some soil bioengineering techniques do not function well under geotextiles, and placing holes through the geotextile may provide a seepage path that would weaken the structure. This may require a trade-off analysis to balance the advantages of incorporating soil bioengineering techniques against the advantages of an intact filter geotextile. Finally, it should be noted that some streambanks may have sufficient gravel or clay content (PI>15), precluding the need for either bedding or geotextiles.

Reinforced slopes

The reinforced slope obtains its internal stability from the tensile strength of the geosynthetic reinforcement layers. The reinforced slope design may be completed with guidance provided by USACE (1995b), U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) 2001c), or Designing with Geosynthetics

Figure TS14D–10 Separation and/or filtration beneath erosion protection material

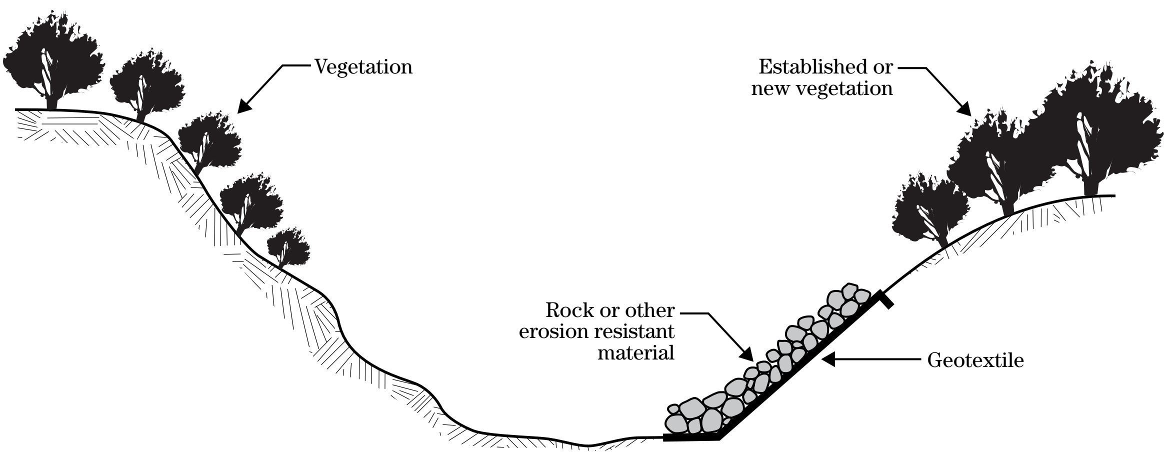


Figure TS14D–11 Reinforcement of steep streambank slope

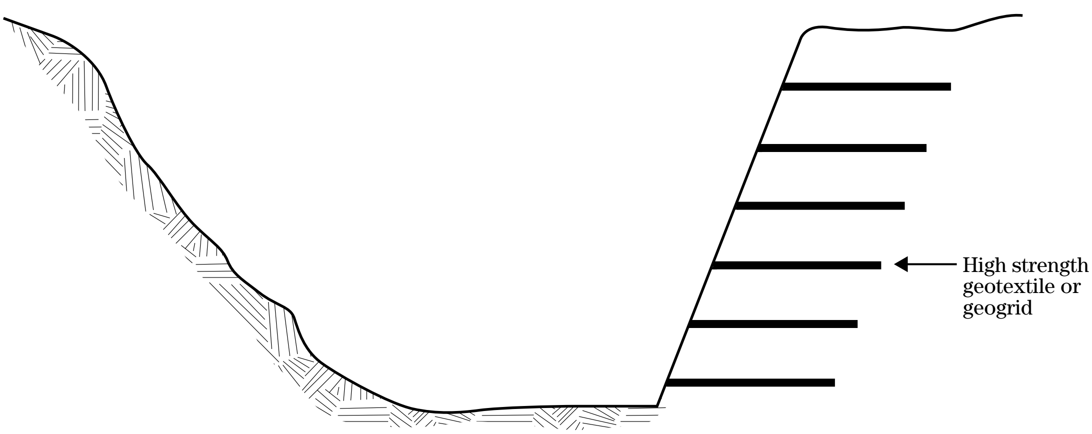


Figure TS14D–12 Mechanically stabilized earth wall

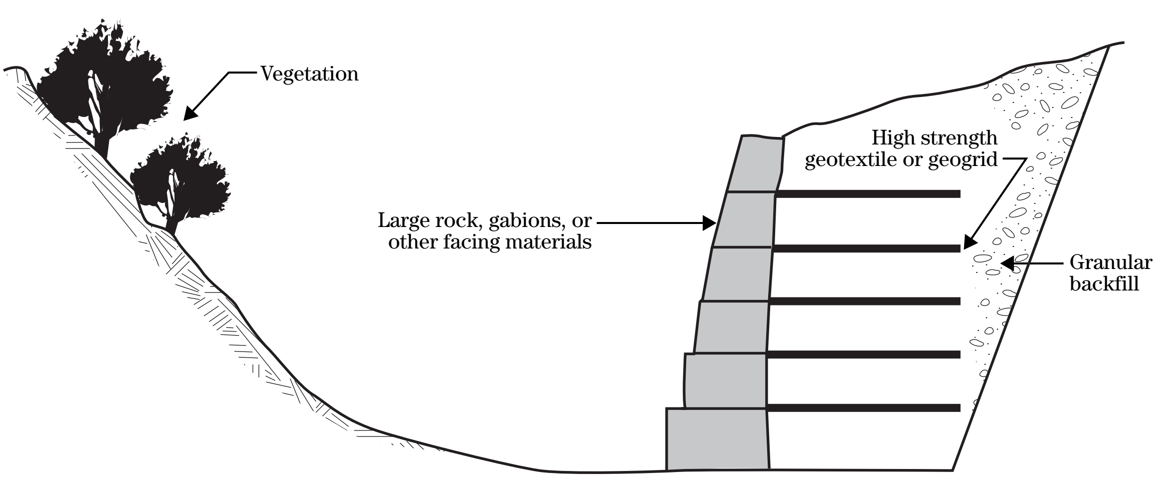


Figure TS14D–13 Earth retaining structure

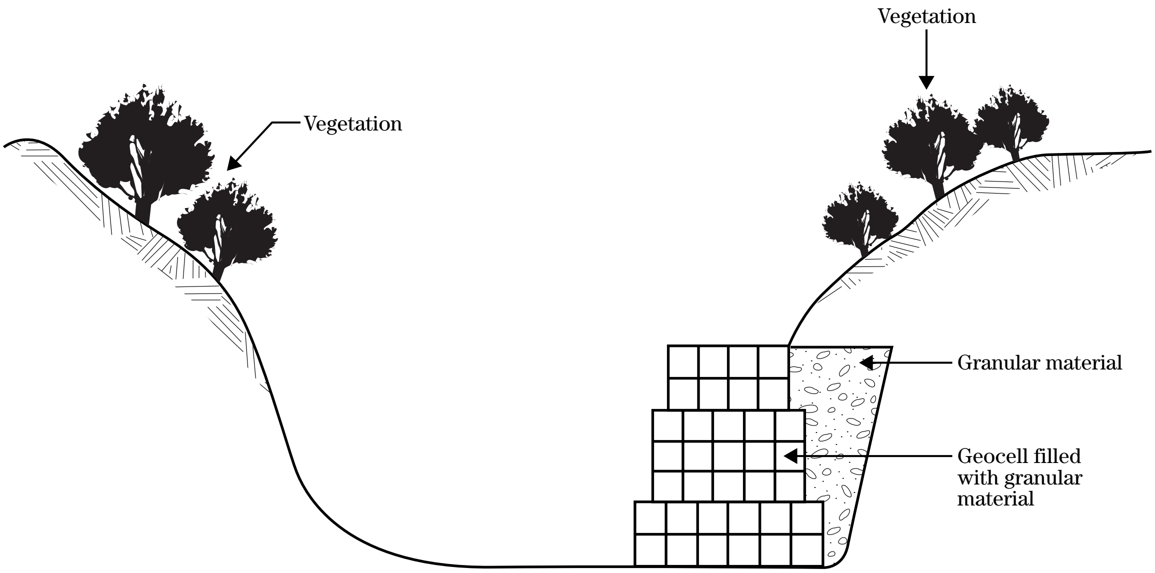
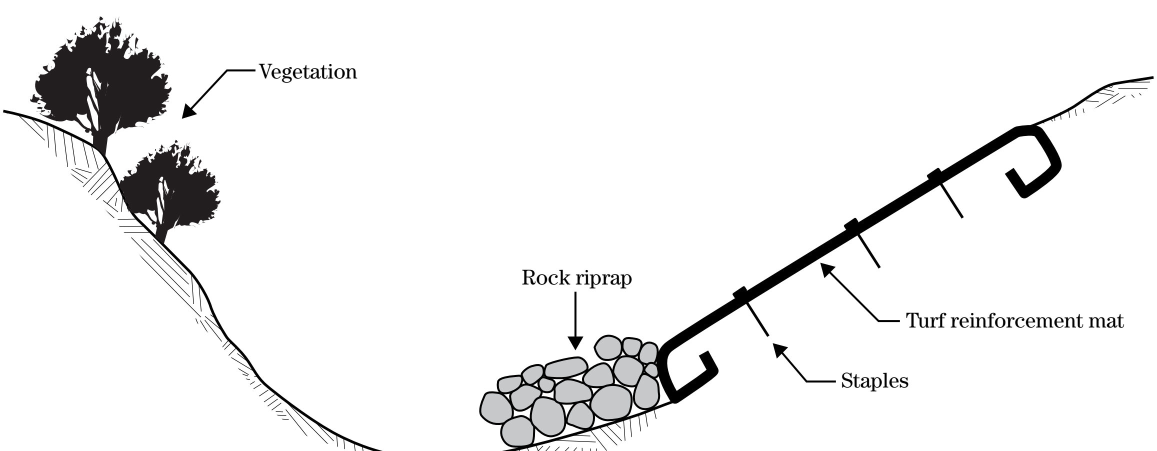


Figure TS14D–14 Erosion protection



(Koerner 1998). The computer program ReSlope may also aid in the design.

Once the internal stability of the slope is satisfied, the external stability must be evaluated, including an analysis of sliding, overturning, bearing capacity, and settlement.

The global stability of reinforced slopes must be analyzed with the appropriate slope stability analysis method. Slope stability analyses are typically performed with computer software such as SLOPE/W, PCSTABLE, or UTEXAS software.

A photograph of a reinforced soil slope with a rock facing is shown in figure TS14D–15.

Mechanically stabilized earth walls

A mechanically stabilized earth (MSE) wall must be designed for external, internal, and local stability. The external stability analyses include sliding, overturning, bearing capacity, and settlement. The internal stability analyses include geosynthetic pullout, tensile strength of the geosynthetic, and internal sliding. Local stability analyses include an analysis of the facing connection to the geosynthetic and bulging of the facing. A photograph of an MSE wall that is under construction is shown in figure TS14D–16.

Guidance for MSE wall design is provided by FHWA (FHWA 2001c), Designing with Geosynthetics (Koerner 1998), or National Concrete Masonry Association (NCMA) 1997). A computer program entitled MSEW may also aid in the design.

Figure TS14D–15 Reinforced soil slope with rock face (*Photograph courtesy of Frank Cousin, NRCS MI*)

Figure TS14D–16 MSE wall under construction

The global stability of the MSE wall, retained soil, and soil foundation must be analyzed, just as reinforced slope design.

Earth retaining structures

An earth retaining structure must be designed for external stability and internal stability. The external stability analyses include an analysis of sliding, overturning, bearing capacity, and settlement. In a geocell wall, the internal stability analysis includes an analysis of the friction between each geocell layer.

The global stability of earth retaining structures must be analyzed just as reinforced slopes. A photograph of a geocell earth retaining structure is shown in figure TS14D–17.

Erosion protection

Selection and installation of an ECB or TRM is a function of the hydraulic characteristics of the site, streambank slopes, and expected lift of the product. ECBs are used for temporary erosion protection until adequate vegetation can be established. TRMs are considered permanent erosion protection and are designed to reinforce the soil surface and root system of the vegetation.

Figure TS14D–17 Geocell earth retaining structure (*Photograph courtesy of Carl Gustafson, NRCS MA*)

Example: Geotextile filter calculations

Problem: A streambank stabilization project will include a rock chute constructed on soil with the gradation in table TS14D–1.

Using design criteria for a ***woven geotextile*** in Design Note 24, Guide for the Use of Geotextiles (USDA SCS 1991) (table TS14D–2), determine the geotextile filter requirements.

Solution: Soil contains 15 to 50 percent finer than the # 200 sieve, so:

Apparent opening size (AOS) $<D_{85}$
Percent open area (POA) >4%
Permeability, $K_{geotextile} > 10\ K_{soil}$

D_{85}= 0.150 mm, so AOS ≤0.15 mm (#100 sieve)

Percent open area (POA) >4%
The soil contains 25 percent finer than the #200 sieve with an estimated K_{soil} = 0.004 cm/s, so $K_{geotextile}$ >0.04 cm/s

Using design criteria for a nonwoven geotextile in Design Note 24, Guide for the Use of Geotextiles (USDA SCS 1991) (table TS14D–3).

AOS ≤0.425 mm (#40 sieve)
A mechanically bonded needle-punched nonwoven geotextile is required.

Using design criteria from the AASHTO M–288 Geotextile Specification for Highway Applications (AASHTO 2000)

Since this is a permanent erosion control (AASHTO M–288) (table TS14D–4), use Class 2 for woven geotextiles and Class 1 for woven geotextiles.

Soil contains 25 percent finer than the #200 sieve so:
Permittivity= 0.2 s^{-1}
AOS ≤0.25 mm (#60 sieve)
Woven slit film geotextiles are not allowed.

A summary of the design using the three criteria is shown in table TS14D–5.

Table TS14D–1 Example problem soil gradation

Soil sample gradation	
Size	**% Finer**
#40 (0.42 mm)	100
#60 (0.25 mm)	98
#140 (0.105 mm)	60
#200 (0.074 mm)	25
0.005 mm	4

Table TS14D–2 Requirements for woven geotextiles

Property	Test method	Class I	Class II and III	Class IV 3/
Tensile strength (lb)1/	ASTM D4632 Grab test	200 min. in any principal direction	120 min. in any principal direction	180 min. in any principal direction
Bursting strength (lb/in^2)1/	ASTM D3786 Diaphragm tester	400 min.	300 min.	NA
Elongation at failure (%)	ASTM D4632 Grab test	<50	<50	<50
Puncture (lb)	ASTM D4833	90 min.	60 min.	60 min.
Ultraviolet light (percent residual tensile strength)	ASTM D4355 150-hr exposure	70 min.	70 min.	70 min.
Apparent opening size (AOS)	ASTM D4751	As specified, or a min. #100 2/	As specified, or a min. #100 2/	As specified, or a min. #100 2/
Percent open area (%)	CWO–02215–86	4.0 min.	4.0 min.	1.0 min.
Permittivity (1/s)	ASTM D4491	0.10 min.	0.10 min.	0.10 min.

1/ Minimum average roll value (weakest principal direction)
2/ U.S. standard sieve size
3/ Heat-bonded or resin-bonded geotextile may be used for Class IV only and are particularly well suited for this use. Needle-punched geotextiles are required for all other classes.

Table TS14D–3 Requirements for nonwoven geotextiles

Property	Test method	Class I	Class II	Class III	Class IV 3/
Tensile strength (lb)1/	ASTM D4632 Grab test	180 min.	120 min.	90 min.	115 min.
Bursting strength (lb/in^2)1/	ASTM D3786 Diaphragm tester	320 min.	210 min.	180 min.	WA
Elongation at failure (%)	ASTM D4632 Grab test	>50	>50	>50	>50
Puncture (lb)	ASTM D4833	80 min.	60 min.	40 min.	40 min.
Ultraviolet light (percent residual tensile strength)	ASTM D4355 150-hr exposure	70 min.	70 min.	70 min.	70 min.
Apparent opening size (AOS)	ASTM D4751	As specified, max. #40 2/	As specified, max. #40 2/	As specified max. #40 2/	As specified, max. #40 2/
Permittivity (1/s)	ASTM D4491	0.70 min.	0.70 min.	0.70 min.	0.70 min.

1/ Minimum average roll value (weakest principal direction)
2/ U.S. standard sieve size
3/ Heat-bonded or resin-bonded geotextile may be used for Class IV only and are particularly well suited for this use. Needle-punched geotextiles are required for all other classes.

Table TS14D–4 Default geotextile class and design class for the subsurface drainage, permanent erosion control, separation, and stabilization applications

Application class	Default class	Design
Subsurface drainage	Class 2	Class 3
Permanent erosion control	Class 2 for woven monofilaments Class 1 for all others	Class 2
Separation	Class 2	Class 3
Stabilization	Class 1	Class 2 or 3

Table TS14D–5 Summary of design solutions for example problem

Property	NRCS DN 24 – Woven	NRCS DN 24 – Nonwoven	AASHTO M–288
AOS	0.155 mm (#100 Sieve)	0.425 mm (#40 Sieve)	0.25 mm (#60 Sieve)
Permeability	0.04 cm/s	NA	NA
Permittivity	NA	NA	0.2 s^{-1}