NEH Part 633 Soils Engineering
National Engineering Handbook

Chapter 28 Use of Geotextiles

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633.2800 Introduction

Geotextiles provide a versatile means for solving problems associated with soil and water conservation work. NRCS uses geotextiles to improve drainage, protect against piping or erosion, and provide reinforcement or separation of fill materials. Ensuring adequate function and service requires proper design and placement. The materials used to manufacture geotextiles deteriorate over time, depending on the use environment, installation period, and/or method of pre-installation storage. Designers must evaluate the location and intended function of geotextiles to determine their appropriateness for use and the type of geotextile(s) required. Properties requiring evaluation include strength, maximum opening size, net open area, and durability (length of life) under storage, construction, and installed conditions. Field tests by NRCS and others have shown that buried geotextiles retain most of their original strength after 20 to 25 years.

Geotextiles have a great variety of engineering properties and physical characteristics. The designer must recognize the testing methods and test results that are significant to the intended application. NRCS uses test data to evaluate the acceptability of geotextiles for an application, and to verify the physical properties of a specified geotextile.

Geotextiles in NRCS engineering practice generally serves four primary functions: drainage, filtration, reinforcement, and separation.

A. Drainage. The ability of a geotextile to convey fluid (liquid or gas) within the plane of the fabric. Thick nonwoven geotextiles have this capability, while woven and heat bonded nonwoven geotextiles do not.

B. Filtration. The ability of a geotextile to allow fluid flow through the fabric plane but prevent the movement of soil particles and/or fines.

C. Reinforcement. The ability of a geotextile to distribute or carry loading imposed on or by the soil, develop tensile strength, and bridge over voids, cracks, or gaps.

D. Separation. The ability of a geotextile to keep two different materials apart during installation and subsequent use that would otherwise tend to mix and compromise the intended integrity of the materials. Important functions related to separation include prevention of fines intrusion into aggregate voids and loss of stone aggregate into soft soil subgrade.

NRCS applications use two major types of geotextiles: woven and nonwoven geotextiles. Woven geotextiles have an appearance like cloth in that they consist of two sets of parallel filaments woven together at right angles to each other to form a planar fabric. Nonwoven geotextiles, on the other hand, consist of filaments laid down in a random orientation and bonded to each other by thermal, chemical, or mechanical treatment. NRCS refers to these methods of bonding as heat-bonding, resin-bonding, and needle-punching, respectively. For a detailed discussion of manufacturing processes for both woven and nonwoven geotextiles, refer to Koerner (2005). Woven geotextiles tend to have higher tensile strength and lower elongation than nonwovens. The most commonly used geotextile in NRCS applications is a nonwoven, needle punched, polypropylene geotextile. Nonwoven geotextiles are puncture and abrasion resistance, therefore absorbs high strain, and comes in large choice of thickness of materials.

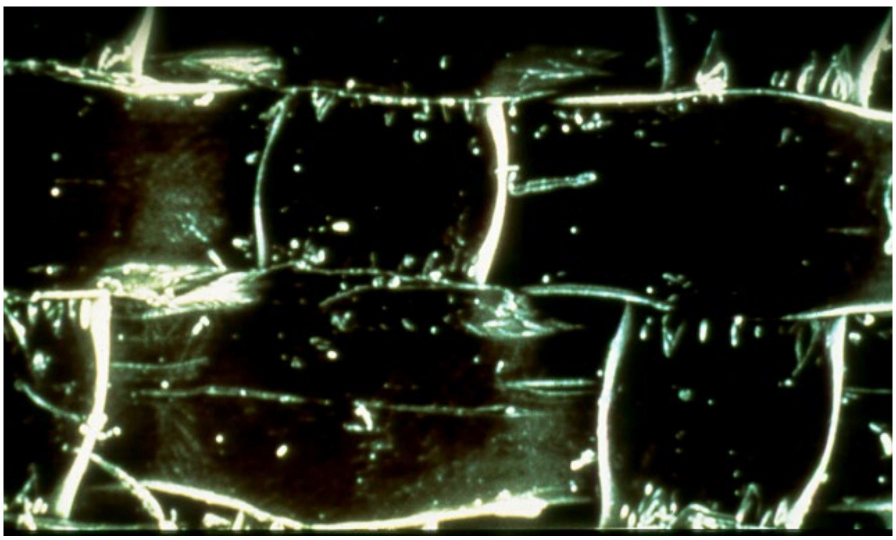

Figure 1. Monofilament Woven Geotextile

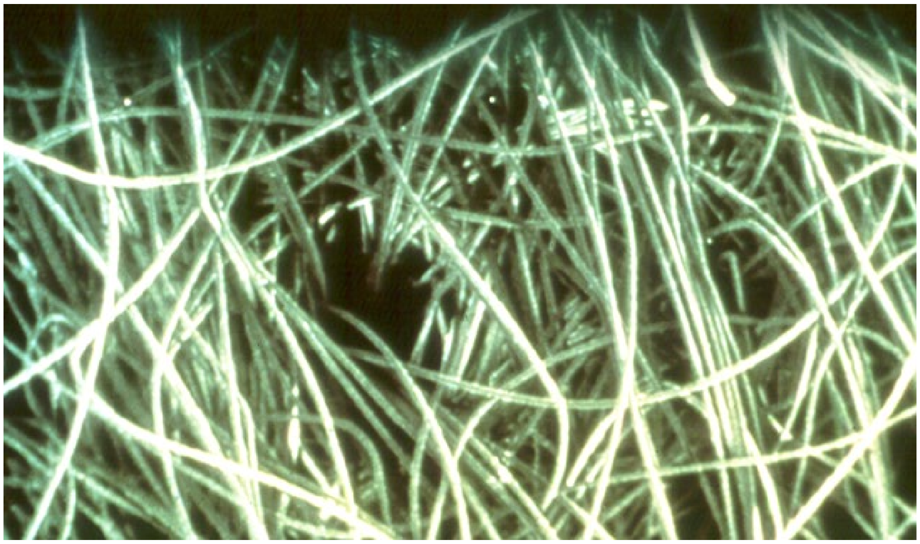

Figure 2.   Needle Punched Non-woven Geotextile

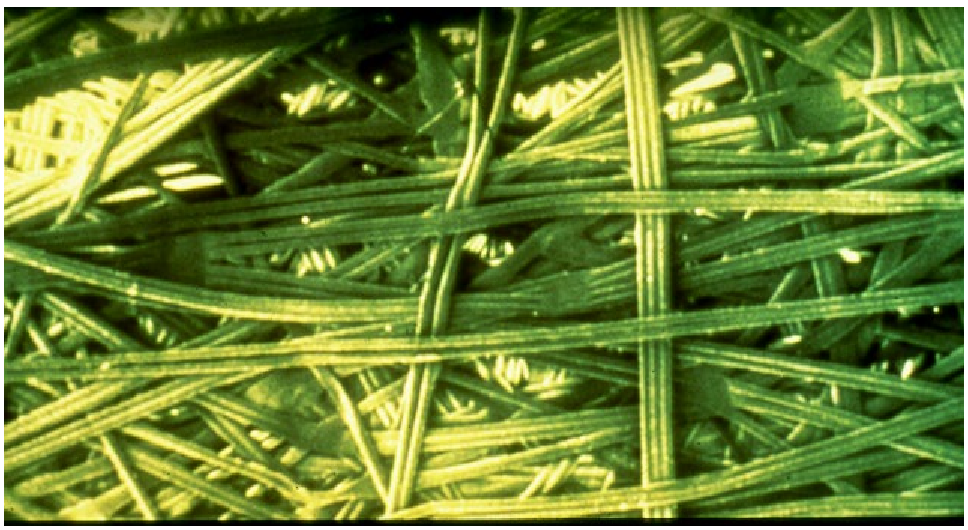

Figure 3. Heat Bonded Non-woven Geotextile

633.2801 Specified Uses

Figure A1, Requirements for Woven Geotextiles and Figure A2, Requirements for Nonwoven Geotextiles contain specifications developed to meet the requirements for each of the following uses:

A. Permanent Erosion Control. This application involves the use of a geotextile between in situ soil and revetment armor materials, such as rock riprap, gabions, and articulated concrete blocks (ACBs), to protect the soil from excessive erosion and to provide filter compatibility between the soil and the armor material. This specified use includes both the **filtration** and the **separation** functions. In soft soil conditions, the **reinforcement** function may also apply. Important performance properties include adequate permeability to allow subgrade drainage, proper size and distribution of openings for filtration, and adequate strength to resist installation stresses. Installation stresses are directly related to the weight and angularity of the armor material, the height of drop, and the optional use of an aggregate layer to protect the geotextile and cushion the impact of the drop. A rough fabric surface to promote bond with the base soils and resistance to sliding by the armor material is also a consideration in assessing the adequacy for use in sloping applications. Nonwoven, needle punched geotextiles are generally superior to woven geotextiles in this feature.

B. Subsurface Drainage. This application involves placing a geotextile between in situ soil and a subsurface drainage system to allow for the free passage of liquid into the drain while retaining the soil in place. The functions involved in this specified use are **filtration** and **separation**. Adequate permeability and size and distribution of opening size are important properties. Strength is mostly a factor in the installation of the geotextile. Flexibility and the ability of the geotextile to be in close contact with the surface irregularities are important.

C. Stabilization. This application involves the use of a geotextile over wet, and possibly soft, conditions to permit the installation of engineered fill material, such as road base or structural fill. The functions involved in this use are **separation**, **filtration**, and in many cases, **reinforcement**. Some permeability is needed, as well as the ability to take tensile loads with uniform deformation. Backfill or covering procedures are also important for the geotextile to function as intended.

D. Temporary Silt Fence. In this application, a geotextile serves as a vertical, permeable interceptor designed to remove suspended sediment from overland water flow. . The silt fence is intended to capture settled suspended sediment particles behind the fence whereas allowing continuous flow of water thru it. Reduced flow velocity due to this fence results in particles settling out. The main function performed by the geotextile in this application is **filtration**. Silt fence constructed using slit-film geotextile may serve as a temporary silt fence; however, NRCS does not recommend slit-film fabric for other applications. Silt fence materials must meet the requirements of ASTM D 6461.

633.2802 Physical Properties

Geotextile properties and associated tests that are pertinent to the indicated specified uses are given below. Test values for commercially available geotextiles are available in the Geosynthetics Specifier's Guide or in manufacturers' technical data. Koerner (2005) provides detailed discussion of test methods for geotextiles.

A. Tensile Strength. The industry uses several tests to determine tensile strength of geotextiles. The grab tensile test (ASTM D 4632), measures the total force required to pull a 4-inch wide specimen apart, using 1-inch wide clamps. The wide-width tensile test (ASTM D 4595 determines the tensile strength per unit width of an 8-inch wide specimen, using full width clamps.

B. Elongation. The stretching or elongation of a geotextile is measured at the point of failure or rupture of the fabric during the tensile strength test (ASTM D 4632 or D 4595).

C. Puncture Strength. The force needed to penetrate or rupture a fabric with a 50 mm diameter cylindrical probe is measured (ASTM D 6241).

D. Apparent Opening Size (AOS or O95). For woven geotextiles, the POA is the summation of the open area of an observed unit area of fabric divided by the total area, expressed in percent (CWO-02215, U. S. Army Corps of Engineers). The POA test is not applicable to nonwoven geotextiles. A detailed description of this test is also available in "Engineering Use of Geotextiles" (JDAAF, 1995), Reference No. 23.

E. Percent Open Area (POA). For woven geotextiles, the POA is the summation of the open area of an observed unit area of fabric divided by the total area, expressed in percent (CWO-02215, U. S. Army Corps of Engineers). The POA test is not applicable to nonwoven geotextiles. A detailed description of this test is also available in "Engineering Use of Geotextiles" (JDAAF, 1995), Reference No. 23.

F. Permittivity. Permeability or hydraulic conductivity of a geotextile divided by the geotextile thickness. It is equal to the volumetric flow rate of water per unit cross sectional area per unit head under laminar flow conditions, normal to the plane of the fabric. (ASTM D 4491).

G. Transmissivity. The volumetric flow rate of water per unit width of a geotextile specimen per unit gradient in a direction parallel to the plane of the specimen (ASTM D 4716).

H. Ultraviolet (UV) Light Deterioration. UV deterioration is a measure of the potential for the loss of tensile strength in the fabric due to exposure to ultraviolet light and water (ASTM D 4355).

I. Minimum Average Roll Value (MARV). MARV is a term from manufacturing quality control (MQC) and refers to the value that is two standard deviations less than the mean value in a given population of test results for the weakest principal direction of a geotextile for a given test and property. This means that the results of 97.7 percent of the tests taken would be equal to or greater than the MARV value, assuming the data have a normal distribution. This chapter reports all geotextile properties in MARV values, except for AOS.

J. Maximum Average Roll Value (Max. ARV). The Max. ARV is an MCQ term related to the MARV, except that it is two standard deviations greater than the mean value. Designers use Max. ARV values to specify AOS.

633.2803 Design Considerations

A. General. Geotextiles can be designed in several different ways, including: 1) design-by-specification; and 2) design-by-function (Koerner, 2005). Design-by-specification involves setting various physical, mechanical, hydraulic, and endurance properties of geotextiles for specified applications, site characteristics, and installation conditions. This method is typically used by larger public agencies and allows efficient, standardized design of routine applications by many designers. AASHTO M288, Geotextile Specification for Highway Applications, is an example of such a specification.

Design-by-function, on the other hand, involves comparing the allowable value of the geotextile property related to its ability to perform a certain function (e.g., tensile strength for the reinforcement function) with the value of that property required to perform that function. A factor of safety can be calculated as the ratio of the allowable (test) property to the required (design) property. This design method is particularly applicable to large, unique, or complex designs for which the standardized approach of the design by specification method may be over- or under-conservative, not as cost-effective, or otherwise sub-optimal.

The guidance in this chapter is based on the requirements in AASHTO M288 and therefore falls into the category of design-by-specification. AASHTO M288 has the advantages of widespread familiarity and acceptance within the civil engineering profession as well as being extremely easy to use. This chapter also references, for information, the filtration design procedure for geotextiles given in FHWA (2008). The FWHA approach allows the user to consider both severity of site conditions and risk when designing the geotextile (see Figure A-3). The flow chart in Figure 1 shows the FHWA procedure.

For applications and conditions addressed in AASHTO M288 but not included in this chapter – for example, separation – designers may use AASHTO M288. In addition, Chapter 2 in Koerner (2005) provides a detailed presentation of the design-by-function method when more appropriate for a design.

B. Filtration. Geotextile filters function in a comparable manner to traditional aggregate filters, but with several important differences. Giroud (2009) postulates four theoretical filter criteria for geotextiles: 1) retention; 2) permeability; 3) porosity; and 4) minimum thickness. The retention criterion states that the largest opening in the geotextile filter must be small enough so as to not allow the in-situ soil to pass through the filter. The permeability criterion states that the filter should be sufficiently permeable so that the disturbance to the flow due to the presence of the filter will be small. The permeability criterion further consists of both a pore pressure requirement and a flow requirement. The first requires that the pore pressure increase due to the filter should be small, while the second requires that the decrease in flow rate due to the filter should also be small.

These first two criteria (retention and permeability) are identical in concept with the traditional filter criteria for granular filters. However, since geotextiles are so much thinner than granular filters, they can be subject to clogging unless the final two criteria (porosity and minimum thickness) are also satisfied. The purpose of the porosity criterion is to ensure that the geotextile has enough openings in comparison to the number of openings in the soil. If not, disturbance in the flow from the soil into the geotextile can result, causing soil particles to enter the filter and clog it. The minimum thickness criterion serves to show the optimal number of constrictions in the geotextile to ensure homogeneous opening size within the geotextile and, therefore, homogeneity of its filtration characteristics (Giroud, 1998). The minimum thickness criterion applies only to nonwoven geotextiles.

The filtration requirements in AASHTO M288 incorporate the first two filter criteria mentioned above: retention and permeability. The FWHA procedure also incorporates the porosity criterion. The minimum thickness criterion is theoretical in nature, and not reflected in either method.

C. Reinforcement. The use of geotextiles for reinforcement involves combining a material that is strong in tension but weak in compression (the geotextile) with one that is weak in tension but strong in compression (the soil) to improve the strength of the overall system. Geotextiles are used for reinforcement in many applications, including segmental retaining walls, reinforced soil slopes, and embankments on soft foundations. Koerner (2005) identifies three different mechanisms of geotextile reinforcement: 1) membrane type, where the reinforcement acts in response to a vertical load applied to a geotextile placed on a deformable subgrade; 2) shear type, where the sliding resistance along a geotextile/soil interface is considered; and 3) anchorage type, where soil acts on both sides of the geotextile and the pullout resistance is considered.

The geotextile properties of greatest importance in reinforcement applications are tensile strength and tensile strain (elongation). In applications where relatively large deformations are acceptable, tensile strength may be most important. But in applications where deformations must be kept small, such as with retaining walls, tensile strain will likely govern the design. Designers should use the tensile properties from the wide-width tensile test (ASTM D4595), rather than from the grab tensile test (ASTM D4632), in designs for reinforcement applications.

Detailed guidance on the design of reinforcement applications involving geotextiles is beyond the scope of this chapter. Figure A-4 provides guidance on selected reinforcement applications.

D. Stabilization. The use of geotextiles for stabilization applies to wet or saturated soil subgrades with a medium to stiff consistency (i.e., having a California Bearing Ratio (CBR) of 1 to 3 or, equivalently, an undrained shear strength when saturated of about 600 to 2,000 psf). These consistency values correspond to saturated blow counts (N) of approximately 4 (medium) to 15 (stiff). The permittivity of the geotextile should be greater than that of the soil. Designers should address the functioning of the geotextile for reinforcement as a project-specific design issue.

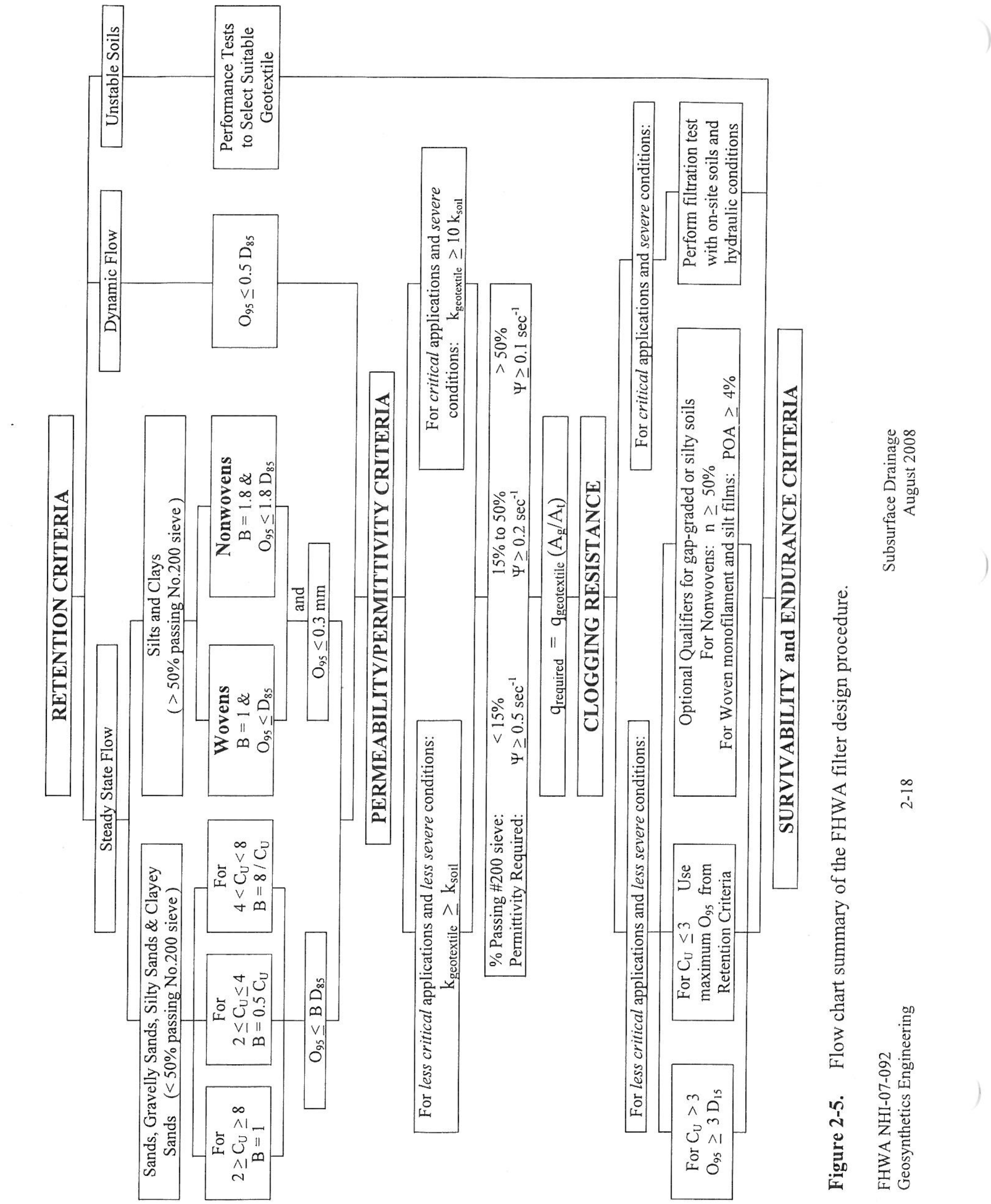

Figure 1. Flow chart summary of FHWA filter design procedure (from FHWA, 2008).

E. Temporary Silt Fence. The geotextile in a temporary silt fence serves to clog and pond water behind the fence. Designers select the spacing of the rows of silt fence to prevent overtopping of the individual rows. Once ponding occurs behind the fence, the design then becomes a structural design where the designer must consider the strength of the geotextile, the spacing of the support posts, and the contribution of any reinforcement. Silt fence can be either supported or unsupported. 14 gage steel wire with a 6-inch by 6-inch mesh spacing or prefabricated polymeric mesh of equivalent strength provides support. Since the silt fence receives exposure from sunlight, the geotextile must have adequate ultra-violet light resistance to prevent excessive deterioration of its strength during the period of use. ASTM D 6461 specifies the minimum material properties for temporary silt fence.

F. Interface Shear Strength. The sliding resistance along an interface between a geotextile and soil, or another geosynthetic, for a given normal load is referred to as interface shear strength. The interface shear strength consists of a friction component, δ (analogous to internal friction angle in soils), and in some cases an adhesion component, ca (analogous to cohesion in soils). When the geotextile is placed against soil, the friction and adhesion components can be expressed in terms of an efficiency relative to the shear strength parameters of the soil itself (Koerner, 2005). The respective efficiency factors are equal to the parameter for the interface (tanδ or ca) divided by the corresponding parameter for the soil alone (tanϕ or c), expressed as a percent. Efficiency factors for geotextiles range from about 70 to 100 percent. Efficiency can never exceed 100 percent, because then the soil would simply fail within itself, just outside the limits of the interface. The shear strength efficiency of a geotextile is proportional to its roughness, so nonwoven geotextiles typically have higher efficiencies than wovens. Nonwoven needle punched geotextiles can have efficiencies in the 90+ to 100 percent range (Koerner, 2005).

The technical literature contains data on considerable interface shear testing performed on a wide variety of geosynthetics and soils. For information, Figure A-5 provides the data on geotextile interface shear strengths from a compilation by Koerner and Narejo (2005). Designers should not use these values for final design. Instead, designers should perform site-specific testing as warranted for the size, cost, and complexity of an individual project.

Interface shear strength can be used to calculate such parameters as available pullout resistance and required embedment length. The available shear strength for one surface of a geotextile is given by:

$$\mathrm{ISS} = (\sigma'_n * \tan\delta + c_a) * L$$

Where,

ISS = interface shear strength (force/ unit width)

σ'_n = effective normal stress acting on interface (force/length^2)

δ = interface friction angle, degrees

c_a = interface adhesion, (force/length^2)

L = length of geotextile, (length)

To calculate the pullout resistance of a horizontal piece of geotextile with soil on both sides, the value for ISS is multiplied by two to account for the geotextile/soil interface on both sides of the geotextile. The required embedment length, $L_{required}$, to develop the allowable tensile stress, $T_{allowable}$, in the geotextile is calculated by setting the total ISS (for both sides of the geotextile) equal to $T_{allowable}$ and then solving for $L = L_{required}$. The resulting expression is:

$$L_{required} = \frac{T_{allowable}}{n * (\sigma'_n * \tan\delta + c_a)}$$

Where,

$L_{required}$ = required embedment length of geotextile, (length)

$T_{allowable}$ = allowable tension in geotextile, (force/unit length)

n = number of geotextile/soil interfaces (normally 2)

The allowable tensile stress, $T_{allowable}$, is equal to the ultimate or test value of tensile strength multiplied by all applicable reduction factors. The reader is referred to Koerner (2005) for a comprehensive discussion of reduction factors for geotextiles and other geosynthetics.

G. Ultraviolet (UV) Light Protection. Geotextiles, even if permanently covered following installation, need to have some resistance to UV deterioration because of temporary exposure to sunlight during construction. Geotextiles for all applications should retain at least 50 percent of tensile strength after 500 hours of exposure in a test according to ASTM D 4355. For exposed applications, designers should specify longer test durations, depending on the intended life of the system. Geotextiles should be completely covered during transport and storage and should be covered or buried as soon as practical during construction, with the total exposure time not to exceed 14 days (AASHTO, 2006). For applications such as geotextile-reinforced soil slopes, the ability of the facing system to protect the geotextile from UV exposure over the life of the structure is an important design consideration. Geotextile for silt fence requires a higher degree of UV resistance than buried geotextiles because it is continuously exposed to sunlight during its use. Therefore, geotextile for silt fence should retain at least 70 percent of its tensile strength after 500 hours of exposure in a test according to ASTM D 4355.

H. Problem Soils. Certain soil environments present special challenges to the successful functioning of geotextiles. These include: 1) highly erodible soils such as non-cohesive silts and dispersive clays; 2) internally unstable soils including gap-graded and broadly graded soils; 3) alternating sand/silt laminated soils; and 4) rock flour (from glacial action). The risk of clogging of the geotextile is significantly higher for these soils. AASHTO M288 recommends performing site specific geotechnical testing and analysis when such soils are present to verify the compatibility of candidate geotextiles with the on-site soils. Requiring a POA of at least 4 percent (woven geotextiles) or a porosity of at least 50 percent (nonwoven geotextiles) maximizes the likelihood that the geotextile will not clog, according to the above-mentioned porosity criterion. Nonwoven, needle-punched geotextiles generally have a porosity in excess of 50 percent, even in a very compressed state (Giroud, 1996). NRCS recommends that a qualified geologist or geotechnical engineer be consulted if problem soils are suspected.

Several laboratory tests are available to determine the clogging potential of geotextiles when used with a given soil. These tests include the Gradient Ratio (GR) Test (ASTM D 5101) and the Hydraulic Conductivity Ratio (HCR) Test (ASTM D 5567). In both tests a soil/geotextile column is placed in a flow cell or permeameter and then subjected to constant head flow until observing some recognizable equilibrium or stabilization of the system.

In the GR Test, measurement of the hydraulic gradient occurs in two places: 1) between the bottom of the geotextile and one inch above the geotextile; and 2) between one inch above the geotextile and two inches above it. If the ratio of the first gradient to the second gradient exceeds 3.0, this indicates the potential for clogging of the geotextile. The GR Test is the most appropriate test for sandy soils with a hydraulic conductivity of more than 1x10-4 cm/sec.

In the HCR Test, testing of the hydraulic conductivity occurs for two different conditions: 1) first, placement of clean geotextile on top of the soil sample and with downward flow; and then 2) reversal of the flow direction on the same soil/geotextile column. The ratio between the second hydraulic conductivity (soil and geotextile) and the first (soil only) is calculated. A high ratio (> 0.8) indicates piping of soil particles through the geotextile, while a low ratio (< 0.4) indicates clogging of the geotextile. A mid-range value suggests compatibility between the soil and the geotextile. The HCR test is the most appropriate test for fine-grained soils with a hydraulic conductivity of less than 1x10-4 cm/sec. A variation of the GR test using a flexible wall permeameter is currently under development by ASTM Committee D-35, Geosynthetics. Upon adoption by ASTM, this test is expected to replace the HCR test.

These tests for clogging potential can involve considerable time and expense to run. Therefore, it is unlikely that such testing will be justifiable except on large, complex, or high cost projects. In most cases it will be preferable to simply avoid the use of geotextiles in favor of traditional granular filters whenever problem soils are present. For example, if rock riprap is to be placed on a stream bank consisting of non-cohesive silt, then the following two options could be considered: 1) place progressively coarser layers of graded sand and gravel until filter compatibility in accordance with the criteria given in NRCS (2017) is provided between the silt base soil and the rock riprap; or 2) place a layer of filter sand on the silt and then place geotextile between the filter sand and the riprap.

Do not use geotextiles in conjunction with liquid or solid agricultural waste because of the potential for mechanical and biological clogging of the fabric.

I. Seam Strength. Use sewn seams instead of simple overlaps when necessary to transfer the tensile strength of the fabric across adjacent panels. For example, designs using a geotextile to stabilize soft foundation soils often need sewn seams. In such applications, simple overlaps may experience separation due to foundation settlement, squeezing, or mud flow action. When using sewn seams, the designer should specify the required seam strength as an absolute value, rather than attempt to specify the method and materials required to produce a satisfactory seam. Seam strength is a function of geotextile cross-direction strength, seam type, thread type, stitch type and density, and sewing equipment. Measure the tensile strength of sewn seams according to ASTM D 4884, Standard Test Method for Strength of Sewn or Thermally Bonded Seams of Geotextiles. The strength of sewn seams is generally in the range of 40 to 60 percent of the cross-machine direction strength of the geotextile, when measured according to ASTM D 4884.

Seam type – Geotextiles commonly use three types of seams: 1) the “flat” or “prayer” seam (Type SSa, according to Federal Standard 751a-1965); 2) the “J” seam (Type SSn); and 3) the “butterfly” seam (Type SSd). With all three types, NRCS recommends a double row of stitching for added seam reliability. For double seams, a “2” is added to the type designation, for example, “SSa-2” for a double flat seam. The flat seam is the easiest to make and is commonly used for required seam strengths of 240 lb/inch or less. The “J” and butterfly seams are more difficult to make but produce higher strength seams.

Thread type – In order of increasing tensile strength, geotextile seaming commonly uses three types of thread: 1) polypropylene; 2) polyester; and 3) Kevlar ® aramid.

Polypropylene thread is typically used to seam lower strength geotextiles (< 300 lb/inch), while polyester thread is used with higher strength geotextiles. Kevlar thread is very strong, but also quite expensive, and is probably not justified except with very high strength geotextiles. Nylon thread is not recommended for seaming geotextiles.

Stitch type and density – Joining geotextiles commonly involves two types of stitches: 1) Type 101 single thread “chain stitch”; or 2) Type 401 double thread “lock-stitch”. The Type 101 stitch should only be used for low strength geotextiles and low required seams strengths. Since it is prone to unravel, a double row of stitching should always be used with this type of stitch. The Type 401 stitch is less prone to unraveling and should be used when seaming heavier geotextiles or when the required seam strength is greater than about 150 lb/inch. Even with this more robust stitch type, a double row of stitching is suggested. Stitch densities typically range from 3 to 6 stitches per inch. High stitch density should be avoided on lighter-weight geotextiles because this can cause damage to the fibers within the geotextile from the perforating action of the needle and the tension of the sewing thread pulling on the base fabric.

Sewing equipment – Geotextile installers commonly use two types of sewing equipment: 1) a hand-held, portable sewing machine; or 2) a heavy-duty, machine mounted sewing machine weighing approximately 100 pounds. The hand-held machine can sew either the Type 101 or the Type 401 stiches and can produce seam strengths up to about 240 lb/inch. If designs require higher seam strengths, use the heavier machine.

TenCate “Seaming of Geosynthetics” provides further guidance on sewn seam design.

J. Cushion Layer for Geomembrane Liners. Designers can use geotextiles as a protective cushion layer between a geomembrane liner and its soil subgrade. The geotextile provides protection to the geomembrane against puncturing by stones or other sharp or hard objects in the subgrade. Use nonwoven, needle punched geotextiles for this application. Geotextiles used as a cushion layer should meet the requirements in GRI Test Method GT-12a (GRI, 2016).

Designers have also used nonwoven geotextiles to collect and vent gasses that can collect under geomembranes. Geotextiles have a relatively low capacity to transmit gasses compared to other geosynthetics, particularly geonets, and so the design of any such gas-venting system will require careful attention by the designer. Koerner (2005) provides further guidance on venting design using geotextiles and other geosyntheticsWoven geotextiles tend to have higher tensile strength and lower elongation than nonwovens. The most commonly used geotextile in NRCS applications is a nonwoven, needle punched, polypropylene geotextile.

633.2804 Construction Considerations

A. Satisfactory performance of the selected geotextile is greatly dependent on the installation procedures and field preparation of the surface to be protected. When geotextile fabrics are used adjacent to fill or backfill, the fill soil placement is critical in preventing conditions conducive to clogging of the fabric. The following techniques help minimize the movement of soil particles toward the fabric surface and provide more area for flow through the fabric.

Prepare the soil surfaces adjacent to fabrics so that all flow channels or voids larger than the openings in the fabric are eliminated.

Utilize placement techniques to ensure that intimate contact between the fabric and the soil is maintained.

Provide a surface area as large as possible for the filter (e.g., it is better to place the geotextile around the periphery of the drain trench with gravel and pipe inside than to place the fabric around the pipe where the surface area is smallest).

B. When a geotextile is used as a filter material replacement (i.e., to prevent particle migration), use sewn seams to connect overlaps of adjacent fabric panels or use some other positive means of preventing separation of the overlaps. Designs may use securing pins with washers installed according to manufacturer's recommendations, if soil conditions permit easy penetration of the pins into the subgrade. Specify the method of securing overlaps on the drawings or in the construction details.

C. Design a minimum overlap of 18 inches between adjacent fabric panels for relatively firm subgrades. For medium to soft subgrades, increase the minimum overlap to 24 to 36 inches. For underwater placement, use an overlap of at least 36 inches.

D. Carefully inspect all sewn seams. The final position of the seam should allow easy inspection and accessibility for seam repair. The color of the thread should contrast with the color of the geotextile to ease seam inspection. The lines of stitching should be parallel to the edges of the geotextile and should be no closer than 0.75 inches, and no farther away than 2 inches, from the edge of the fabric. For double rows of stitching, the spacing between the rows should be about 0.75 inches. If needed, collect samples of the sewn seams to verify design strength requirements. NRCS recommends using a three-person crew for the sewing operation with a hand-held machine: one operating the sewing machine and one person both ahead of and behind the machine to support the panels of geotextile in the proper location and orientation to permit effective seaming.

E. Other construction considerations specific to the function or type of application are:

(1) **Permanent Erosion Control** – Class I and II (as indicated in Tables xx-1 and -2).

(a) Specify the method of placement of rock or other material on the geotextile. Accomplish placement by equipment capable of controlling the drop. Do not allow pushing or rolling the armor material over the geotextile. The maximum drop is 3 feet for protected or unprotected geotextile. Where conditions require a larger drop, the strength of the geotextile and/or the thickness of the cushioning material need to be increased.

Class I – Severe Conditions - For rocks up to 220 pounds in weight, limit the height for dropping the rocks onto exposed geotextile to 3 feet. For rocks over 220 pounds, use a 6-inch aggregate cushion layer for bedding the rock on the geotextile, and the height of drop should be limited to 3 feet. The cushion material should be filter-compatible per NRCS (2017) with the overlying armor material so that the cushion material will not migrate through voids or other openings in the armor material. For sharp, angular rock reduce the maximum height of drop to 1 foot, or specify a heavier geotextile.

Class II – Moderate Conditions – For rocks up to 220 pounds, use a 6-inch aggregate cushion layer for bedding the rock on the geotextile, and limit the height of drop to 3 feet. Provide cushion filter-compatible with the overlying armor material.

(b) When riprap is placed directly on a geotextile, the stones may not provide confining pressure over the entire geotextile surface to ensure intimate contact between the geotextile and the underlying base soil. This can allow the geotextile to separate from the soil under flow conditions and result in clogging of the geotextile by a soil slurry. This condition can be avoided by: 1) placing an aggregate cushion layer on top of the geotextile before placing the riprap; or 2) placing a graded granular filter against the base soil before placing the geotextile and the riprap.

Embedment of the geotextile in a trench to form a cutoff at regular intervals down the slope will also help prevent rilling beneath the fabric. Place cutoffs at a close spacing in highly erodible soils (sands and non-cohesive silts) and space wider apart in more erosion-resistant soils (clays and cohesive silts).

(2) **Subsurface Drainage** – Class III (as indicated in Tables xx-1 and -2).

(a) The strength values given in Tables xx-1 and -2 are for subsurface drain depth less than 6 feet, aggregate diameter less than 1.2 inches, and compaction requirement less than 95 percent of ASTM D698. For more severe conditions, increase the strength requirements in Tables xx-1 to those for Class I, and in Table xx-2 to those for Class II.

(b) To prevent movement of surface soil where groundwater and seepage pressures are a factor, the geotextile must be in intimate contact with the subgrade soil. Voids between the geotextile and the base soil must be minimized to prevent the collecting of fines behind the fabric and subsequent clogging. Pull the geotextile during installation to eliminate wrinkles and folds that create voids, but it should be allowed to move freely so that it can be pressed against and conform to the subgrade without developing large tensile stresses.

(3) **Road Stabilization** – Class IV (as indicated in Figures A-1 and A-2).

(a) Tables xx-1 and -2 provide values for light to medium loading in both weight and frequency of traffic.

(b) Provide at least 12 inches of cover before operating equipment over the geotextile, unless site-specific tests show that a lesser thickness of cover gives satisfactory results. Construction quality assurance should include checking for damage to the geotextile caused during placing and spreading operations.

(c) The minimum geotextile overlap should be as indicated in Figure 2.

Figure 2: Table of geotextile overlap for road stabilization

Soil CBR [a]	Blow Count (N) (when saturated) [b]	Minimum Overlap (inches)
≥ 3	> 4	18
1-3	2-4	24-39
0.5-1	1-2	39 or sewn
< 0.5	<1	sewn
All roll ends	---	or sewn

[a] - CBR denotes California Bearing Ratio.

[b] - See ASTM D 1586.

(4) **Temporary Silt Fence** – Requirements as shown in ASTM D 6241.

(a) Installation of temporary silt fence should conform to the guidelines in ASTM D6461, Standard Specifications for Silt Fence Materials.

(b) Proper keying of the geotextile into the soil to prevents flow from passing under the silt fence. Install the bottom edge of the geotextile in a trench extending at least six inches below ground level. Compact the trench backfill to at least the same density as the surrounding in-place soil. As an alternative, mechanically slice the geotextile into the soil.

633.2805 General Discussion of Figures A-1 and A-2

A. Figures A-1 and A-2 are based on the requirements in AASHTO M288. The class designations in the tables (Classes I – IV) refer to the functions discussed in Section 633.2804, Construction Considerations.

B. The materials covered under Figure A-1 are woven monofilaments that are generally black in color and don't change noticeably from one class to the next. Heavier monofilaments will produce stronger fabric, but if the AOS and POA also change, a heavier fabric could have the same strength as a lighter fabric. In woven geotextiles, the AOS and POA must be considered along with fabric mass per unit area, thus making field identification difficult.

C. The nonwoven materials covered under Figure A-2 are restricted to needle punched geotextiles, with the exception of Class IV. One can generally recognize these needle-punched fabrics in the field by weight. The Class I geotextiles are approximate 8 oz./yd2; Class II, 6 oz./yd2; and Class III, 5 oz./yd2. Class IV allows the use of heat bonded geotextiles that are spun bonded but generally not previously needle punched. These materials weigh about the same as the Class IV needle punched.

D. Select a class of geotextile based on the intended use, with appropriate consideration for construction and installation methods. Generally, after selecting a class of geotextiles, use materials from either Figure A-1 or A-2. Where specific desired characteristics are provided by one type of geotextile vs. the other, specify the proper class and type.

633.2807 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 fi lter requirements.

Solution: Soil contains 15 to 50 percent fi ner 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 fi ner 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

Specifi cation 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 fi ner than the #200 sieve

so:

Permittivity= 0.2 s^{-1}

AOS ⍰0.25 mm (#60 sieve)

Woven slit fi lm geotextiles are not allowed.

A summary of the design using the three criteria is

shown in table TS14D–5.

633.2807 References

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ASTM International, Standard D 1586, Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils, West Conshocken, PA.

ASTM International, Standard D 4355, Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Apparatus, West Conshocken, PA.

ASTM International, Standard D 4491, Standard Test Methods for Water Permeability of Geotextiles by Permittivity, West Conshocken, PA.

ASTM International, Standard D 4595, Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method, West Conshocken, PA.

ASTM International, Standard D 4632, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles, West Conshocken, PA.

ASTM International, Standard D 4716, Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of Geosynthetics Using a Constant Head, West Conshocken, PA.

ASTM International, Standard D 4751, Standard Test Methods for Determining Apparent Opening Size of Geotextiles, West Conshocken, PA.

ASTM International, Standard D 4884, Standard Test Method for Strength of Sewn or Bonded Seams of Geotextiles, West Conshocken, PA.

ASTM International, Standard D 5101, Standard Test Method for Measuring the Filtration Compatibility of Soil-Geotextile Systems, West Conshocken, PA.

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ASTM International, Standard D 6241, Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe, West Conshocken, PA.

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633.2807 Appendix

Figure A-1. Requirements for Woven Geotextiles

Property	Test Method	Units	Class I	Class II	Class III	Class IV
Grab Tensile Strength	ASTM D4632	pounds (MARV)	247 min.	180 min.	180 min.	315 min.
Elongation at Failure	ASTM D4632	percent (MARV)	< 50	<50	<50	<50
Trapezoidal Tear Strength	ASTM D4533	pounds (MARV)	90 min.	67 min.	67 min.	112 min.
Puncture Strength	ASTM D6241	pounds (MARV)	495 min.	371 min.	371 min.	618 min.
Ultraviolet Light (percent tensile strength retained)	ASTM D4355	percent (MARV)	50 min.	50 min.	50 min.	50 min.
			Percent Fines (< No. 200 Sieve) [a]			
			Class	**< 15**	**15-50**	**>50**
Permittivity (ψ)	ASTM D4491	sec^{-1} (MARV)	I, II	0.7 min.	0.2 min.	0.1 min.
			III	0.5 min.	0.2 min.	0.1 min.
			IV	0.05 min., but not < ψ_{soil} [b]		
Apparent Opening Size (AOS)	ASTM D4751	mm (Max. ARV)	I, II, III	0.43 max.	0.25 max.	0.22 max. [c]
			IV	0.43 max.		
Percent Open Area (POA)	USACE CWO-02215	percent (MARV)	All	4 min. [d]		

[a] - Percent fines based on portion of base soil finer than No. 4 sieve (< 4.75 mm).
[b] - ψ_{soil} = permittivity of base soil
[c] – For cohesive soils with a plasticity index greater than 7, geotextile maximum average roll value for AOS is 0.30 mm.
[d] - Applies only to problem soils such as gap-graded, broadly-graded, or silty soils.

Figure A-2. Requirements for Nonwoven Geotextiles

Property	Test Method	Units	Class I	Class II	Class III	Class IV
Grab Tensile Strength	ASTM D 4632	pounds (MARV)	202 min.	157 min.	112 min.	202 min.
Elongation at Failure	ASTM D 4632	percent (MARV)	> 50	> 50	> 50	> 50
Trapezoidal Tear Strength	ASTM D 4533	pounds (MARV)	79 min.	56 min.	40 min.	79 min.
Puncture Strength	ASTM D 6241	pounds (MARV)	433 min.	309 min.	223 min.	433 min.
Ultraviolet Light (percent tensile strength retained)	ASTM D 4355	percent (MARV)	50 min.	50 min.	50 min.	50 min.
			Percent Fines (< No. 200 Sieve) [a]			
			Class	**< 15**	**15-50**	**>50**
Permittivity (ψ)	ASTM D 4491	sec^{-1} (MARV)	I, II	0.7 min.	0.2 min.	0.1 min.
			III	0.5 min.	0.2 min.	0.1 min.
			IV	0.05 min., but not < ψ_{soil} [b]		
Apparent Opening Size (AOS)	ASTM D 4751	mm (Max. ARV)	I, II, III	0.43 max.	0.25 max.	0.22 max. [c]
			IV	0.43 max.		

[a] - Percent fines based on portion of base soil finer than No. 4 sieve (< 4.75 mm).
[b] - ψ_{soil} = permittivity of base soil
[c] - For cohesive soils with a plasticity index greater than 7, geotextile maximum average roll value for AOS is 0.30 mm.

Figure A-3. Guidelines for Evaluating the Critical Nature or Severity of Drainage Applications and Erosion Control Applications (from FHWA, 2008)

A. Critical Nature of the Project		
Item	**Critical**	**Less Critical**
1. Risk of loss of life and/or structural damage due to drain failure:	High	None
2. Repair costs versus installation costs of drain:	Much greater	Equal to or less than
3. Evidence of drain clogging before potential catastrophic failure:	None	Yes
B. Severity of the Conditions		
Item	**Severe**	**Less Severe**
1. Soil to be drained:	Internally unstable, pipable, or dispersive	Well-graded or uniform
2. Hydraulic gradient:	High	Low
3. Flow conditions:	Dynamic, cyclic, or pulsating	Steady state

Figure A-4. Suggested References for Selected Reinforcement Applications

Application	**Reference (see Section 7 below)**
Reinforced segmental retaining walls	Ref. No. 26, NCMA (2009) Ref. No. 32, FHWA (2008) Ref. No. 33, FHWA (2009)
Reinforced soil slopes	Ref. No. 32, FHWA (2008) Ref. No. 33, FHWA (2009)
Embankments on soft foundations	Ref. No. 22, Holtz, et al. (1997) Ref. No. 23, JDAAF (1995) Ref. No. 32, FHWA (2008)

Figure A-5. Geotextile Interface Shear Strengths from Koerner and Narejo (2005)

Surface No. 1	Surface No. 2	Peak Friction Angle (degrees)	Residual Friction Angle (degrees)	Peak Adhesion (psf)	Residual Adhesion (psf)
Gran. Soil	NW-NP-GT	33	33	0	0
Gran. Soil	NW-HB-GT	28	16	0	0
Gran. Soil	W-SF-GT	32	29	0	0
Cohes. Soil	NW-NP-GT	30	21	104	0
Cohes. Soil	NW-HB-GT	29	10	19	0
Cohes. Soil	W-SF-GT	29	19	0	0
Gran. Soil	NW-NP-GC	27	21	292	376
HDPE-S	NW-NP-GT	11	9	0	0
HDPE-T	NW-NP-GT	25	17	167	0
LLDPE-S	NW-NP-GT	10	9	0	0
LLDPE-T	NW-NP-GT	26	17	169	198
PVC-S	NW-NP-GT	20	16	0	0
PVC-S	NW-HB-GT	18	12	0	0
PVC-S	W-SF-GT	17	7	0	0
PVC-F	NW-NP-GT	27	23	4	0
PVC-F	NW-HB-GT	30	27	0	0
PVC-F	W-SF-GT	15	10	0	0
GN	NW-NP-GT	23	16	0	0

Abbreviations

Gran. - Granular
Cohes. – Cohesive
HDPE – High Density Polyethylene (Geomembrane)

LLDPE – Linear Low Density Polyethylene (Geomembrane)
PVC – Poly Vinyl Chloride (Geomembrane)
GT – Geotextile
GC – Geocomposite (geonet bonded to geotextile)
GN – Geonet
W – Woven
NW – Nonwoven
NP – Needle Punched
HB – Heat Bonded
SF – Slit Film
S – Smooth
T – Textured
F – Faille (roughened)

Peak strength parameters are applicable to initial failures, i.e., prior to significant displacement along the failure surface. Residual strength parameters are applicable after significant displacement has taken place along the failure surface.