Technical Report Documentation Page

<table>
<tr><td>1. Report No.
FHWA/TX-10/0-5812-1</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Application Guide and Specifications for Geotextiles in Roadway Applications</td><td colspan="2">5. Report Date
February 2010, Revised February 2012</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
Jorge G. Zornberg, Nathan Thompson</td><td colspan="2">8. Performing Organization Report No.
0-5812-1</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe, Suite 4.202
Austin, TX 78701</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
0-5812</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Texas Department of Transportation
Research and Technology Implementation Office
P.O. Box 5080
Austin, TX 78763-5080</td><td colspan="2">13. Type of Report and Period Covered
Technical Report
Sept 2007–August 2009</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.</td></tr>
<tr><td colspan="4">16. Abstract
Geotextiles, one among the different geosynthetic products, can be used for a number of functions or applications in pavement design. The benefits of using geotextiles in pavements and other transportation applications have triggered a proliferation of products. While this abundance of new products has led to reduction in costs, it has also made it difficult for TxDOT personnel to choose appropriate products based on their engineering properties. Consequently, this report provides the basis for (i) guidelines for proper use and selection of geotextiles in pavements, (ii) material specifications for geotextiles in pavement applications, and (iii) draft construction specifications.</td></tr>
<tr><td colspan="2">17. Key Words
geosynthetics, geotextiles, woven, nonwovens, filtration, separation, stabilization, reinforcement.</td><td colspan="2">18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161; www.ntis.gov.</td></tr>
<tr><td>19. Security Classif. (of report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of pages
128</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Application Guide and Specifications for Geotextiles in Roadway Applications

Jorge G. Zornberg
Nathan Thompson

CTR Technical Report:	0-5812-1
Report Date:	February 2010, Revised February 2012
Project:	0-5812
Project Title:	Development of Application Guide and Specifications for Geotextiles in Soil and Base
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe, Suite 4.202
Austin, TX 78701

www.utexas.edu/research/ctr

Disclaimers

Author's Disclaimer: The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

Patent Disclaimer: There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

Engineering Disclaimer

NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES.

Project Engineer: Jorge G. Zornberg
Professional Engineer License State and Number: California No. C 056325
P. E. Designation: Research Supervisor

Acknowledgments

The authors express appreciation to Mark McDaniel from the Texas Department of Transportation for valuable input and guidance throughout this project.

Products

Appendix A contains Product 0-5812-P1, *Guide for the Application and Selection of Geotextiles*.

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

1.1 Background

The geosynthetics industry has expanded rapidly in recent years, and the number and types of geotextiles manufactured with a specific focus in roadway design has increased dramatically. This increase has resulted in many new performance-enhancing and cost-saving design alternatives for roadways. However, the proliferation of geotextiles and aggressive marketing from manufacturers has also made it difficult for TxDOT personnel to quantify geotextile benefits as well as the criteria for their selection. Design information is lacking. The only information currently available in TxDOT's Departmental Material Specifications (DMS) regarding the use of geotextiles—DMS 6200, "Filter Fabric"—involves (i) the use of geotextiles only in filter applications (i.e., only one of the several potential applications of geotextiles), and (ii) the use of only nonwoven geotextiles (i.e., only one of the various types of geotextiles). It should be noted, though, that a number of geotextile types are currently being used for multiple applications in pavement design (AASHTO 2006, Holtz et al. 1998, Zornberg and Christopher 2000, 2006).

Traditionally, the use of geotextiles in pavement applications has addressed five main functions: separation, filtration, drainage, reinforcement, and mitigation of crack propagation. More recently, geotextiles have also been used to create a capillary break, acting as a barrier to moisture (Christopher et al. 2000, Henry et al. 2002, McCartney et al. 2005). Depending on the type of geotextile and its location within the pavement system, geotextiles can perform one or more of these various functions simultaneously as part of an overarching application. The challenges facing engineers who will potentially use geotextiles in roadway design are to select the appropriate application, determine relevant properties and criteria for selection of an adequate product, and practice proper installation and construction technique in order to ensure the integrity of the placed geotextile.

1.2 Research Objectives

This research project was designed to determine the most pertinent properties of geotextiles when used in soil and base course of pavement for Texas conditions, provide TxDOT engineers a guide for selection and installation of appropriate geotextiles based on these properties, and promote this information to design engineers throughout the state. Significant opportunities for more cost-effective pavements are being missed by not using (or using incorrectly) geotextiles in pavement design. TxDOT's DMS on geotextiles is not comprehensive enough, as it addresses one function and a single type of geotextiles. A DMS addressing the major applications of geotextiles in roadway design has been compiled as part of this study—a comprehensive literature review and survey of engineers on both the state and national level provided input throughout the project life.

A recent survey of TxDOT districts conducted by the Research Team as part of project 0-4829 showed lack of awareness among TxDOT engineers on the benefits, types, functions, and applications of geosynthetics in pavement design. Results from the survey conducted as part of this project reaffirmed this observation. Anticipating this, the research team tailored the work plan to provide TxDOT engineers not only the tools for correct selection of geotextiles, but also opportunities for education on the benefits and potential concerns regarding the use of geotextiles. This education will be provided in the form of a short course.

More specifically, the objectives of this project are to

- conduct a literature review to assess current selection and design methodologies for use of geotextiles in roadway applications, with particular emphasis on their suitability for conditions typical of TxDOT pavements and Texas materials and environmental conditions;
- perform a survey of TxDOT and other state DOTs in order to assess usage of geotextiles in pavement systems and gain insight from the experience of various sources;
- compile a guide for the application and selection of appropriate geotextiles in roadway design;
- develop an updated Departmental Material Specification (DMS) covering various applications of geotextiles in roadway design;
- compile installation and construction guidelines to complement the application and selection guide; and
- develop a pilot short course to aid in the implementation objectives of this research and contribute towards professional development of TxDOT personnel.

1.3 Design Approach

In outlining the overall design approach, it is important to note a distinction between application and function. While a function refers to a fundamental process performed by a geotextile, an application (often a combination of multiple functions) refers to the specific purpose for placing the geotextile in a pavement system. For example, the Trench Drain application described below is a combination of the separation and filtration functions. The research team initially set out to produce selection guidelines and material specifications with a strictly function-based design approach. However, it became clear during the early stages of the literature review that staying consistent with the current state of practice and, more importantly, producing documents most effective for practicing design engineers, is best achieved by taking an application-based approach. The nomenclature used in the literature to describe roadway applications varies extensively, but the applications themselves are fairly consistent. The project team has identified these applications and tailored the selection guidelines, material specification, and installation guidelines to work cooperatively in addressing each application.

1.4 Report Outline

The first work item of the project is the literature review. This review is divided into two sections—national and state level documents. Chapter 2 covers information published on the national level and Chapter 3 covers those at the state level. These two chapters provide general information about the main sources used in the project. More detailed analysis as it relates to different aspects of the project is given throughout the report.

Chapter 4 covers the survey conducted as the next item of work for the project. Notes on the survey approach, execution, and obtained results are given for both the TxDOT and national surveys. Results from each are analyzed and compared to gain insight on the state of roadway design with geotextiles in Texas.

Design and selection guidelines for roadway applications involving the use of geotextiles are the main expected output of the project. Chapter 5 focuses on this aspect. Background information, including a clarification of the nomenclature used by the research team, an overview of the design process for inclusion of geotextiles in roadway applications, and an overview of the applications identified and targeted by the research team, is first covered. Next, more detailed information focusing on selection criteria for each application is given.

Other outputs of the project include a draft Departmental Material Specification and a set of construction/installation guidelines. Chapter 6 describes the proposed material specification extensively, giving a rationale for the layout, each section, and each proposed property value. Notes on the intended use for the document are also included. Similarly, Chapter 7 covers the installation guidelines. The project team noted that, in analyzing the sources reviewed for each of these documents, determining their basis was very difficult. For example, it was often impossible to determine the source of specified property values or footnote restrictions found in material specifications. Thus, determining which property values or related information should be included in the proposed TxDOT document was made difficult. In an effort to avoid this type of confusion, the rationale behind each proposed item is documented.

A summary of the research team's work and proposed documents is provided in Chapter 8. Final remarks on all aspects of the project, including the need for future work, are included.

Chapter 2. Literature Review

2.1 Geotextile Overview

Much confusion is evident throughout typical design sources regarding geotextiles themselves as well as applications relevant to roadway design. With this in mind, the first objective for the literature review was to gain a comprehensive understanding of geotextiles, the variety of polymers and methods used in manufacturing, functions and applications geotextiles may be used to address, and relevant geotextile properties and testing methods. A widely referenced text focused on design involving geosynthetics (Koerner 2005) was used as the major source for background information. Much of the information gained is covered in the background included in the introduction to this report.

2.2 Manufacturing Process

A ***geotextile*** is defined as a permeable geosynthetic made of textile materials. Among the different geosynthetic products, geotextiles present the widest range of properties (Zornberg and Christopher 2006) and can be used for the widest variety of transportation applications. It should be noted that, consistent with the Research Problem Statement, this project will focus on all the applications that apply to pavement design but only for geotextiles (i.e., only one of the various types of geosynthetics). Special emphasis will be made in this project regarding the use of rigorous nomenclature, as inappropriate terminology has often led to confusion. For example, the term "fabric" is often used to describe a geotextile—in fact, it is in the title of the only DMS focused on geotextiles. This term is considered inaccurate and is inconsistent with the terminology established by ASTM. Instead, the appropriate term is *geotextile*. The terminology used in the guidelines and specifications to result from this project will be rigorously follow the guidelines established by the International Geosynthetics Society (IGS 2000), which are in agreement with the terminology established by ASTM Committee D35 on Geosynthetics.

The ***polymers*** used in the manufacture of geotextile fibers include the following, listed in order of decreasing use: polypropylene (≈85%), polyester (≈12%), polyethylene (≈2%), and polyamide (≈1%). The most common types of ***filaments*** used in the manufacture of geotextiles include *monofilament, multifilament, staple filament,* and *slit-film.* If fibers are twisted or spun together, they are known as a *yarn*.

The filaments, fibers, or yarns are formed into geotextiles using either ***woven*** or ***nonwoven*** methods. Figure 1.1 shows a number of typical geotextiles. *Woven geotextiles* are manufactured using traditional weaving methods and a variety of weave types: plain weave, basket weave, twill weave, and satin weave. *Nonwoven geotextiles* are manufactured by placing and orienting the filaments or fibers onto a conveyor belt, which are subsequently bonded by needle punching or by melt bonding. The nonwoven geotextiles (on the right side of the picture) have tremendously different engineering properties than the woven geotextiles (on the left side of the picture). The type of polymer will also influence significantly the engineering properties of these products.

Common terminology associated with geotextiles includes machine direction, cross machine direction, and selvage. ***Machine direction*** refers to the direction in the plane of the fabric in line with the direction of manufacture. Conversely, ***cross machine direction*** refers to the direction in the plane of fabric perpendicular to the direction of manufacture. The ***selvage*** is the finished area on the sides of the geotextile width that prevents the yarns from unraveling.

Figure 2.1: View of different types of geotextiles

2.3 Geotextile Functions

The primary functions of geotextiles used for pavement applications have traditionally included separation, filtration, drainage, and reinforcement. However, a certain geotextile product can perform different functions and, conversely, the same function can often be performed by different types of geotextiles. In addition to their primary function, geotextiles can perform one or more secondary functions—these must also be considered when selecting the geotextile material for optimum performance. For example, a geotextile can provide separation of two dissimilar soils (e.g., aggregate base and clay subgrade), but it may also provide filtration as a secondary function by minimizing the build-up of excess pore water pressure in the soil beneath the separator. A brief overview of functions typically performed by geotextiles in pavement applications is given here.

Separation is the introduction of a flexible porous geotextile placed between dissimilar materials so that the integrity and the functioning of both materials remains intact for the life of the structure or is improved (Koerner 2005). In pavement applications, separation refers to the geotextile's role in preventing the intermixing of two adjacent layers. For example, a major cause of failure of roadways constructed over soft foundations is contamination of the aggregate base course with the underlying soft subgrade soil (Figure 2.2a). A geotextile placed between the aggregate and the subgrade acts as a separator, minimizing contamination of the aggregate base by the subgrade (Figure 2.2b).

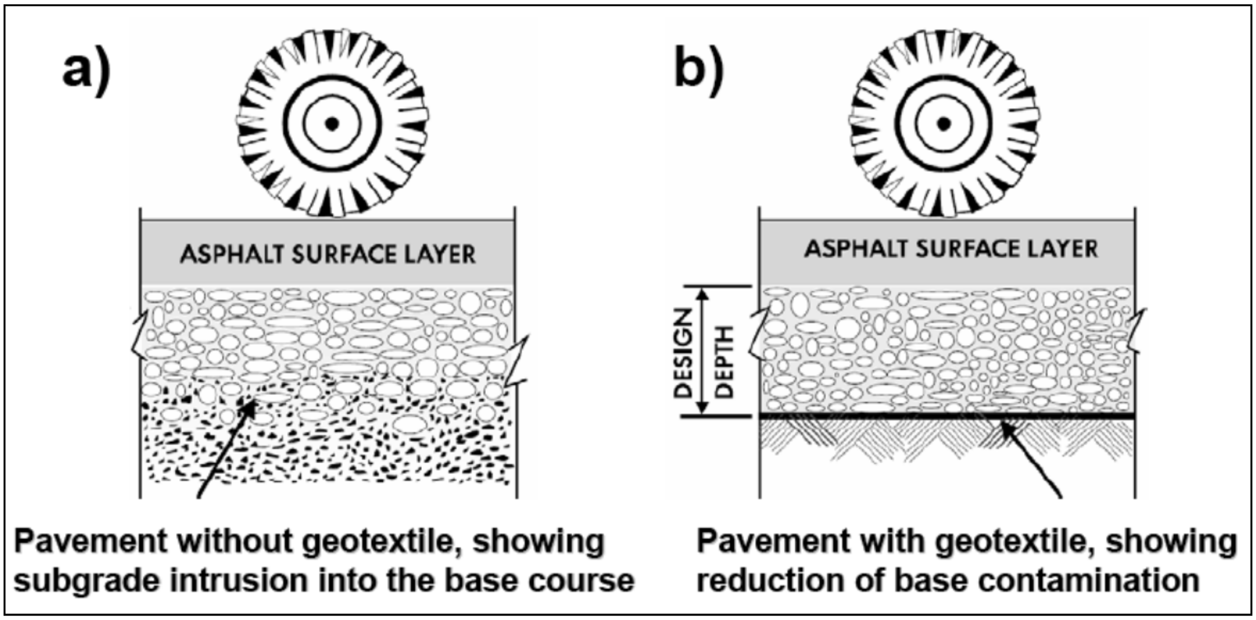


Figure 2.2: Separation function of a geotextile placed between base aggregate and a soft subgrade: (a) without geotextile; (b) with geotextile

Filtration is defined as the equilibrium of a geotextile-soil system that allows for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime compatible with the application under consideration (Koerner 2005). A common application illustrating the filtration function is the use of a geotextile in a pavement trench drain (Figure 2.3). The geosynthetic-soil system should achieve an equilibrium that allows for adequate liquid flow under conditions of consideration. As the flow of liquid is perpendicular to the plane of the geosynthetic, filtration refers to the cross plane hydraulic conductivity or permittivity, which is defined as

$$\psi = \frac{k_n}{t}$$

where ψ is the permittivity, k_n is the cross-plane hydraulic conductivity, and t is the geotextile thickness at a specified normal pressure. Another important property relevant to filtration is apparent opening size (AOS)—the opening size larger than 95% of the geotextile's pores—which is compared to soil particle size characteristics. The coarser-sized particles eventually create a filter bridge, which in turn retains the finer-sized particles, building a stable upstream soil structure.

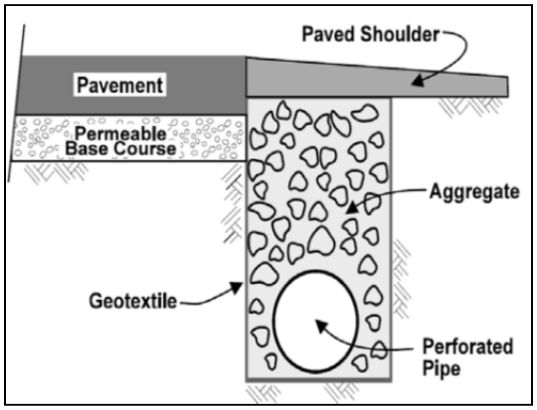


Figure 2.3: Filtration function provided by a geotextile in a pavement trench drain

Drainage refers to the ability of geotextiles (typically thick, nonwoven geotextiles) to provide an avenue for flow of water through the plane of the geotextile. The geosynthetic is generally quantified by its transmissivity, which is defined as

$$\theta = k_p * t$$

where θ is the transmissivity, k_p is the in-plane hydraulic conductivity, and *t* is the geotextile thickness at a specified normal pressure.

Reinforcement is the synergistic improvement in pavement strength created by the introduction of a geotextile into a pavement layer. While the function of reinforcement in the U.S. has often been fulfilled by geogrids, geotextiles have been used extensively as reinforcement inclusions, particularly overseas, in transportation applications (Bueno et al. 2005, Benjamim et al. 2007). The reinforcement function can be developed primarily through the following three mechanisms (Holtz et al. 1998):

1. *Lateral restraint* through interfacial friction between geotextile and soil/aggregate. When an aggregate layer is subjected to traffic loading, the aggregate tends to move laterally unless it is restrained by the subgrade or geosynthetic reinforcement. Soft, weak subgrade soils provide very little lateral restraint, so rutting develops when the aggregate moves laterally. A geotextile with good frictional capabilities can provide tensile resistance to lateral aggregate movement (Figure 2.4a).
2. *Increased bearing capacity*, i.e., by forcing the potential bearing surface failure plane to develop at alternate higher shear strength surface (Figure 2.4b).
3. *Membrane type of support* of the wheel loads (Figure 2.4c).

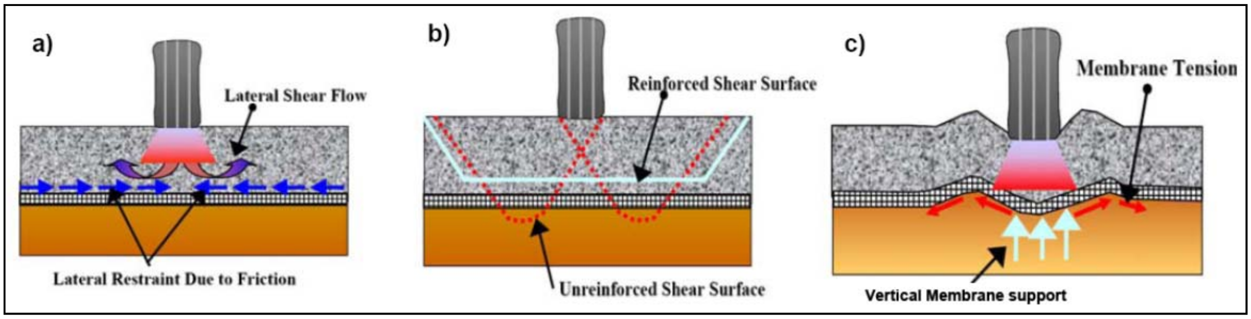


Figure 2.4: Reinforcement mechanisms induced by a geotextile used for base reinforcement: (a) lateral restraint; (b) increased bearing capacity; (c) membrane-type support.

Protection refers to placement of a geotextile to act as a stress relief layer.

Fluid barrier refers to the ability of a geotextile to prevent the passage of fluid. A geotextile is typically placed as a fluid barrier in roadways in one of two ways: when saturated with bituminous material and placed beneath a pavement overlay, and when placed adjacent to a finer material under unsaturated conditions.

2.4 Important Properties and Test Methods

Geotextile properties are generally categorized in the following groups: physical, mechanical, hydraulic, endurance, and degradation. Each group encompasses testing that characterizes a different aspect of geotextiles and their performance. In addition to these property groups, geotextile testing may be characterized as either index or performance. Index tests are used for general characterization of a geotextile product and do not provide values that can be directly used for design purposes, while performance testing provides information about the expected behavior of a geotextile in an engineered system. Index testing is performed on the geotextile alone, or in-isolation, while performance testing often involves both the geotextile and soil to be placed in an engineered system.

Physical properties are used to characterize the geotextile in the as-received, manufactured condition, and are obtained with index testing. Common physical properties include specific gravity, mass per unit area, thickness and stiffness.

Mechanical properties provide an understanding of geotextile strength and/or compressibility under varying loads. Common mechanical properties include compressibility, tensile strength, tear strength, puncture strength, and seam strength. A wide variety of tests are available to characterize geotextile strength, generally designed to replicate conditions encountered in field installation. Depending on the specific strength property, the testing may be described as either index or performance. Many of the most common geotextile strength tests are descendants of testing used for decades in the industrial fabrics industry, and therefore do not provide much useful engineering design information—these may be described as index tests. Others, however, have been designed with engineering purposes in mind, and provide a more representative strength value that may be used to describe a geotextile's expected performance in the field.

The ability of water to flow through or within a geotextile is a function of geotextile hydraulic properties. As with mechanical properties, testing for hydraulic properties includes both index and performance tests. Performance testing usually involves both the geotextile and the soil expected to be placed adjacent to the geotextile in an engineered system. Common hydraulic properties include porosity, percent open area, AOS, permittivity, and transmissivity.

While all the tests described thus far have focused on the short-term behavior of geotextiles, the performance of a given geotextile in an engineered system will vary over the geotextile's lifetime. This is commonly due to damage of the geotextile during installation, the effects of sustained loading on the geotextile structure and strength, and/or the effects of migrating soil particles on the hydraulic properties of the geotextile. Endurance testing focuses on long-term geotextile behavior. Common testing addresses creep response, stress relaxation, long-term clogging, abrasion, and installation damage.

Long-term performance of geotextiles is also affected by geotextile degradation via different mechanisms including ultraviolet light (sunlight), chemical reactions with geotextile polymers, and/or thermal degradation. Degradation testing is important in determining the ultimate lifetime of a geotextile in an engineered system.

Table 2.1 provides a list of commonly reported geotextile properties and their associated ASTM standard test methods. This table is presented as an overview of the tests most commonly reported in the literature and in manufacturer information, and is not an exhaustive list of available geotextile testing. Additional information on the tests covered in Table 2.1 is provided to give potential geotextile users a better understanding of reported property values.

Table 2.1: Geotextile properties and associated ASTM standard test methods

Property	Reporting Units	Standard Test Designation
Grab Strength	lbf (kN)	ASTM D 4632
Sewn Seam Strength	lbf (kN)	ASTM D 4632
Tear Strength	lbf (kN)	ASTM D 4533
Puncture Strength	lbf (kN)	ASTM D 6241 / ASTM D 4833
Permittivity	sec^{-1}	ASTM D 4491
AOS	US Sieve No. (mm)	ASTM D 4751
Ultraviolet Stability	%	ASTM D 4355

One of the most important strength properties for a geotextile is the tensile strength. Geotextile tensile strength is measured by clamping two opposite ends of a geotextile specimen in a mechanical testing machine and stretching the specimen until failure occurs. Typically, both the force applied to the geotextile and the geotextile strain are measured, allowing observation of the stress-strain curve and development of associated modulii. Several tests are available for measuring geotextile tensile strength, with the primary variations lying in the type of clamps used and the size of the geotextile specimen. The grab tensile test, ASTM D 4632, is the most commonly specified and reported geotextile tensile strength. It involves testing a 100 mm wide by 150 mm long geotextile specimen.

Often, due to manufacturing size limitations, it is desirable to join multiple geotextile sections together when placed in an engineered system. The most common method of joining geotextiles is by sewing them. For the case in which sewing is used when installing geotextiles, characterization of the strength of a given seam type is important for ensuring the integrity of the sewn sections. This is accomplished by performing a tensile test on a sewn geotextile sample. The most commonly specified test is ASTM D 4632, the same test used to obtain the grab tensile strength.

Other tests for geotextile strength are focused on ensuring that a geotextile is strong enough to survive installation stresses, often the most severe stresses placed on the geotextile over its lifetime. The most commonly specified tests cover tear strength and puncture strength. Tear strength of a geotextile is generally measured by making a small cut in a prepared specimen and testing in a tensile testing apparatus. Puncture strength is tested by measuring the force required to punch a probe through a geotextile specimen. Traditionally, ASTM D 4833 is the standard specification for obtaining puncture strength. However, the small size of the probe head used in ASTM D 4833, 8 mm, resulted in highly inconsistent test results due to the variability inherent in nonwoven geotextiles as well as the potential for the probe to "slip" between yarns in a woven geotextile. As a result, a standard CBR probe is used for test method ASTM D 6241—this probe has a larger head, 50 mm in diameter, and provides more consistent results.

The two most commonly specified hydraulic properties of a geotextile are permittivity and AOS. Permittivity is defined as the cross-plane permeability of a geotextile. In other words, permittivity is a measure of the ease at which water may flow through the geotextile. Permittivity is obtained with ASTM D 4491, by measuring the flow of water, under a given head, moving perpendicularly through a geotextile. Values are reported in units of sec^{-1}, allowing for a more traditional value of permeability to be obtained by multiplying the permittivity by the thickness of the geotextile. The current standard in the United States for measuring this average pore size, or AOS, is ASTM D 4751. The test method consists of dry sieving glass beads of uniform size through a geotextile specimen and determining the size of glass beads at which 5% of the initial sample passes through the geotextile. This particle size, referred to as O_{95}, is converted to AOS by selecting the US Standard Sieve Number with openings closest in size to the O_{95}.

2.5 National Level Documents

The literature review was conducted in two parts—one focused on sources at the national level, the other on state-level information. This chapter covers national-level documents. Information presented is intended to provide a general overview of documents the research team used most often.

In order to select appropriate material property values from existing literature, without performing any empirical testing, it is imperative to understand the provenance of each referenced document. Specified property values from different sources are often conflicting, so emphasis should be placed on the source based on the most reliable empirical evidence. It is often difficult to determine the rationale used for development of many documents found in the literature survey; as a result, a major focus in this report is placed on clearly explaining the origin and rationale for recommended practices and property values. Section 2.5.1 provides a brief background for the primary national sources used in this project.

Next, brief overviews of the main documents pertaining to the project deliverables—design guidelines, material specifications, and construction/installation guidelines—are given. As the primary source of information for every aspect of the project was continuous review of available literature, more detailed information is given throughout the report as it pertains to each objective. Emphasis is placed on the exact wording used in highlighted documents, as the vocabulary selected is an important aspect of the project and the terminology used is often contradictory in the existing literature.

2.5.1 Identification and Provenance of Relevant Documents

The most commonly used national source for design and selection criteria is the FHWA *Geosynthetic Design and Construction Manual* (Holtz et al. 1998). This document provides information related to the design of multiple applications relevant to roadway design. The work is a synthesis of research focused on transportation-related design involving geosynthetics. Much of the basis for geotextile-related material lies in the *Geotextile Engineering Manual* (Christopher and Holtz 1985), the first major publication to present an extensive set of background information and design guidelines for geotextiles.

The FHWA manual is updated from the 1995 version to include more recent information, mainly material specifications published in the 1997 version of AASHTO M288 *Geotextile Specification for Highway Applications*. The 2006 AASHTO M288, the most recent update (AASHTO 2006), is the national standard for a material specification focused on geotextiles used in transportation applications. Material properties specified in M288 are generally based on recommendations from Task Force 25 (AASHTO 1990), a group formed by the AASHTO-AGC-ARTBA Committee on Highway Materials to develop specifications for standard geosynthetics applications of the time. Another common material specification is FHWA FP-03: *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects* (FHWA 2003). However, the logic and recommended material properties in this document are adopted from the FHWA *Geosynthetic Design and Construction Manual* and AASHTO M288.

The prominent national sources for installation guidelines are FHWA *Geosynthetic Design and Construction Manual*, FHWA FP-03, and AASHTO M288. Much of the material found in these installation guidelines can be traced back to the *Geotextile Engineering Manual* (Christopher and Holtz 1985).

2.5.2 Design and Selection Guidelines

The most prominent and extensive source for design and geotextile selection guidelines is the FHWA *Geosynthetic Design and Construction Manual* (Holtz et al. 1998). The document takes an application-based approach. Of relevance to this project are the chapters devoted to subsurface drainage systems and roadways and pavements (Holtz et al. 1998).

In a typical roadway project, the most extreme conditions to which a geotextile is subjected occur during construction. In order to perform as designed during a project's lifetime, the geotextile must maintain its integrity through the duration of the construction process—the ability of a given geotextile to do so is termed its "survivability" (Holtz et al. 1998). Survivability, a function of a number of project- and site-specific variables, controls the required strength properties of a geotextile, regardless of the application. Survivability requirements were originally determined by Task Force 25 (AASHTO 1990), and have been updated in more recent versions of AASHTO M288 (AASHTO 2006). The FHWA manual follows the M288 specification, which is covered in detail in the following section of this report.

In addition to strength requirements based on survivability, selection of an appropriate geotextile depends on certain property requirements relevant to each application. A review of the design basis presented in the FHWA manual follows, with specific focus on the two chapters most relevant to this study, *Subsurface Drainage Systems* and *Roadways and Pavements*.

Subsurface Drainage Systems

Geotextiles used for subsurface drainage systems perform the filtration function as part of a drainage structure. Filtration is required to maintain the integrity and usefulness of the structure over its design life. The distinction between function and application is important in this instance, as the geotextile is placed as part of a drainage application but performs the filtration function. Several specific applications are illustrated in the FHWA manual, including filters “around trench drains and edge drains” and “beneath pavement permeable bases, blanket drains and base courses,” and “geotextile wraps for slotted or jointed drain and well pipes” (Holtz et al. 1998). Illustrations from the FHWA manual are shown in Figure 2.5.

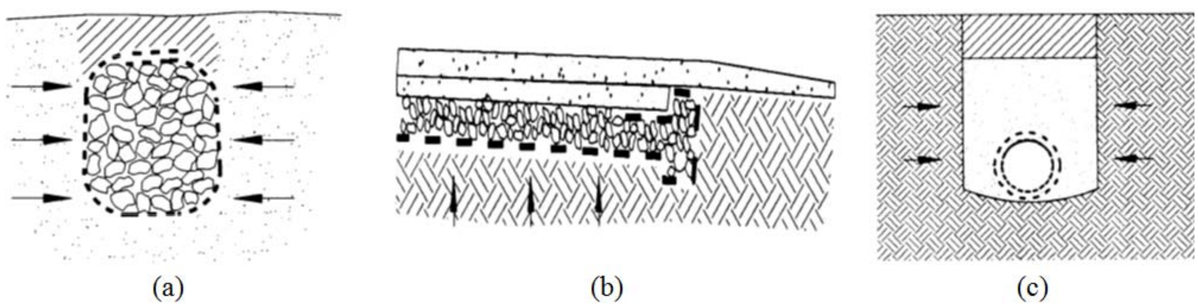


Figure 2.5: Subsurface drainage applications in a roadway structure cited in Holtz et al. 1998—(a) filters around trench and edge drains; (b) filters beneath pavement permeable bases, blanket drains and base courses; (c) geotextile wraps for slotted or jointed drain and well pipes (Holtz et al. 1998)

Design for a geotextile performing the filtration function must address the same issues related to design of a traditional granulated filter. The relationship between average geotextile pore size and soil particle size must be such that, for the duration of the structure’s projected life cycle, soil is retained on the upstream side of the geotextile while an adequate amount of water is allowed to pass through.

Recommended design requirements vary based on the type and characteristics of soil used, type of geotextile, flow conditions, and criticality of the application or severity of conditions. A highly critical project or set of severe conditions typically should not be addressed with a set of standardized design guidelines or generic specifications. In most cases, engineering judgment backed with sufficient experience and/or project-specific performance testing should be relied upon. Determining the criticality of a given application or set of conditions is somewhat subjective, but the FHWA manual follows the example set forth in Carroll (1983). Table 2.2 provides recommended guidelines for determining the critical nature of a project.

In order for the geotextile to provide adequate retention of soil particles at its upstream face, the larger pore sizes in the geotextile must be smaller than the larger particles in the adjacent soil. This creates a filter bridge at the soil-geotextile interface, illustrated in Figure 2.6. The geotextile AOS is compared to a representative particle size for the adjacent soil to ensure that these filtration criteria are adequately addressed.

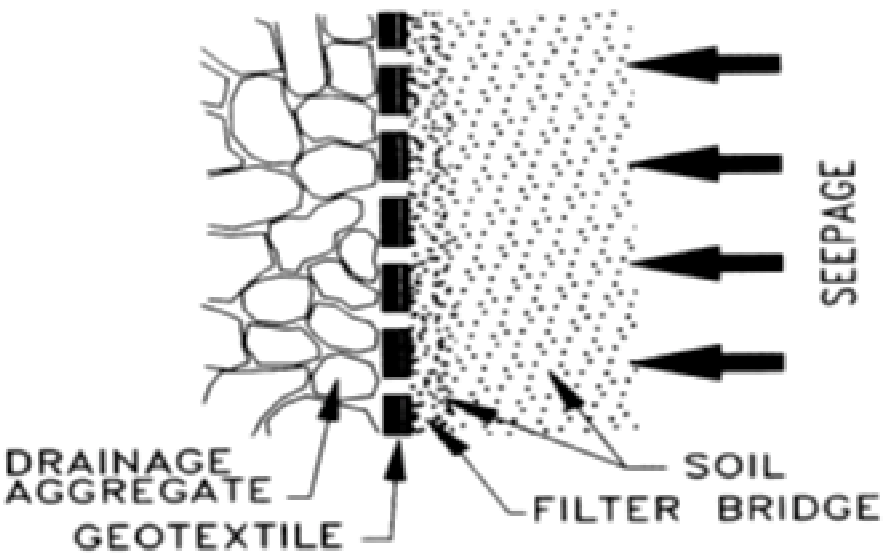


Figure 2.6: Formation of filter bridge at soil-geotextile interface (Holtz et al. 1998)

Table 2.2: Guidelines for evaluating the critical nature or severity of subsurface drainage applications (Holtz et al. 1998)

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	>>>	= or <
3. Evidence of drain clogging before potential catastrophic failure	None	Yes
B. Severity of Conditions		
Item	**Severe**	**Less Severe**
1. Soil to be drained	Gap-graded, pipable, or dispersible	Well-graded or uniform
2. Hydraulic gradient	High	Low
3. Flow conditions	Dynamic, cyclic, or pulsating	Steady state

A representative value for the larger soil particles, obtained from the soil particle size distribution, is D_{85}, the particle size at which 85% of the soil is smaller. This general relationship is

$$AOS \leq B * D_{85}$$

where B is a dimensionless coefficient depending on soil type, geotextile type, and the uniformity coefficient, C_u, if the soil is granular. C_u is defined as D_{60}/D_{10}, where D_{60} and D_{10} are defined in the same manner as D_{85}. A B value of 1 is a conservative design requirement for retention. Recommended practice in the FHWA manual allows for higher B values, up to 2, for well-graded granular soils with C_u values between 2 and 8. For silts and clays, the recommended B value depends on the type of geotextile used. Nonwoven geotextiles generally retain finer particles for a given AOS as a result of their irregular pore structure, and a less conservative B value of 1.8 is recommended.

Requirements for adequate water flow through the geotextile are presented in terms of both permeability and permittivity in the FHWA design guidelines. At minimum, the permeability of the geotextile should be greater than that of the adjacent soil to ensure that the geotextile does not create an impedance to flow. For more critical applications or severe conditions, when an impedance to flow would result in unacceptable consequences, the FHWA manual recommends a more conservative requirement, that the geotextile permeability be at least one order of magnitude greater than that of the soil (Holtz et al. 1998).

Permittivity is better representative of a geotextile's cross-plane flow capacity. Moreover, it is readily determined in the lab through standard ASTM D 4491, whereas there is no standard for determining a geotextile's permeability empirically. Required permittivity depends on the amount of fines in the adjacent soil—more fines require a larger geotextile permittivity to offset the effect of entrapped fines, unavoidable in a geotextile's pore structure. Table 2.3 lists the recommended permittivity values (Holtz et al. 1998).

Table 2.3: Recommended permittivity requirements for geotextiles in subsurface drainage structures

For < 15% passing 0.075mm sieve	$\psi \geq 0.5 sec^{-1}$
For 15 to 50% passing 0.075mm sieve	$\psi \geq 0.2 sec^{-1}$
For > 50% passing 0.075mm sieve	$\psi \geq 0.1 sec^{-1}$

The final primary design requirement is to ensure that flow through the geotextile remains adequate over the life of the drainage structure, ensuring that excessive clogging does not occur. Fine soil particles are expected to enter the geotextile pore structure with passing water as the filter bridge, illustrated in Figure 2.6, is forming on the upstream side of the geotextile. Clogging occurs when those fine particles are not flushed out by water flowing across the plane of the geotextile. To minimize clogging, the average pore size in the geotextile should be larger than the smaller soil particle size. The FHWA manual recommends the following relationship (Holtz et al. 1998):

$$AOS \geq 3 * D_{15}$$

where D_{15} is the particle size at which 15% of the soil is smaller.

Clogging is most likely to occur when dealing with gap-graded and/or silty soils. Unlike well-graded soils, these will form poor filter bridges and are likely to pass a significant amount of fines into the geotextile pore structure. To address this, the FHWA manual recommends additional qualifiers for both nonwoven and woven geotextiles. For both geotextile types, clogging reduces the total amount of pathways available for water flow. The amount of pathways initially available for flow is identified by porosity for nonwovens, and percent open area (POA) for wovens. The following optional qualifiers are recommended (Holtz et al. 1998):

- Nonwoven geotextile: $n \geq 50\%$
- Woven geotextile: $POA \geq 4\%$

Again, a distinction is made based on the critical nature, or severity of conditions, of the proposed application. For more severe conditions, e.g., using a gap-graded silty soil for a subsurface drainage structure likely to cause major structural damage if flow is impeded, project-specific performance tests should be run to ensure the adequacy of the soil-geotextile structure. The gradient ratio test, ASTM D 5101, is recommended for sandy soils with a hydraulic conductivity greater than approximately 10^{-6} m/sec. Other tests are available for soils with significant amounts of fines.

All other property requirements are based on survivability, covered in a review of AASHTO M288 later in this report.

Roadways and Pavements

Geotextiles may be placed between adjacent layers in a pavement structural section to perform the separation, filtration, and/or reinforcement functions. In temporary roads, typically used during construction to provide access or a working platform, a geotextile may be placed between existing subgrade and placed fill to improve site conditions to a condition acceptable for construction traffic. Geotextiles may be placed between subgrade and base in a permanent roadway to improve long-term performance and increase the pavement life cycle.

As is the case for subsurface drainage applications, survivability concerns control geotextile strength requirements, regardless of the specific application for which the geotextile is placed. Recommended survivability classes and property values are adopted from AASHTO M288 (AASHTO 2006), reviewed in Chapter 5.

In a permanent roadway constructed over a subgrade with significant fines content, a geotextile may be placed between subgrade and aggregate base layer to perform the separation function. The geotextile prevents intrusion of aggregate into the subgrade and migration of fines into the base. Intermixing of the two layers causes localized bearing failures in the roadway, resulting in increased maintenance costs and a shortened life cycle. By preserving the integrity of both layers, the geotextile improves pavement performance. However, no decrease in required base thickness is warranted due to inclusion of a geotextile—design of the pavement structural section should be completed as if no geotextile is included (Holtz et al. 1998).

Selection of a geotextile appropriate for separation is largely based on survivability concerns. Filtration should be checked to ensure that the geotextile does not act as a barrier to flow, but is not the focus of geotextile selection for separation. As a result, selecting an appropriate geotextile does not call for full filtration design, i.e., the procedure outlined for a geotextile used in subsurface drainage. The FHWA manual (Holtz et al. 1998) recommends minimum filtration requirements set forth in AASHTO M288.

When constructing over a soft subgrade, often characterized by wet, saturated conditions, placing aggregate atop the subgrade will result in significant losses of aggregate due to intrusion resulting from construction traffic loads. To account for this, a stabilizing layer of aggregate is often placed prior to that of the base layer. A geotextile may be placed between the subgrade and stabilizing aggregate to perform both the separation and filtration functions. In addition to maintaining the integrity of both layers, water in the underlying subgrade is allowed to pass through the geotextile and drain to the aggregate layer, thereby dissipating destabilizing pore pressures resulting from wheel loadings (Holtz et al. 1998). The base layer is designed with traditional structural pavement design methods, i.e., placement of the stabilizing layer typically does not call for a reduction of required base thickness.

A geotextile placed for stabilization is counted on to behave as a filter, so more strict consideration of geotextile hydraulic properties—namely, AOS and permittivity—is recommended. The FHWA manual recommends a procedure similar to that described for subsurface drainage, but provides the simplified specification presented in AASHTO M288. M288 recommends AOS and permittivity values based on the amount of fines in the adjacent soil (Holtz et al. 1998, AASHTO 2006).

An important distinction to be made in determining whether a geotextile should be placed for separation or stabilization is whether the subgrade is soft enough to require stabilization. The FHWA manual recommends using a California Bearing Ratio (CBR) value of 3 to determine this cutoff. If a subgrade has a CBR strength less than 3, it is typically wet and saturated, and requires a geotextile acting as a filter in addition to a separator (Holtz et al. 1998).

The main purpose of geotextile placement in temporary roads—i.e., construction access roads or working platforms—is to provide support for construction equipment where the existing ground is too soft to support equipment by itself. Design procedures recommended in the FHWA manual assume the geotextile acts mainly to provide separation and filtration. In addition to these benefits, the manual assumes that some tensile reinforcing benefit arises with development of rutting in the overlying fill. The benefit of this reinforcement is incorporated in the design process through an empirical bearing capacity factor. Selection of an appropriate geotextile is the same as that for a geotextile used for stabilization of a permanent roadway.

2.5.3 Material Specifications

Prior to the work of Task Force 25 (AASHTO 1990), AASHTO's main geotextile specification dealt only with drainage applications. In 1992, AASHTO broadened the coverage of its specification to include the five applications focused on by Task Force 25. The resulting document was AASHTO Specification M288: *Geotextile Specification for Highway*

Applications. Revisions to AASHTO M288 are controlled by Technical Section 4e of AASHTO; updated versions have been published periodically, with the latest update occurring in 2006.

The most recent version, AASHTO M288-06, covers strength and hydraulic properties of geotextiles used in subsurface drainage, separation, and stabilization applications. Other applications not relevant to this study are covered in M288 but not mentioned here. Strength requirements are based on required survivability, independent of the given application for which a geotextile is being placed. A class system is used to provide a framework for specifying relative survivability conditions—Class 1 is for severe installation conditions where higher strength is required, Class 2 for more moderate conditions, and Class 3 for moderate to light conditions. A geotextile's required strength can be determined by identifying an appropriate survivability class based on expected site conditions. The strength values proposed in AASHTO M288 have their origin in the work of Task Force 25—they are based on engineering experience rather than large volumes of systematic research and testing data and should be viewed as minimum requirements only, rather than definitive numbers (AASHTO 1990, Holtz et al. 1998).

Unlike strength-related properties, required hydraulic properties—AOS and permittivity—vary based on the application for which the geotextile is placed. A geotextile placed to perform the separation function only has less stringent hydraulic requirements than one expected to perform the filtration function.

Similar to the FHWA manual, AASHTO M-288 provides information for subsurface drainage, separation, and stabilization, in addition to several other applications not included in the scope of this study.

2.6 State Level Documents

2.6.1 Introduction

A review of state-level documents was completed to address the following objectives:

- Document available state DOT specifications which incorporate the use of geotextiles in highway projects.
- Evaluate state DOT specifications and compare them with national guidelines such as FHWA HI 95-038, AASHTO M288, and other available documents.
- Summarize state DOT information.

To achieve these objectives, the following documentation from all 50 states was reviewed: Standard Specifications for Highway Construction, supplements to the Standard Specifications, and special provisions for the Standard Specifications. During the literature search, the following keywords were used: geosynthetics, geotextile, and fabric. The main findings, including the sources of the findings relevant to this research project, have been documented and summarized in Table 2.4.

The main challenge in evaluating state DOT specifications was that the background information and data used to create the specifications could not be obtained.

Material specifications from each state are discussed and commented on individually in the following sections. By reviewing and evaluating individual DOT specifications for geotextiles, a better understanding of the current state of practice was gained.

Table 2.4: Geotextile applications in state DOT specifications

State	Source	Specifications Category Based on Application				
		Separ-ation	Stabiliz-ation	Drainage	Reinforce-ment	Paving fabric
Alabama	2008 Standard Specifications for Highway Construction	x		x		x
Alaska	2004 Standard Specifications for Highway Construction	x	x	x		x
Arkansas	2003 Standard Specifications for Highway Construction	x	x	x		x
Arizona	2002 Standard Specifications	x		x		x
California	2006 Standard Specifications			x	x	
Colorado	2005 Standard Specifications Revision/Special Provision	x		x		x
Connecticut	2005 Standard Specifications for Roads, Bridges and Incidental Construction			x		
Delaware	2001 Standard Specifications	x	x			x
Florida	2000 Standard Specifications for Road and Bridge Construction		x	x		
Georgia	2001 Standard Specifications		x	x	x	
Hawaii	2005 Standard Specifications	x	x	x		x
Idaho	2004 Standard Specifications for Highway Construction	x		x		x
Illinois	2002 Standard Specifications for Road and Bridge Construction		x			
Indiana	2008 Standard Specifications Book			x		
Iowa	2007 Standard Specifications with GS.01007 Revisions		x	x		x
Kansas	2007 Specifications for State Road and Bridge Construction	x				
Kentucky	2004 Standard Specifications for Road and Bridge Construction		x	x		

State	Source	Specifications Category Based on Application				
		Separ-ation	Stabiliz-ation	Drainage	Reinforce-ment	Paving fabric
Louisiana	2000 Standard Specifications for Roads and Bridges	x	x	x		x
Maine	2002 Standard Specifications Revision for December	x	x	x	x	
Maryland	2001 Standard Specifications for Construction and Materials/Supplement		x	x		
Massachusetts	2007 Standard Special Provisions&1997 Standard Specs	x	x		x	
Michigan	2003 Standard Specifications for Construction	x	x	x		
Mississippi	2004 Standard Specs for State Aid Road and Bridge Construction	x	x	x	x	x
Minnesota	2005 Standard Specifications for Construction	x		x		x
Missouri	2004 Specification Book for Highway Construction	x	x	x		x
Montana	2006 Standard Specs for Road and Bridge Construction/Supplement	x	x	x		
Nevada	2007 Standard Specifications for Road and Bridge Construction				x	
New Hampshire	2006 Standard Specifications for Road and Bridge Construction	x	x	x		
New Jersey	2007 Standard Specifications for Road and Bridge Construction		x	x		
New Mexico	2007 Standard Specs for Highway and Bridge Construction/Supplement	x	x	x		
New York	2006 Standard Specifications			x		
North Carolina	2002 Standard Specifications		x	x		
North Dakota	2002 Standard Specifications for Road and Bridge Construction	x		x	x	
Ohio	2008 Construction and Material Specifications	x	x	x		
Oklahoma	1999 Standard Specifications for Highway Construction	x		x		x
Oregon	2008 Standard Specifications/2002 Supplement		x	x	x	x

State	Source	Specifications Category Based on Application				
		Separ-ation	Stabiliz-ation	Drainage	Reinforce-ment	Paving fabric
	to Standard Specs					
Pennsylvania	2000 Standard Specifications for Highway and Bridge Construction	x	x	x	x	
Rhode Island	2007 Standard Specifications for Road and Bridge Construction			x		
South Carolina	2007 Standard Specification for Highway Construction/Supplement	x				
South Dakota	2004 Standard Specifications for Roads & Bridges	x		x		
Tennessee	2004 Standard Specifications for Road and Bridge Construction		x	x		
Texas	2004 Standard Specifications for Construction and Maintenance of Highway			x		
Utah	2008 Standard Specifications / 2005 Supplement	x	x	x		
Vermont	2006 Standard Specifications for Construction Book	x	x	x		
Virginia	2007 Road and Bridge Specifications		x	x		x
Washington	2008 Standard Specifications for Road, Bridge, and Municipal Construction	x		x		
Wisconsin	2008 Standard Specifications for Highway and Structure Construction	x		x	x	
West Virginia	2000 Standard Specifications for Roads and Bridges	x	x			x
Wyoming	2003 Standard Specifications for Road and Bridge Construction	x	x	x		
Total States	**50**	**31**	**30**	**42**	**10**	**17**

2.6.2 State DOT Geotextile Materials Specifications

The objective of this section is not to assess the merits of the different specifications compiled by the various states. Instead, the objective is to document the main characteristics of the specifications in the various states with emphasis in identifying differences with AASHTO M288.

Ten states have adopted geotextile property requirements that are based directly on AASHTO M288, with no significant differences apparent between AASHTO M288 and the state DOT specifications. These states are presented in Table 2.5.

Table 2.5: States having specifications consistent with AASHTO M288

State	Sources
Alabama	2008 Standard Specifications for Highway Construction
Alaska	2004 Standard Specifications for Highway Construction
Arkansas	2003 Standard Specifications for Highway Construction
Delaware	2001 Standard Specifications
New Jersey	2007 Standard Specifications for Road and Bridge Construction
New Mexico	2007 Standard Specs for Highway and Bridge Construction
Oklahoma	1999 Standard Specifications for Highway Construction
Tennessee	2004 Standard Specifications for Road and Bridge Construction
Utah	2008 Standards Specifications / 2005 Supplement
West Virginia	2000 Standard Specifications Roads and Bridges

In **Alabama**, the 2006 *Standard Specification for Highway Construction Division 800, Material Section 810: Geotextiles* clearly states that geotextile filters shall meet the appropriate chemical and physical requirements of AASHTO M288 for the application for which the material is to be used. The state has also a required product list for geotextiles. In addition, *Section 604 Geotextile in Separation Application* clearly states that the geotextile shall meet the requirements of AASHTO M288 for Separation Applications, Class 2. *Section 605 Pavement and Special Underdrain* clearly states that the geotextile filter for aggregate-filled underdrain shall be a non-woven material meeting the requirements of AASHTO M288 for Class 2 Subsurface Drainage Geotextile.

In **Alaska**'s 2004 *Standard Specification for Highway Construction, section 729-2.01 Geotextiles Separation and Stabilization*, the materials requirements also refer to AASHTO M288 for the following functions: (1) Separation, meet AASHTO M288, Table 3 for Separation Geotextile Property Requirements, Meet Class 2, except provide a minimum permittivity of 0.05 sec-1 and (2) Stabilization, meet AASHTO M288, Table 5 for Stabilization Geotextile Property Requirements. Meet, Class 1 except provide a minimum permittivity of 0.08 sec-1. For subsurface drainage, 729-2.02 Geotextile Subsurface Drainage is used. Subsurface Drainage geotextile should Meet AASHTO M288, Table 2 for Subsurface Drainage Geotextile Requirements. Meet Class 2 with minimum permittivity of 0.5 sec-1.

In **Arizona**, the 2002 *Standard Specification for Roads and Bridges 1014-4 Separation Geotextile Fabric* requires that separation geotextile fabric shall be a non-woven or woven fabric consisting only of long chain polymeric filaments such as polypropylene or polyester formed or woven into a stable network such that the filaments retain their relative position to each other. The fabric shall be inert to commonly encountered chemicals, resistant to rot and mildew, and shall have no tears or defects which adversely affect or alter its physical properties. The physical requirements for the separation fabric will be determined by the survivability rating called out for the fabric in the Special Provisions or as shown on the project plans. Physical requirements for nonwoven or woven fabrics for each survivability rating are listed in Subsections 1014-4.01, 1014-4.02, 1014-4.03, and 1014-4.04. The Arizona DOT has developed separate tables with different property requirements, including strength requirements based on different construction conditions, which follows a similar approach as AASHTO M288.

The **California** 2006 *Standard Specification* ("Material Section 88 Engineering Fabrics") contains information related to paving fabric, filter fabric, and rock slope protection fabric. *Section 88-1.02 Pavement Reinforcing Fabric* includes the following requirements for a non-woven geotextile: manufactured from polyester, polypropylene or polypropylene-nylon material, heat treated on at least one side, and conforming to the traits listed in Table 2.6.

Table 2.6: California reinforcement fabric requirements (California 2006 Standard Specification)

Specification	Requirement
Weight, grams per square meter ASTM Designation: D3776	102 to 271
Grab tensile strength (25-mm grip), KiloNewton, min, in each direction ASTM Designation: D4632	0.4
Elongation at break, percent min. ASTM Designation: D 4632	40
Fabric thickness, millimeters ASTM Designation: D461	0.76 to 2.54

The most important properties for a geotextile performing the reinforcement function are stiffness and tensile strength. There is no requirement in this specification; therefore, the reinforcing fabric here should be categorized as paving fabric.

Section 88-1.03 Filter Fabric requires that filter fabric shall be manufactured from polyester, nylon, or polypropylene material, or any combination thereof. The fabric shall be permeable, nonwoven, shall not act as a wicking agent, and shall conform to the traits listed in Table 2.7.

Table 2.7: California filter fabric requirements (California 2006 Standard Specification)

Specification	Requirement	
	Trench Drains	**Underdrains**
Weight, grams per square meter ASTM Designation: D3776	135	135
Grab tensile strength (25-mm grip), kilonewtons, min, in each direction ASTM Designation: D4632	0.22	0.4
Elongation at break, percent min. ASTM Designation: D 4632	10	30
Toughness, kilonewtons, min (Percent elongation x grab tensile strength)	13	26
Permittivity, l/see min ASTM Designation: D4491	0.5	0.5

(Note: for filter geotextile, the key material property requirement AOS is not included in this specification.)

Colorado's 2006 *Standard Specification/Special Division Section 712-Miscellaneous Construction* has the property requirements for geotextile used for separation and drainage. See Tables 2.8 and 2.9 for detailed specification.

Table 2.8: Colorado separation geotextile requirements (Colorado 2006 Standard Specification)

Table 712-8 Physical Requirements for Separator					
Property	**ClassA**		**ClassB**		**Test Method**
	Elongation <50% [2]	**Elongation >50%** [2]	**Elongation <50%** [2]	**Elongation >50%** [2]	
Grab Strength, N (lbs)	1200(270)	800(180)	800(180)	510(115)	ASTM D 4632
Puncture Resistance, N (lbs)	445(100)	310(70)	310(70)	180(40)	ASTM D 4833
Trapezoidal Tear Strength, N (lbs)	445(100)	335(75)	310(70)	180(40)	ASTM D 4533
AOS, mm (US Sieve Size)	AOS<0.3mm (US Sieve Size No. 50				ASTM D 4751
Permittivity, see $^{-1}$	0.02 default value, must also be greater than that of soil				ASTM D 4491
Permeability, cm/sec	k fabric > k soil for all classes				ASTM D 4491
Ultraviolet Degradation at 500 hrs	50% strength retained for all classes				ASTM D 4355

Table 2.9: Colorado drainage geotextile requirements (Colorado 2006 Standard Specification)

Table 712-3 Physical Requirements for Drainage Geotextiles			
Property	**ClassA** [2]	**ClassB** [2]	**Test Method**
Grab Strength, N (lbs)	800(180)	360(80)	ASTM D 4632
Seam Strength, N(lbs)	710(160)	310(70)	ASTM D 4632
Puncture Strength, N (lbs)	360(80)	110(25)	ASTM D 4833
Trapezoidal Tear Strength, N (lbs)	225(50)	110(25)	ASTM D 4533
AOS, US Std Sieve	AOS less than 0.297mm (greater than NO. 50 sieve)		ASTM D 4651
Permittivity, cm/s $^{-1}$	k fabric >k soil for all classes		ASTM D 4491
Ultraviolet Degradation at 500 hrs	50% strength retained for all classes		ASTM D 4355

As other state specifications and AASHTO M288, the default permeability requirement for separation and drainage is $K_{fabric} > K_{soil}$.

Georgia's 2006 *Standard Specification Section 881 Fabrics_881.2.06 Pavement Reinforcement Fabric* (which will be categorized into Paving Fabric based on material requirements) classifies as Pavement Reinforcement Fabrics those geotextiles with the following characteristics (see Table 2.10):

- Non-woven, heat-resistant material composed of polypropylene or polyester fibers
- Can be saturated with asphalt cement
- Can be placed smooth with mechanical devices and be without wrinkles
- Can withstand the heat of asphaltic concrete mixes during paving operations
- Can withstand normal field handling and construction operations without damage

Table 2.10: Georgia paving fabric property requirements (Georgia 2006 Standard Specification)

Property	Type I	Type II
Tensile strength, minimum	90 lbs (400N)	125 lbs (555N)
Elongation at break	40% min, 100% max	40% min, 100% max
Asphalt retention, minimum	0.18 gal/yd^2 (0.8L/m^2)	0.28 gal/yd^2 (1.3L/m^2)

881.2.05 Plastic Filter Fabric reports the requirements for woven fabrics, as summarized in Table 2.11.

Table 2.11: Georgia filter fabric property requirements (Georgia 2006 Standard Specification)

Woven Fabrics	
Tensile strength (any direction)	200 lbs (890N) minimum
Bursting strength	500 psi (3.5 Mpa) minimum
Elongation before breaking	10% to 35%
Percent open area	4.0% to 6.5%
Non-Woven Fabrics	
Puncture resistance	30 lbs (890N) minimum
Grab tensile strength	65 lbs (290N) minimum
Grab elongation	40% minimum

For geotextiles used as a filter in pavement, the main objective is to let the water pass then retain the integrality of the base or subbase, therefore the key properties should be permittivity and AOS to obtain this objective.

Hawaii's 2005 *Standard Specifications Division 700 Materials Section 716 Geotextiles* has property requirements for different geotextile applications as listed in Table 2.12.

Per *716.02 Geotextiles for Permeable Separator Applications*, the default values for permittivity and AOS (two key properties) are typical and consistent with AASHTO M288.

Table 2.12: Hawaii separation geotextile property requirements (Hawaii 2005 Standard Specifications)

TABLE 716.02-1 MATERIAL REQUIREMENTS		
PHYSICAL PROPERTY	**TEST PROCEDURE**	**REQD. MARV**
Grab Strength, (lbs) (minimum)	ASTM D 4632	180
Sewn Seam Strength, (lbs)(minimum)	ASTM D 4884	160
Trapezoid Tear Strength, (lbs)(minimum)	ASTM D 4533	75
Puncture Resistance, (lbs)(minimum)	ASTM D 4833	80
Permittivity (sec^{-1})(minimum)	ASTM D 4491	0.02[1]
AOS, U.S Standard Sieve)[2]	ASTM D 4751	70-120
Ultraviolet Degradation, 500hthiss (Percent Strength Retained) (minimum)	ASTM D 4355	50
1. Permittivity of geotextile shall be greater than that of soil. 2. AOS requirement may be adjusted when less than 50% of soil particles, by weight, pass U.S No. 200 sieve, or when geotextile permeability (ASTM D 4491) is equal to or less than soil permeability.		

716.03 Geotextiles for Underdrain Applications specifications are listed in Table 2.13.

Table 2.13: Hawaii filtration geotextile property requirements (Hawaii 2005 Standard Specifications)

TABLE 716.03-1 MATERIAL REQUIREMENTS		
PHYSICAL PROPERTY	**TEST PROCEDURE**	**REQ'T MAR V**
Grab Strength, (lbs) (minimum)	ASTM D 4632	180
Seam Strength, (lbs)(minimum)	ASTM D 4884	160
Trapezoid Tear Strength, (lbs)(minimum)	ASTM D 4533	75
Puncture Resistance, (lbs)(minimum)	ASTM D 4833	80
AOS, U.S Standard Sieve)[1]	ASTM D 4751	70-120
Ultraviolet Degradation, 500hthiss (Percent Strength Retained)(minimum)	ASTM D 4355	50
1. AOS requirement may be adjusted when less than 50% of soil particles, by weight, pass U.S No. 200 sieve, or when geotextile permeability (ASTM D 4491) is equal to or less than soil permeability.		

Indiana's 2008 *Standard Specifications Book Section 918.03 Geotextile for Use with Underdrain* specifications are listed in Table 2.14.

Table 2.14: Indiana filtration geotextile property requirements (Indiana 2008 Standard Specifications)

TEST	METHOD	REQUIREMENTS[2]
Grab Strength	ASTM D 4632	80 lb (355.8N)
Seam Strength[1]	ASTM D 4632	70 lb (311.4N)
Puncture Strength	ASTM D 4833	25 lb (111.2N)
Trapezoid Tear	ASTM D 4533	25 lb (111.2kg)
AOS	ASTM D 4751	Sieve No.50 or smaller opening
Permeability	ASTM D 4491	0.1mm/sec
Ultraviolet Degradation at 150 h	ASTM D 4355	70% strength retained
1. Values will apply to both filed and manufactured seams. 2. The value in the weaker principal direction shall be used. All numerical values will represent		

The strength requirements of this specification are close to the class 3 geotextile from AASHTO M288, and it requires permeability rather than permittivity.

Michigan's 2003 *Standard Specification for Construction-Division 9 Materials Section 910 Geosynthetics* categorizes geotextile applications, including separation and stabilization, which are two applications reviewed in this research project. These two functions are covered as follows:

> **Geotextile Separator.** Geotextile separator is designed to prevent intermixing of dissimilar aggregate or soil layers, such as subbase material and drainage aggregate. Geotextiles with grab tensile elongation-at-break less than 50% must meet the requirements in Table 2.15 for woven geotextiles. Geotextiles with grab tensile elongation-at-break equal to or greater than 50% must meet the strength requirements in Table 2.15 for non-woven geotextiles.
>
> **Stabilization Geotextile.** Designed to prevent intermixing of soft subgrade and subbase materials (subgrade stabilization), stabilization geotextile must meet the requirements in Table 2.15.

Minnesota's 2005 *Standard Specifications for Construction (DIVISION III –MATERIALS-3733 Geotextiles)* provide the requirements summarized in Tables 2.15 and 2.16.

Table 2.15: Michigan physical requirements for geotextiles (Michigan 2003 Standard Specification)

GEOTEXTILE CATEGORY	Property/ Test Method					
	Grab Tensile Strength(min) (min)ASTM D 4632 lbs	Trapezoid Tear Strength (min) ASTM D 4533 lbs	Puncture Strength (min)ASTM D 4833 lbs	Mullen Burst Strength (min) ASTM D 3786 psi(a)	Permittivity ASTM D 4491 per second	Apparent Opening Size(max) ASTM D 4751(b) millimeters
Geotextile Separator Woven (<50% elongation)	270	100	100	400	0.05	0.425
Geotextile Separator Nonwoven (>50% elongation)	200	75	75	200	0.05	0.425
Stabilization Geotextile	270	100	100	400	0.05	0.05

Table 2.16: Minnesota geotextile property requirements (Minnesota 2005 Standard Specification)

Geotextile	Test Method	Type		
		I	V	VI
Grab Tensile Strength (Min)	ASTM D4632 (Pounds)	0.45 (100)	0.9(200)	(C)
Elongation (Min)	ASTM D4632 (%)	—	—	(C)
Seaming Breaking(Min)	ASTM D4632 (Pounds)	0.4(90)	0.8(180)	(C)
AOS (Min)	ASTM D4751 (mm)	0.425(40)	0.6(30)	0.85
Permittivity (Min)	ASTM D4491 (Per sec)	0.7	0.05	0.05
Puncture (Min)	ASTM D6241 (N)	—	—	—
Wide Width Strip Tensile Strength (Min)	ASTM D4595 (kN/m)	—	—	(C)

Geotextiles are classified as follows:

- Type I—for use in wrapping subsurface drain pipe or for other specified drainage applications (it should be categorized into trench drain by this definition)
- Type V—for use in separating materials
- Type VI—for use in earth reinforcement

For type I filtration geotextile, the permittivity is 0.7, which is higher than that indicated in AASHTO M288 and in most of the other state requirements for filtration geotextiles. For type II, the AOS and permittivity are within the typical range. Sources could not be identified to clarify the basis for the selected values. The note “(C)” establishes that requirements are site specific and shall be as specified in the contract. In no case shall these values or the properties be less than shown for Type V. (Type V typically does not have a Wide Width Strip Tensile Strength requirement.)

Mississippi’s 2004 *Standard Specs for State Aid Road and Bridge Construction Section 700-Materials and Test* identify geotextile requirements as provided in Table 2.17.

Table 2.17: Mississippi geotextile property requirements (Mississippi 2004 Standard Specs)

Type Designation	III	V	VI	VII	
Application	Drainage	Separation/Drainage	Separation & Stabilization & Reinforcement		
Physical Properties(min)			W NW	W NW	Test Method
Grab Strength lb	110	200	280 180	450 280	ASTM D4632
Elongation %	0.2	50%	50% max, 50% min	50% max, 50% min	ASTM D4632
Seam Strength lb	70	180	240 160	400 240	ASTM D4632
Puncture Strength lb	40	80	110 75	180 115	ASTM D4833
Trapezoidal Tear lb	40	80	100 70	150 100	ASTM D4533
Permittivity, sec-1	0.5	0.15	0.2	0.2	ASTM D4491
AOS Woven, mm	0.15~0.43	0.21~0.43	0.15~0.21 ___	0.15~0.21 ___	ASTM D4751
Aos non-woven, mm	<0.43	<0.43	___ <0.43	___ <0.43	ASTM D4751
Tensile Strength, After, %	70%, 150hr	70, 150hr	70, 150hr	70, 150hr	ASTM D4335
Melting Point, F	—	—	—	—	ASTM D276

Section 714.13.3.1 Geotextile for Trench Drains requires that the geotextile shall conform to the physical requirements of Type V as shown in Table 2.17, except the AOS for the woven geotextile shall have a range of 0.15 mm to 0.43 mm. *Section 714.13.3 Geotextile for Subsurface Drainage* requires that unless otherwise specified, the geotextile shall conform to the physical requirements of Type III as shown in Table 2.17. *Section 714.13.6 Geotextile Stabilization* requires that geotextile shall meet the physical requirements as shown in Table 2.17 for the type specified in the plans or contract documents.

The values of the permittivity and AOS in this specification are comparable to those adopted by AASHTO M288 and other state specifications. As far as AOS requirements, this specification establishes that its values should be defined considering the soil type, as defined by the grain size distribution.

Montana's 2006 *Standard Specs for Road and Bridge Construction Division 700 Material-Section 716 Geotextiles* classify geotextiles as indicated in Table 2.18.

Table 2.18: Montana geotextile classification requirements (Montana 2006 Standard Specs)

			Geotextiles Survivability			
			Moderate Survivability		High Survivability	
Property	**Test Method**	**Units**	**Woven**	**Nonwoven**	**Woven**	**Nonwoven**
Grab Elongation	ASTM D 4632	%	<50	>=50	<50	>=50
Grab Strength	ASTM D 4632	N	1100	700	1400	900
Seam Strength	ASTM D 4632	N	990	630	1260	810
Tear Strength	ASTM D 4533	N	400	250	500	350
Puncture Strength	ASTM D 4833	N	400	250	500	350
AOS	ASTM D 4751	mm	Required Property values for AOS, permittivity, and UV stability are based on the geotextile application.			
Permittivity	ASTM D 4491	Sec				
UV Stability	ASTM D 4355	%				

Montana geotextile classification specification is consistent with AASHTO M288. This specification requires that permittivity of the geotextile must be greater than that required for the soil. Use greater value as specified on the plans or in the special provisions. The property requirement for separation geotextile from Table 2.19 is the same as the separation geotextiles of AASHTO M288.

Table 2.19: Separation geotextile property requirements (Montana 2006 Standard Specs)

	TEST METHODS	UNITS	REQUIREMENTS
Geotextile Survivability	As specified from table 716-1		
Permittivity[1]	ASTM D 4491	sec^{-1}	≥0.02
AOS	ASTM D 4751	Sieve size(mm)	#30(≤0.60)
Ultraviolet Stability (Retained Strength)	ASTM D 4355	%	≥50 after 500hrs,of exposure

The geotextile requirements for stabilization purposes are provided in Table 2.20. These requirements are consistent with those established by AASHTO M288, except the permittivity requirements (AASHTO M288 minimum value is 0.05 sec^{-1}).

Table 2.20: Stabilization geotextile property requirements (Montana 2006 Standard Specs)

	TEST METHODS	UNITS	REQUIREMENTS
Geotextile Survivability	High Survivability from Table 716-1		
Permittivity [2]	ASTM D 4491	sec^{-1}	≥0.10
AOS	ASTM D 4751	Sieve size(mm)	#40(≤0.43)
Ultraviolet Stability (Retained Strength)	ASTM D 4355	%	≥50 after 500hrs,of exposure

As shown in Table 2.21, the AOS and permittivity for geotextiles used for drainage purposes is consistent with those established by AASHTO M288 for geotextile used for subsurface drainage.

Table 2.21: Subsurface drainage geotextile filter property requirements (Montana 2006 Standard Specs)

			REQUIREMENTS [2]		
	TEST METHODS	UNITS	CLASS A	CLASS B	CLASS C
Geotextile Survivability			As specified from table 716-1		
Permittivity [3]	ASTM D 4491	sec	≥0.5	≥0.4	≥0.3
AOS	ASTM D 4751	Sieve size(mm)	#40(≤0.43)	#60(≤0.25)	#80(≤0.18)
Ultraviolet Stability (Retained Strength)	ASTM D 4355	%	≥50 after 500hrs,of exposure		

Pennsylvania's 2000 *Standard Specification Section 700 materials–section 735 Geotextiles* establishes geotextile requirements as listed in Table 2.22.

Table 2.22: Pennsylvania geotextile property requirements (Pennsylvania 2000 Standard Specification)

FABRIC PROPERTIES	TEST METHOD	CONSTRUCTION CLASS			
		CLASS 1	CLASS 4		
		Subsurface drainage	separation	stabilization	reinforcement
1. Grab tensile strength, lbs	ASTM D 4632	158	270	400	500
2. Grab tensile elongation,%	ASTM D 4632	20 min	50 min	20	20
3. Burst strength, psi	ASTM D 3786	189	430	—	—
4. Puncture, lbs. (5/16-inch flat end rod	ASTM D 4833	56	100	140	200
5. Trapezoid tear strength, lbs	ASTM D 4533	56	100	—	—
6. AOS sieve No.	ASTM D 4751	(3)~(4)	(3)~(4)	>#30	>#30
7. Permittivity, K cm/sec	ASTM D 4491	Kfabric>=10Ksoil	Kfabric>=10Ksoil	—	—
8. Permittivity, sec-1	ASTM D4491	0.2	—	—	—
9. Seam strength, lbs.(5)	ASTM D 4632	70	240	360	450
10. UV resistance Strength Retention %	ASTM D 4355	70, 150hr	70, 150hr	70, 150hr	70, 150hr

Pennsylvania requires that $K_{fabric} > 10*K_{soil}$, which ensures that the geotextile will not act as a hydraulic barrier. For geotextile used for stabilization, it does not provide value for permittivity and permeability, which should be key property for stabilization geotextile.

Virginia's 2007 *Road and Bridge Specifications Section 245—Geosynthetics* establishes the following material requirements for geotextiles (Geotextile Fabric for Use in Drainage Systems):

- Drainage fabric shall be nonwoven, clog resistant, suitable for subsurface application, and stable both thermally and biologically.
- The geotextile shall retain at least 75% of its ultimate strength when subjected to substances having a pH of a minimum of 3 and a maximum of 12 for a period of 24 hours.

Requirements for filtration and stabilization are summarized in Tables 2.23 and 2.24. In addition to this requirement, the geotextile shall meet the requirements of AASHTO M228 for strength property requirements, Table 1, class 3 for grab strength, tear strength and puncture strength.

Table 2.23: Virginia filtration geotextile property requirements (Virginia 2007 Road and Bridge Specifications)

PHYSICAL PROPERTY	TEST METHOD	REQUIREMENTS
Permittivity	ASTM D 4491	0.5 sec^{-1} (min)
AOS	ASTM D 4751	No.50 sieve(max)

Table 2.24: Virginia stabilization geotextile property requirements

PHYSICAL PROPERTY	TEST METHOD	REQUIREMENTS
AOS	ASTM D 4751	No.20 sieve(max)

The **Washington** DOT's *2006 Standard Specifications for Road, Bridge, and Municipal Construction Division 9 Materials Section 9-33. Construction Geosynthetics* establishes geotextile requirements as listed in Table 2.25.

Table 2.25: Washington filtration geotextile property requirements (Washington 2006 Standard Specifications)

GEOTEXTILE PROPERTY	ASTM TEST METHOD[2]	GEOTEXTILE PROPERTY REQUIREMENTS[1]		
		CLASS A	CLASS B	CLASS C
AOS	D 4751	U.S No 40,max	U.S No 60,max	U.S No 80,max
Water Permittivity	D 4491	0.5 sec^{1}min	0.4 sec^{1} min	0.3 sec^{1} min

Table 2.26 summarizes the requirements for geotextiles used as separators, which are consistent with those adopted by several other states. The requirements for geotextiles used for filtration are similar to those of AASHTO M288, including the selection of AOS and permittivity values considering the subgrade soil characteristics.

Table 2.26: Washington separation/stabilization geotextile property requirements (Washington DOT 2006 Standard Specifications)

GEOTEXTLES PROPERTIES	TEST METHOD	Separation		Soil Stabilization	
		Woven	Nonwoven	Woven	Nonwoven
Grab tensile strength, lbs	ASTM D4632	250	160	315	200
Grab failure strain,%, min	ASTM D 4632	<=50%	>50%	<=50%	>50%
Sewn-seam strength, lbs	ASTM D 4632	220	140	270	180
Tear Strength, lbs	ASTM D4533	80	50	112	79
Puncture, lbs	ASTM D 4833	495	310	620	430
AOS sieve No. max	ASTM D 4751	U.S. No. 30 Max		U.S. No. 40 Max	
Permittivity,sec-1, min	ASTM D4491	0.02		0.1	
UV resistance Strength Retention %	ASTM D 4355	50%, 500hr			

2.6.3 Construction Specifications from State DOTs for Projects Involving Geotextiles

Most of the state DOTs have adopted the same construction specifications for geotextiles used for base separation and base stabilization. Only a few state specifications deviate from those established in M288. They are summarized in this section.

Alabama's 2006 *Standard Specification for Highway Construction Section 604* (which was limited to the permeable base only, but separation geotextile could be applied to base types other than permeable) has a detailed construction specification about geotextiles in permeable bases. The specification describes how to place geotextiles for use as a means to prevent clogging of the base layer due to the migration of fine material from the underlying roadway layer. In this specification, they clearly describe that the geotextile shall be designed to allow passage of water while retaining untreated base or subbase soils without clogging. This point was incorporated into the specification, as the geotextile should not act as a hydraulic barrier to hold the water into base layer, which will cause base pumping and other pavement distresses. Section 604.03 describes the construction process, and the following procedures are taken directly from the Alabama 2006 *Standard Specification for Highway Construction*.

- The surface area on which the geotextile fabric is to be placed shall be free of loose aggregate, foreign debris and all sharp objects during placement of the fabric.
- The geotextile filter shall be installed immediately prior to placement of the permeable asphalt treated base layer and extended full width between the inside and outside trench drains according to the manufacturer's specifications and as shown on the plans.

Colorado's 2005 *Standard Specifications Section 420.07 Geotextile Separator* provides several aspects that need to be considered into the development of this specification; for example, the geotextile shall be placed by machinery or by hand labor. The geotextile shall not be dragged across the subgrade. Wrinkles and folds in the geotextile (not associated with roadway curves) shall be removed by stretching and staking as required. And the geotextile may be held in place prior to placement of cover by pins, staples, or piles of fill or rock. On curves, the geotextile may be folded to conform to the curve. The fold or overlap shall be in the direction of construction and held in place as prescribed above. And the height of the dumped pile shall be limited to avoid local bearing capacity failures. The first lift of cover material shall be graded to a 300 mm (12 inch) thickness or to top of grade whichever is less and compacted. At no time shall equipment be on the treated area with less than the minimum thickness of compacted cover material over the geotextile. Small dozer equipment or front end loader shall be used to spread the cover material. Construction vehicles shall be limited in size and weight such that rutting in the initial lift is no deeper than 75 mm (3 inches). If rut depths exceed 75 mm (3 inches), the Contractor shall use a smaller size and weight of construction vehicles. Ruts shall be filled in with cover material. Compaction of lifts shall be accomplished using care not to damage the geotextile. Construction equipment shall not make turns on the first lift of cover material.

Montana's 2006 *Standard Specs for Road and Bridge Construction Section 622.03.2 Separation/Stabilization Geotextile* gives us a clear point about how to prepare the installation site by clearing, grubbing, and excavating or filling the area to the design grade. This includes removal of topsoil or vegetation. The Project Manager will identify soft spots and unsuitable areas during site preparation. Excavate these areas and backfill with approved granular material and compact as specified. Grade the area to be covered by the geotextile to a smooth, uniform condition, free from ruts, potholes, and protruding objects such as rocks or sticks.

The minimum overlap requirements established in Montana specifications are summarized in Table 2.27. They are consistent with those provided by AASHTO M288.

Table 2.27: Geotextile overlap requirements (Montana 2006 Standard Specs)

UNDRAINED SHEAR STRENGTH OF SUBGRAD	MINIMUM OVERLAP
>2,000psf (>95 kPa)	1foot(0.3)
500-2,000psf (25-95 kPa)	3 feet(0.9m) or Sewn
< 500psf(<25kPa)	Sewn
All roll ends	3 feet(0.9m) or Sewn

Another point was that **Colorado** does not allow blading the first lift placed over the geotextile in order to minimize the damage. It is believed that if the subgrade is too soft with an undrained shear strength less than 500psf (25 kPa), minimizing pile heights to less than 3 feet (0.9 m) and spreading piles as soon as possible after dumping are required to minimize the potential for localized subgrade failure due to overloading of the subgrade.

South Carolina's *Supplemental Specifications* provide a conceptual illustration for folding or cutting to conform to the curve (Figures 2.7 and 2.8). Although no specific dimensions are recommended for the overlaps, the figures are useful in illustrating the concept.

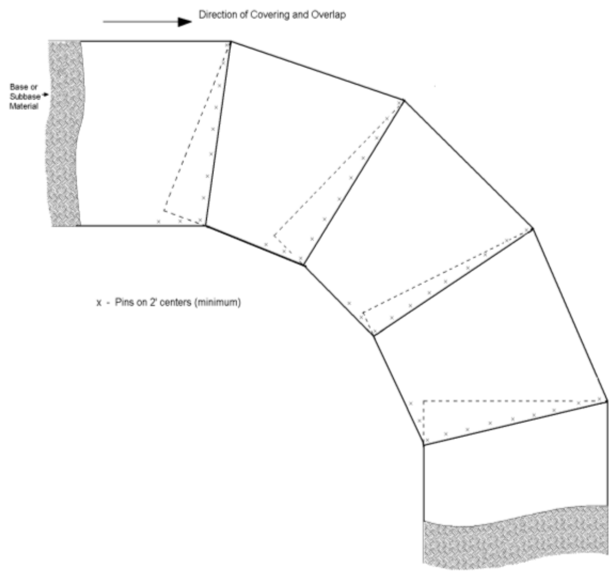


Figure 2.7: Folded overlaps illustration in curve place (South Carolina Supplemental Specifications)

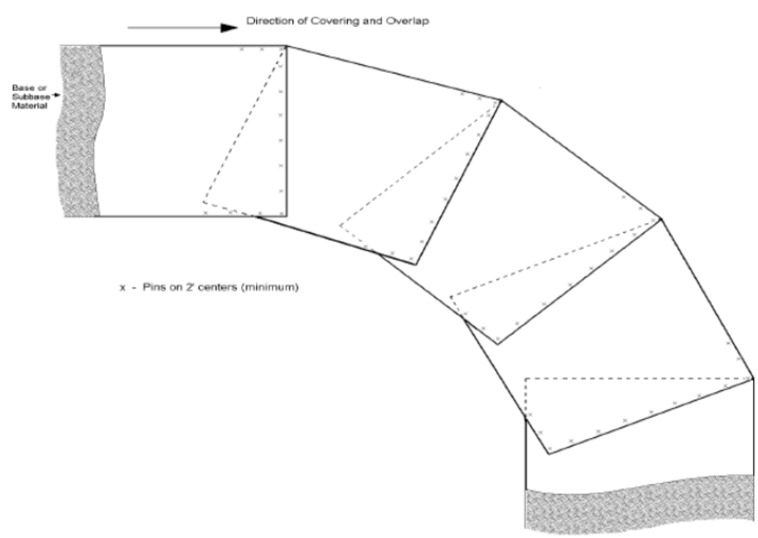


Figure 2.8: Cut overlap illustration curve place (South Carolina Supplemental Specifications)

The **Idaho** *Standard Specifications for Highway Construction Section 640 Construction Geotextile* provide useful information on soft ground considerations. The specifications note that where geotextiles will be placed over soft ground, construction vehicles shall be limited in size and weight such that rutting in the initial lift above the geotextile does not exceed 3 in. (75 mm) deep. Turning the vehicles on the first lift above the geotextile will not be permitted. End-dumping the cover material directly on the geotextile will not be permitted. Compaction of the first lift above the geotextile over soft ground shall be limited to routing of placing and spreading equipment only. No sheep-foot type equipment will be allowed on the first lift. Subsequent lifts will be closely observed during compaction. If any foundation failures occur during compaction operations, lightweight compaction equipment shall be used. Pegs, pins, or the manufacturer's recommended method shall be used as needed to hold the geotextile in place until the specified cover material is placed. Under no circumstances shall cover material be dropped on unprotected geotextile from a height greater than 3 ft. (1 m) above the surface of the geotextile.

Base stabilization geotextile may be placed on the saturated and soft subgrade; therefore, the Idaho DOT's requirements for soft ground make clear that special requirements are necessary to address the soft subgrade in the base stabilization.

The draft construction specification for base separation was developed by combining the construction guidelines from AASHTO M288 and the state DOT construction specification for geotextiles. First is a general description followed by the corresponding material requirements, and finally the specific construction method, which addresses the following aspects:

- Surface Preparation;
- Geotextile Placement;
- Soft Ground Requirement;
- Curve Geotextile Installation;
- Geotextile Inspection;
- Damage Repairs;
- Subbase Placement; and
- Compaction.

Finally, a basic method of how to measure and make payment for geotextile was provided. This structure laid a foundation for other applications, and other applications will adopt the same structure. (Refer to Appendix C for detailed information.)

For the **Trench Drain** application, FHWA HI-95-038 provides detailed construction procedure. As indicated in Figure 2.9, six steps are considered in the construction sequence: excavate the trenches, place geotextile, add bedding for drainage, place and compact drainage aggregate, wrap the geotextile over the top, and then backfill and compact the top.

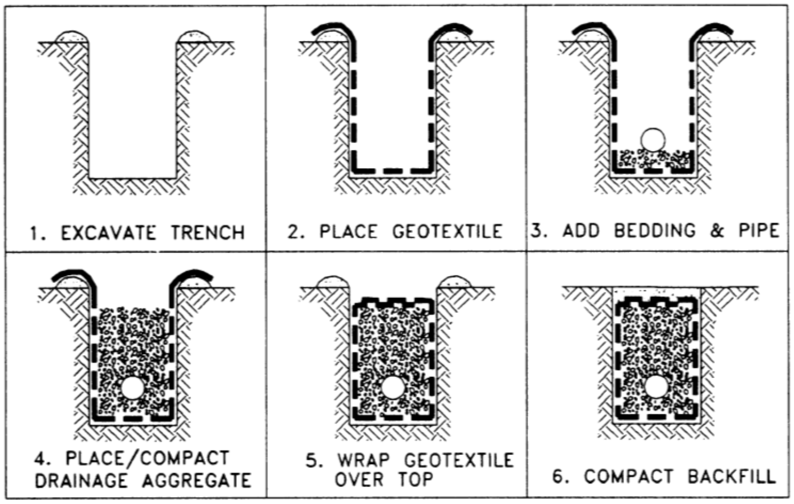


Figure 2.9: Construction procedures illustrations (Holtz et al. 1998)

Figure 2.10 shows each component in the trench drain and the location of each component. Following the figure is a description of the Construction Method of this proposed construction specification.

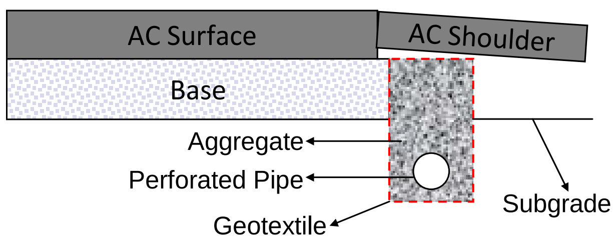


Figure 2.10: Geotextile used for trench drain in roadway (redrawn from AASHTO 2006)

A. Trench Preparation. Prepare the trench on which the geotextile is to be placed so that no damage occurs to the geotextile. The bottom and the sides of the trench receiving the geotextiles shall be smooth and free of stones, sticks, and other debris or irregularities that might puncture or damage the geotextiles during the placement of geotextiles. Dispose of material with defects, rips, holes, flaws, deterioration, or other damage. Do not use defective material in the work. The construction equipment should never be operated directly on the geotextile under any circumstances.

B. Excavating the Trench. Excavate underdrain trenches using a wheel or chain trencher or other trenching methods approved by the Engineer. Grade trench bottoms to the shape of the underdrain pipe. Excavate prefabricated drainage systems trenches to a width of 3 to 6 inch. If the backfill cannot be properly placed or compacted in the narrow trench due to wall collapse, excavate a wider trench. Trench excavation shall be done in accordance with details of the roadway projects plans.

C. **Geotextile Placement.** The graded surface of the bottom shall be smooth and free of debris. When placing the geotextile, it shall be unrolled in line with the placement of the new aggregate and the geotextiles shall be placed free of tension, stress, or wrinkles, and with no void spaces between the geotextile and the ground surface. The geotextiles shall be protected at all times during construction, and the geotextile should be repaired immediately whenever any damage is founded. Place a sufficient width of geotextile to entirely cover the perimeter of the trench and allow for the required overlap. Successive sheets of geotextiles shall be overlapped a minimum of 12 inch, with the upstream sheet overlapping the downstream sheet. The geotextiles shall not be dragged across the site and the backfilled aggregate should not be dropped from a distance to damage the geotextiles (the dropping distance should be less than 3 feet).

D. **Overlapping.** In trenches equal to or greater than 12 inch in width, after placing the drainage aggregate the geotextile shall be folded over the top of the backfill material in a manner to produce a minimum overlap of 12 inch. In trenches less than 12 inch, but greater than 4 inch wide, the overlap shall be equal to the width of the trench. Where the trench is less than 4 inch the geotextile overlap shall be sewn or otherwise bonded. All seams shall be subject to the approval of the engineer.

E. **Damage Repairs.** If the geotextile is damaged during installation or drainage aggregate placement, a geotextile patch shall be placed over the damaged area extending beyond the damaged area a distance of 3 feet.

F. **Aggregate backfill.** Placement of drainage aggregate should proceed immediately following placement of the geotextile. The geotextile should be covered with a minimum of 12 inch of loosely placed aggregate prior to compaction. If a perforated collector pipe is to be installed in the trench, a bedding layer of drainage aggregate should be placed below the pipe, with the remainder of the aggregate placed to the minimum required construction depth.

G. **Compaction.** The aggregate should be compacted with vibratory equipment to a minimum of 95% Standard AASHTO density unless the trench is required for structural support. If higher compactive effort is required, a Class 1 geotextile should be used.

For the **Underdrain application**, the objective was to lower the water table and differences between underdrain and trench drain are the location and the dimensions of the trench. Therefore, only the location and the dimensions of the trench need to be considered for each case. Another aspect to be considered is that underdrain does not drain the pavement surface water, and the backfill soil should be low hydraulic conductivity soil. (Chapter 4 details and illustrates the use of underdrains in roadway applications.)

The construction method for an underdrain is similar to the trench drain except that the trench should be at least 4 feet (1200 mm) deep to be effective but should not exceed 6 feet (1800mm). The top 6 inches (150 mm AASHTO M288 300 mm) of backfill should be impervious. The minimum inside pipe diameter for a standard pipe underdrain shall be 6 inches for lengths of 500 feet (150 m) or less. As a general rule, this size is adequate as a collector in most soils. For lengths exceeding 500 feet (150 m), the minimum diameter shall be 8 inches (200 mm). The above requirements come from the *Wisconsin DOT Facilities Development Manual*, and there are not enough references in this aspect from other sources. However, the practical requirement could vary based on different construction site conditions.

For **Base or Subbase Barrier for Lateral Flow**, the trench drain should be incorporated into the base or subbase barrier to prevent the migration of base material into the trench. See Figure 2.11 for illustration. Several concerns arose regarding the success of the use of a base or subbase barrier for lateral flow. First of all, the geotextile structure should be stiff enough to bear the static weight of pavement and be able to bear the dynamic traffic loading. If any failure occurs in the structure of geotextile, the water will be pumped into both the base and subgrade. Another concern is that the clogging of the geotextile will impair the geotextile's capability to effectively discharge the water. Then the incoming water quantity needs to be estimated, which can vary significantly. Because the location and the construction procedures are consistent with the geotextile used for base separation and base stabilization, no further discussion is required.

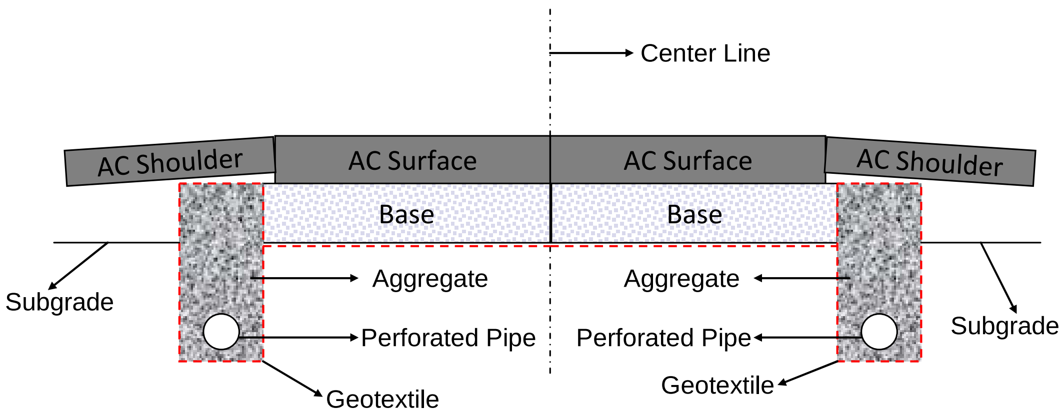


Figure 2.11: Geotextile used for base or subbase barrier for lateral flow in roadway (modified from AASHTO 2006)

2.6.4 Summary

Scrutiny of the state DOTs' specifications for different geotextile applications indicates that the use of geotextiles for separation/stabilization is reasonably well-established. For drainage applications, most states incorporate the use of geotextiles in highway drainage systems for the purposes of filtration.

Regarding the use of geotextiles for reinforcement purposes, 10 states were identified as having incorporated requirements of geotextile reinforcements into their specification. However, significant discrepancies were identified among the various state DOTs regarding the use of geotextiles as reinforcements. Maine and Massachusetts DOT state specifications consider base reinforcement and base stabilization as a single type of application. On the other hand, Georgia and Nevada DOTs have developed specifications that identify the use of paving fabrics as a reinforcement function. The California DOT's *SECTION 88 Engineering Fabrics* specifies the properties of reinforcing fabric; however, asphalt retention is also specified, which indicates that these requirements also correspond to those of paving fabrics (even though they are referred to as fulfilling a reinforcement function). Finally, the Mississippi, Oregon, and Pennsylvania DOTs identify reinforcement as being a function of geotextiles, but they do not provide material properties requirements for geotextiles used as reinforcements.

Inconsistencies regarding the reinforcement function of geotextiles are also found in national level documents. AASHTO M288-06 mentions that geotextile reinforcement is a site-specific design issue, which means that developing general specifications that could be applied to common conditions is infeasible. FHWA HI-95-038 gave the design procedure for geotextile used for reinforcement, but it did not give any specific material property for this application. Another national document, the *GMA White Paper II* developed by the Geosynthetics Materials Association, reaches similar conclusions regarding the use of geotextiles for reinforcement, but remains largely inconclusive. Therefore, it is not feasible to develop a general specification for geotextile reinforcement considering the shortage of existing literature and research time.

As for strength requirements, different states have different specifications for the same geotextile applications. In summary, the recommendation here is to rely on the philosophy of AASHTO M288 to classify the geotextile based on the survivability, and then provide separate tables with property requirements for each different application.

This literature review indicated that the use of geotextiles for separation is already well established at both the state and national level, and these well-established sources could provide a good platform on which to develop our specifications. From the comparison of the property requirements for separation, evidently the most important property for separation geotextile is actually the AOS. In the state DOT documentation, the range for AOS is usually between 0.2–0.6. Per the AASHTO M288-06 and FHWA HI 95-038 development process, the AOS should be chosen based on the subgrade soil particle size. If the subgrade soil has more fines (in other words, if the subgrade soil passes through the geotextile with different percentages), a different AOS requirement should be chosen to effectively prevent the subgrade soil intruding into the base. For permittivity, some states require $\Psi g > \Psi s$ (the worst case design criteria), and other states just give a single specific value usually ranging from 0.02 to 0.5. Because water will not be a main problem in this application, the permittivity should be chosen to ensure that geotextile will not be a hydraulic barrier. For ultraviolet stability, the states-wide application falls into two categories: 150 hr 70% remaining strength or after 500 hr, 50% retaining strength.

The comparison of the property requirements for stabilization geotextiles indicated that because geotextiles used for base stabilization are usually applied wet to a saturated subgrade, the property requirements must be different from the geotextile used for separation. AOS in the state DOT specifications ranges from 0.2 to 0.43 (some states have their unique test methods and property requirements and these states were not taken into this comparison), which is a little smaller than the separation, because the soft subgrade soil has more movement than the regular subgrade soil, and it is necessary to stabilize and prevent the migration of subgrade soil into the base. For the requirement of permittivity, as the subgrade soil is saturated and water might be a problem, a greater value for permittivity should be given to allow water to pass through the geotextile. Note that the geotextile should not act as a hydraulic barrier. For ultraviolet stability, again the states-wide application falls into two categories—150 hr 70% remaining strength or after 500 hr, 50% retaining strength—and picking either would not make a difference, as the geotextile will not be exposed to sun after the construction.

The comparison of filtration geotextile property requirements indicates that several states have their own test methods for property requirements that are much different from those of other states and AASHTO M288-06. However, most of the state specifications are consistent with AASHTO M288-06. Overall, the most important properties for geotextiles are AOS and permittivity. AOS values in the state DOTs vary; some states give the single value without considering the in-situ soil property. Several states use the same approach as the AASHTO M288. Ultimately, it is more reasonable to decide the AOS based on the in-situ soil particle size to effectively prevent intrusion into drainage system. For ultraviolet stability, again the states-wide application falls into two categories—150 hr 70% remaining strength or after 500 hr, 50% retaining strength—and picking either would not make a difference, as the geotextile will not be exposed to sun after the construction.

The existing research regarding for geotextile reinforcement are largely inconclusive and confusing. The state DOTs lack uniform information in this respect, and some states mix the reinforcement geotextile with stabilization geotextile while others mix paving fabric with reinforcement geotextile. However, when comparing all state DOTs' geotextile strength requirements with those of AASHTO M288-06 Class 1, it was found that the Class 1 meets most of the states' strength requirements for geotextile reinforcement. But the real challenge is that geotextile reinforcement is really a design-specific issue (as the AASHTO M288 and FHWA HI 95-038 stated); therefore, specifying a uniform property requirement in this category is not feasible. As AASHTO Designation PP 46-01 (2005) recommends, the feasible method for designing reinforcement geotextiles is to give general design requirements rather than detailed specified property requirements values. For the specific design process, please refer to the FHWA HI 95-038 for detailed information.

As discussed above, no uniform materials requirements were found and creating relevant specification based on the existing literature is infeasible.

Creating a base or subbase barrier for lateral flow is another aspect that does not have valuable references, and the literature from the state DOTs did not provide any information for lateral drainage geotextiles. However, transmissivity is the governing property in this category. More practical research is needed to develop an effective specification for the use of geotextiles as a base or subbase barrier for lateral flow.

All in all, state DOTs have a wide range of geotextile applications in different sections of their roadway systems. By adopting the survivability definition from AASHTO M288—in other words, by specifying geotextiles strength requirements based on construction conditions rather than based on applications—only three major geotextile properties need to be considered: AOS, permittivity, and ultraviolet stability. By comparing AOS, permittivity, and ultraviolet stability from state specifications to AASHTO M288, the process could be simply to decide the values of these properties, and develop a draft property requirement specification for the geotextile.

Chapter 3. Survey of TxDOT and Other State DOTs Regarding the Use of Geotextiles in Pavement Systems

3.1 Introduction

The literature review provided background information about the potential benefits of including geotextiles in roadway design, strategies for design and selection of an appropriate geotextile, and documents available to assist design engineers in this process. The project team complemented this literature review by designing and implementing a survey at both the national and state levels. The survey was an attempt to gauge what is actually common in practice—in terms of geotextile usage, design methods, and document reliance—and to compare the state of design in Texas with that around the nation. Information gained from the survey was expected to provide information useful in developing geotextile selection and design guidelines and effectively presenting this information to TxDOT design engineers. Recipients were targeted on both the national and state level, in similar but separate forms.

3.2 National Level Survey

National recipients were selected from two areas: state transportation agencies and industry as a whole. Representatives from state transportation agencies were targeted by sending surveys to members of two national AASHTO subcommittees: Highway Construction and Highway Design. This approach facilitated the delivery of approximately 200 surveys to state transportation agency representatives. Representatives from industry as a whole were targeted by sending surveys to approximately 300 members of the International Geosynthetics Society (IGS) and approximately 50 members of the Geo-Institute Geosynthetics Committee.

Summaries of the survey responses received are shown in Figure 3.1. A total of 54 total responses were received from state transportation agency representatives, representing 36 states and the District of Columbia. Other national respondents included six representatives from private consulting and two from the FHWA.

3.2.1 Survey Form

As the motivation for including a survey in the project was to develop a general sense of geotextile use in roadway design, the research team hoped to obtain as many responses as possible. To address this goal and to make completion of the survey more appealing to working engineers, the survey was designed to be short and general in nature. Seven basic questions were included to obtain information about the extent of geotextile use, typical applications for which the geotextile was included and associated locations in the roadway, and documents used for material selection and design. The form sent on the national level is shown in Figure 3.2.

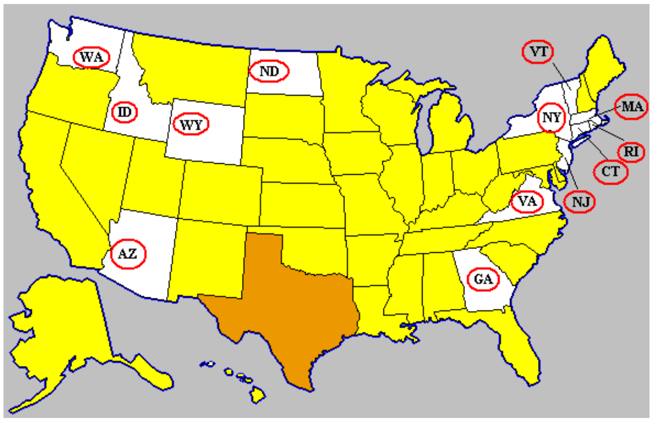


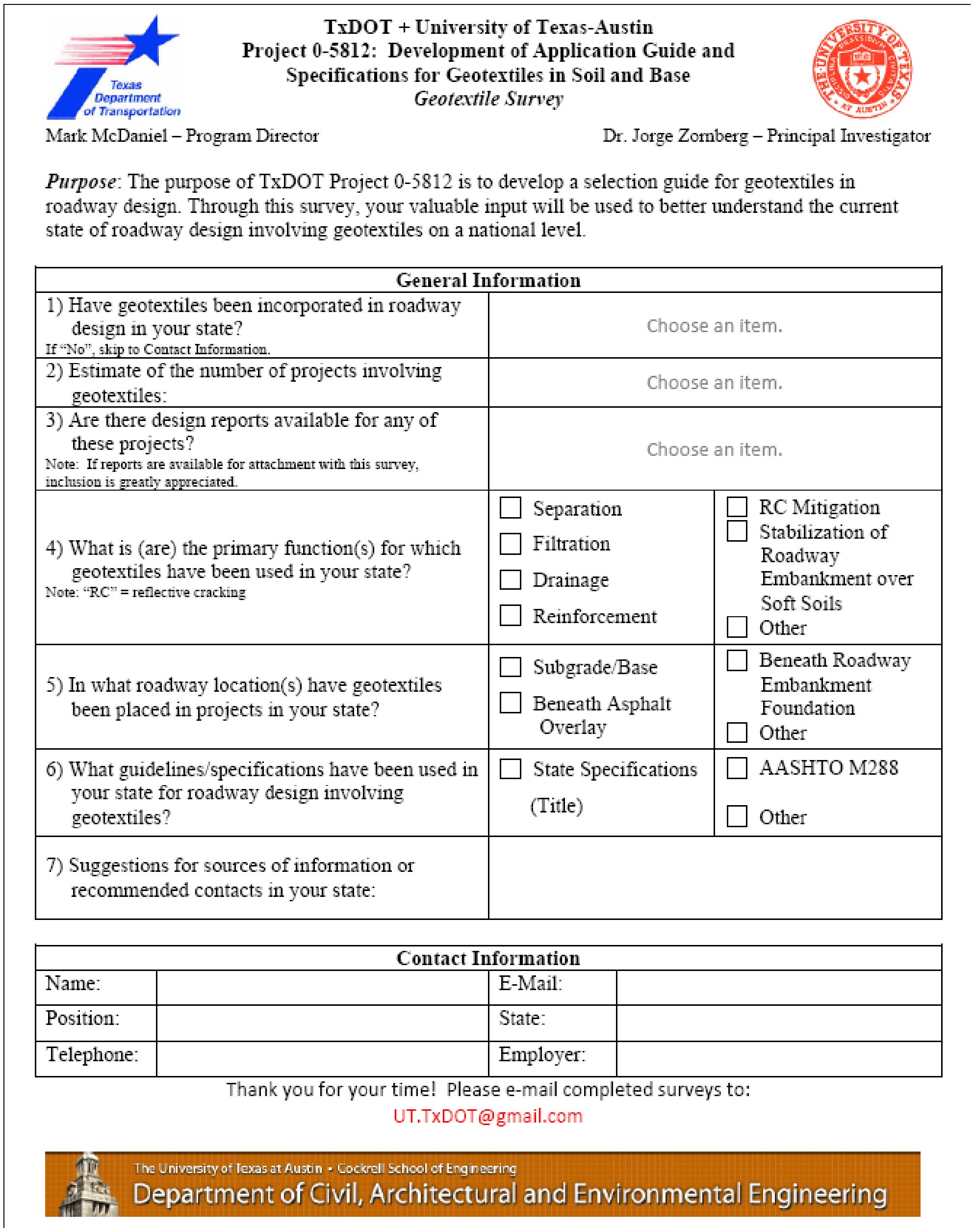
Figure 3.1: National survey response summary

Questions 1 and 2 address the degree of geotextile use in roadway projects nationwide. The project team wished to review design reports from actual projects implementing geotextiles, as these would be very helpful in preparing effective design guidelines, materials specifications, and installation procedures. Question 3 identifies points of contact for obtaining these reports.

The project team initially took a function-based approach to the project. One of the main objectives of the survey was to determine the applications most commonly addressed by using geotextiles in roadway design. Question 4 addresses this objective. Embankment stabilization was identified early on in the literature review as an area of potential benefit not initially addressed in the project. It was included in Question 4 to gauge the need for its inclusion in the project.

Determining the most common locations for geotextile placement is important for understanding the applications, rather than functions, of typical focus. Additionally, this question can be viewed as a complement to Question 4, serving as a check on the validity of the survey results. Respondents who indicate "RC Mitigation" on Question 4 should also indicate "Beneath Asphalt Overlay" on Question 5; similarly, respondents indicating "Stabilization of Roadway Embankment over Soft Soils" on Question 4 should also indicate "Beneath Roadway Embankment Foundation" on Question 5. If these answers do not show good correlation, the validity of the survey results is questionable.

The final major objective of the survey was to gain an understanding of the documents commonly used in design. Early work in the literature review pointed to state specifications and AASHTO M288 as the documents receiving the most widespread use. An "Other" option was given with the hopes of identifying more obscure documents.



TxDOT + University of Texas-Austin
Project 0-5812: Development of Application Guide and Specifications for Geotextiles in Soil and Base
Geotextile Survey

Texas Department of Transportation

Mark McDaniel – Program Director

Dr. Jorge Zornberg – Principal Investigator

Purpose: The purpose of TxDOT Project 0-5812 is to develop a selection guide for geotextiles in roadway design. Through this survey, your valuable input will be used to better understand the current state of roadway design involving geotextiles on a national level.

General Information		
1) Have geotextiles been incorporated in roadway design in your state? If "No", skip to Contact Information.	Choose an item.	
2) Estimate of the number of projects involving geotextiles:	Choose an item.	
3) Are there design reports available for any of these projects? Note: If reports are available for attachment with this survey, inclusion is greatly appreciated.	Choose an item.	
4) What is (are) the primary function(s) for which geotextiles have been used in your state? Note: "RC" = reflective cracking	☐ Separation ☐ Filtration ☐ Drainage ☐ Reinforcement	☐ RC Mitigation ☐ Stabilization of Roadway Embankment over Soft Soils ☐ Other
5) In what roadway location(s) have geotextiles been placed in projects in your state?	☐ Subgrade/Base ☐ Beneath Asphalt Overlay	☐ Beneath Roadway Embankment Foundation ☐ Other
6) What guidelines/specifications have been used in your state for roadway design involving geotextiles?	☐ State Specifications (Title)	☐ AASHTO M288 ☐ Other
7) Suggestions for sources of information or recommended contacts in your state:		

Contact Information			
Name:		E-Mail:	
Position:		State:	
Telephone:		Employer:	

Thank you for your time! Please e-mail completed surveys to:
UT.TxDOT@gmail.com

The University of Texas at Austin • Cockrell School of Engineering
Department of Civil, Architectural and Environmental Engineering

Figure 3.2: National level survey form

3.2.2 Analysis of National Responses

Figures 3.3 and 3.4 show survey results from state transportation agency and industry representatives, respectively. Similar trends were seen from both response groups. Widespread use of geotextiles in roadway applications was confirmed across the board—every national respondent acknowledged the use of geotextiles, with 83% indicating awareness of more than 10 projects in their respective state.

Separation, filtration, drainage, and reinforcement are all indicated as common primary functions. Of the respondents, 87% indicated the use of a geotextile to perform separation, 70%

indicated reinforcement, 55% indicated drainage, and 49% indicated filtration. The numbers for drainage and filtration, respectively, are a bit surprising. The term “drainage” is referring to the function in which a geotextile is designed to transmit water laterally, or in-plane. Filtration, where the geotextile is designed to allow water flow through its plane while retaining soil particles, is a much more common function for a geotextile. These numbers indicate some confusion presented in the survey—respondents most likely considered “drainage” an application in which a geotextile is placed to perform the filtration function.

The large percentage of respondents indicating placement of a geotextile to perform the reinforcement function highlights the need for improved design guidelines in this area. As highlighted in the literature review, there is a lack of understanding regarding the controlling mechanisms when a geotextile is placed for reinforcement. Hence, improved design guidelines and documentation are needed.

A portion of the responses indicating the use of a geotextile for reinforcement may be a result of confusion regarding the reflection crack mitigation function. Twenty respondents indicate the “Beneath Overlay” location, while only eight indicate the “RC Mitigation” function. These two numbers should be the same, as they are synonymous. Presumably, many respondents indicated “Reinforcement” rather than “RC Mitigation.”

One more important trend pertaining to functions from the national survey response data is the popularity of the embankment stabilization application. Of the respondents, 62% (33 of 53 total) indicated using geotextiles in the “Embankment Stabilization” application. This result shows good correlation with the “Embankment” location, in which 36 of the 53 total respondents indicated placement of a geotextile.

Over half of all national survey respondents (29 of 53 total) indicated the use of AASHTO M288 in design. Slightly more respondents (35 of 53 total) indicated the use of state specifications, which was expected, as a large majority of responses were from representatives of state transportation agencies. Of the 29 responses indicating use of M288, 17 did not indicate the use of state specifications while 12 indicated the use of both M288 and state specs.

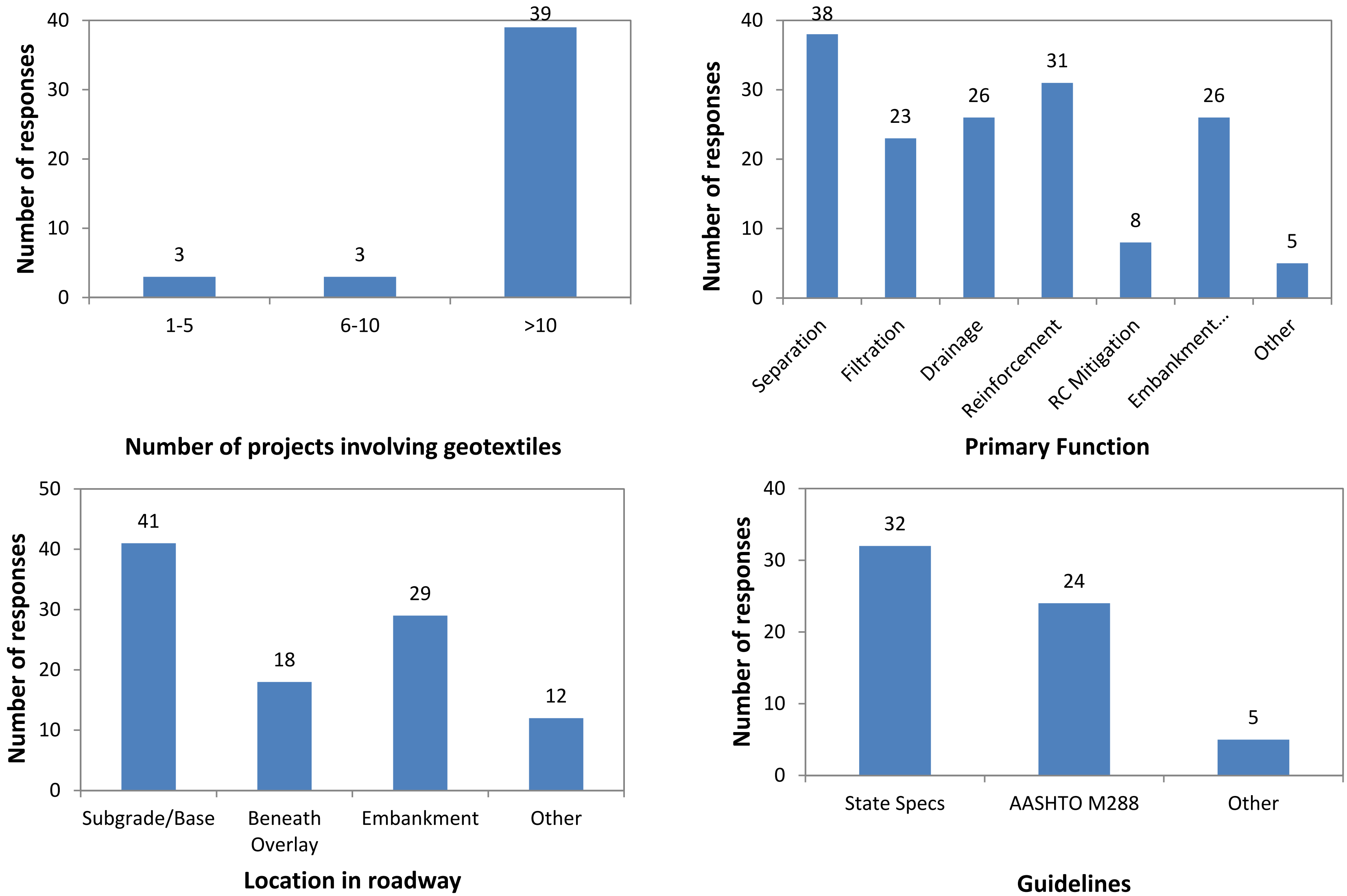


Figure 3.3: National survey results—state transportation agency representatives

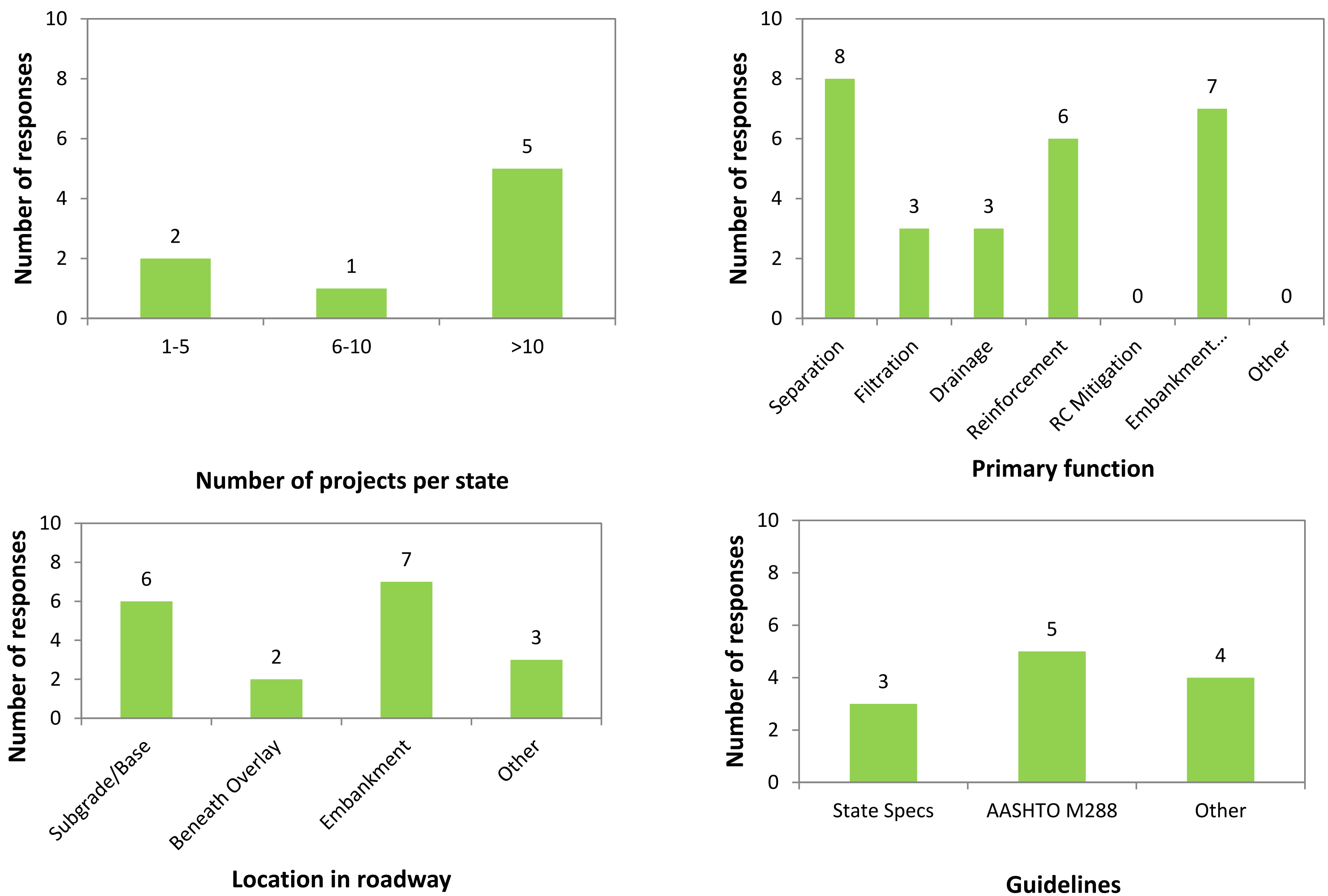


Figure 3.4: National survey results—industry representatives

3.3 TxDOT Survey

Recipients from each of the 25 TxDOT districts, chosen by the Project Director, were targeted to complete the state-level survey. The project team received 28 responses, representing 19 of the 25 districts. Missing states and districts are indicated with red circles in Figure 3.5.

3.3.1 TxDOT Survey Form

The TxDOT survey form, shown in Figure 3.6, was designed with the same objectives as the national survey form described in Section 3.1.1. Slight changes were made regarding the description of purpose and the scope of questions (district rather than state level). Also, selections for Question 6 were revised to include the three DMS involving geotextiles—6200, 6220, and 6260. DMS 6200 is titled "Filter Fabrics," DMS 6220 refers to the "Fabric for Underseals" specification, and DMS 6260 refers to the "Reinforced Fabric Joint Underseal" specification. Both of the latter two address reflective crack mitigation.

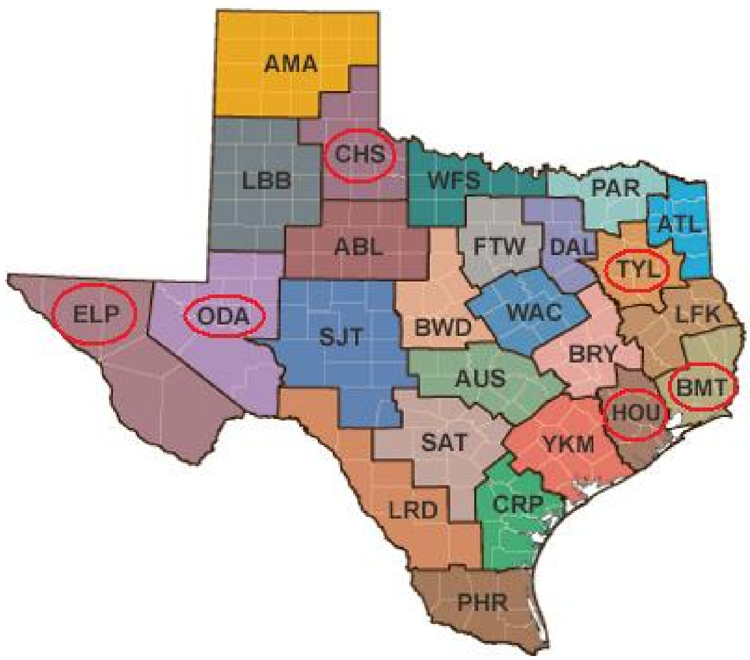


Figure 3.5: TxDOT survey response summary

TxDOT Survey: Geotextiles

Project 0-5812: Development of Application Guide and Specifications for Geotextiles in Soil and Base

Mark McDaniel – Program Director

Dr. Jorge Zornberg – Principal Investigator

Purpose: Geotextiles can be used for multiple functions in roadways. Each function could require different material properties, leading to a complex material selection process. Consequently, the purpose of this study is to develop a guide to aid the selection process. Through this survey, your valuable input will be used to better understand TxDOT needs regarding the use of geotextiles in roadway design.

General Information		
1) Have geotextiles been incorporated in roadway design in your district? If "No", skip to Contact Information.	Choose an item.	
2) In how many projects?	Choose an item.	
3) Are there design reports available for these projects? Note: If reports are available for attachment with this survey, inclusion is greatly appreciated.	Choose an item.	
4) Geotextiles are used to address several different functions in roadway design. What is (are) the primary function(s) for which geotextiles have been used in your district? Note: "RC" = reflective cracking	☐ Separation ☐ Filtration ☐ Drainage ☐ Reinforcement	☐ RC Mitigation ☐ Stabilization of Roadway Embankment over Soft Soils ☐ Other
5) In what roadway location(s) have geotextiles been placed in projects in your district?	☐ Subgrade/Base ☐ Beneath Asphalt Overlay	☐ Beneath Roadway Embankment Foundation ☐ Other
6) What guidelines/specifications have been used in your district for roadway design involving geotextiles? Note: TxDOT DMS 6200: "Filter Fabrics" TxDOT DMS 6220: "Fabric for Underseals" TxDOT DMS 6260: "Reinforced Fabric Joint Underseal"	☐ TxDOT DMS 6200 ☐ TxDOT DMS 6220 ☐ TxDOT DMS 6260	☐ AASHTO M288 ☐ Other
7) Suggestions for sources of information or recommended contacts (e.g. other engineers with experience in geotextiles):		

Contact Information			
Name:		E-Mail:	
Position:		District:	
Telephone:		Area Office:	

Thank you for your time! Please e-mail completed surveys to:

UT.TxDOT@gmail.com

The University of Texas at Austin • Cockrell School of Engineering

Department of Civil, Architectural and Environmental Engineering

Figure 3.6: TxDOT survey form

3.3.2 Analysis of TxDOT Responses

Results from the TxDOT survey are summarized in Figure 3.7. Widespread use of geotextiles in roadway design across Texas is confirmed—only 2 of 28 respondents indicated not being aware of geotextile use in their respective district. Upon review of the survey response data from TxDOT districts, substantial confusion was discovered regarding not only typical functions and roadway locations related to geotextile usage, but related to geotextiles themselves. The following comments pertain to the 26 respondents who indicated that they were aware of the use of geotextiles in their district.

Whenever a geotextile is placed between any two layers in a roadway, e.g., subgrade and base, it performs the primary function of separation. However, 17 TxDOT survey respondents indicated the "Subgrade/Base" location while only 6 respondents indicated the "Separation" function. This discrepancy can be explained if the survey respondents are confusing a *geotextile* with a *geogrid*. Placing a geogrid between subgrade and base does not fulfill the separation function—it performs the reinforcement function. This confusion at least partially explains the relatively high number of TxDOT responses indicating the "Reinforcement" function.

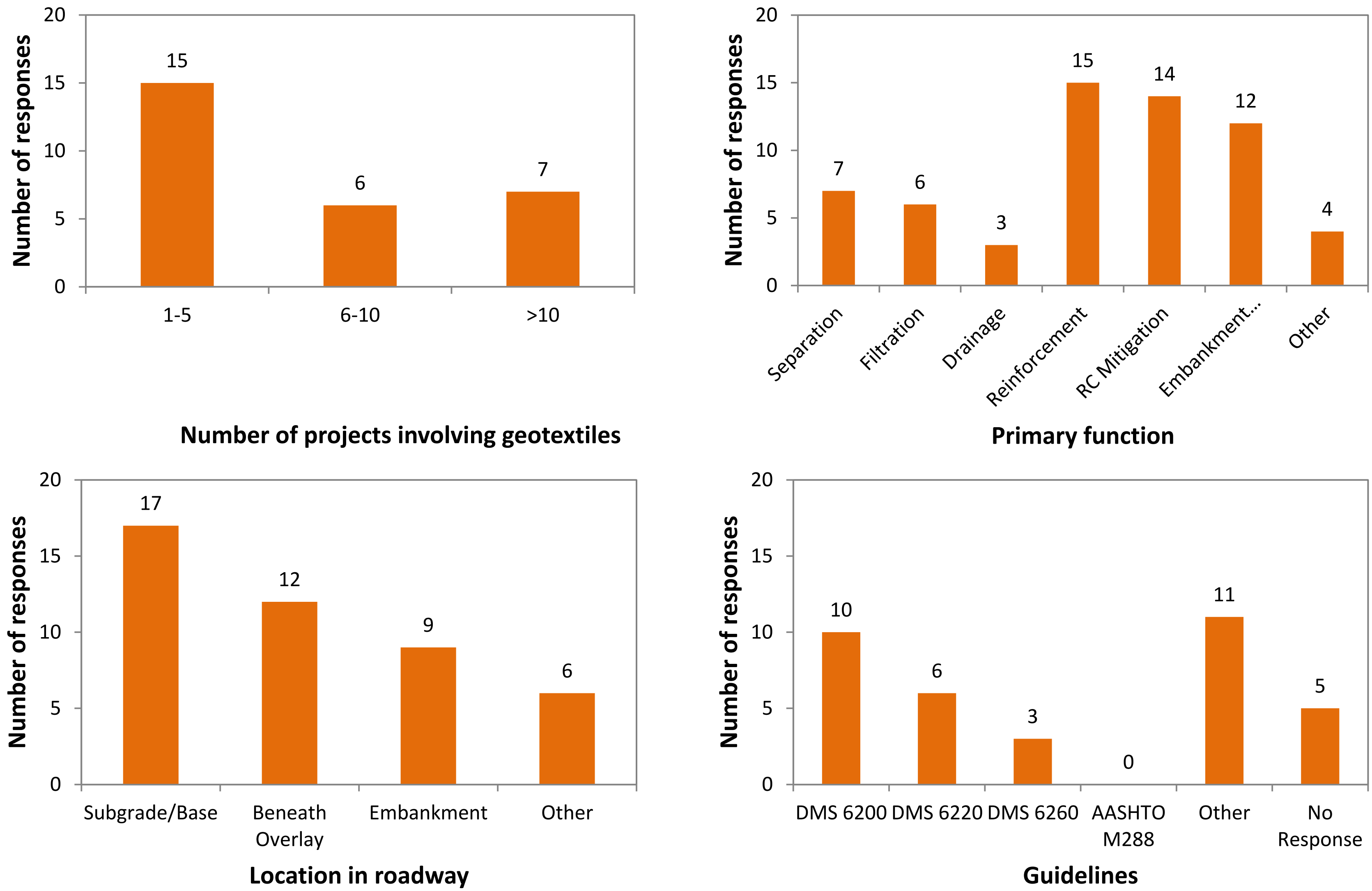


Figure 3.7: TxDOT survey results

Further indication of the confusion between geotextiles and geogrids is found in the responses pertaining to guidelines. Of the 11 respondents indicating “other” for guidelines used in design, 9 were referring to special or provisional TxDOT specifications developed for geogrids. These “other” responses are summarized in Table 3.1.

Table 3.1: TxDOT survey—“Other” guidelines

District	"Other" Response	Description/Notes
Corpus Christi	DMS 6240	“Geogrid for Base/Embankment Reinforcement”
Fort Worth	5440, 5261, 5236, 5338	All are 2004 Special Specifications entitled “Geogrid Base Reinforcement.”
Paris		Project details were attached for a geogrid included in base.
Pharr	DMS 6240	“Geogrid for Base/Embankment Reinforcement”
San Antonio	SS 5287	“Geogrid for Base”
San Antonio	DMS 6240	“Geogrid for Base/Embankment Reinforcement’
Waco	DMS 6250	‘Geogrid-Fabric Composite for Pavements”
Wichita Falls	Special Specs	
Yoakum	SS 5261	“Geogrid Base Reinforcement”
Yoakum	DMS 6240, 2004 Special Spec 4174	DMS 6240: “Geogrid for Base/Embankment Reinforcement;” SS 4174: “Geotextile Reinforcement for Embankments”

In an attempt to address the confusion, the research team sent a follow-up e-mail to 11 respondents whose completed surveys indicated confusion between geotextiles and geogrids. Of the 11 follow-up targets, 4 responded. Figure 3.8 illustrates the confusion by comparing responses to Question 4 from the “good” TxDOT data with the “confused” TxDOT data. The “good” data refers to the initial 17 responses not flagged for confusion and the 4 follow-up responses, while the “confused” data refers to the 11 initial responses indicating confusion. The most telling sign is the lack of responses for separation, filtration, and drainage in the “confused” data. Clearly, from the literature review and the national survey, these should be very common responses in terms of primary function for placement of a geotextile. The “good” TxDOT data confirm this observation.

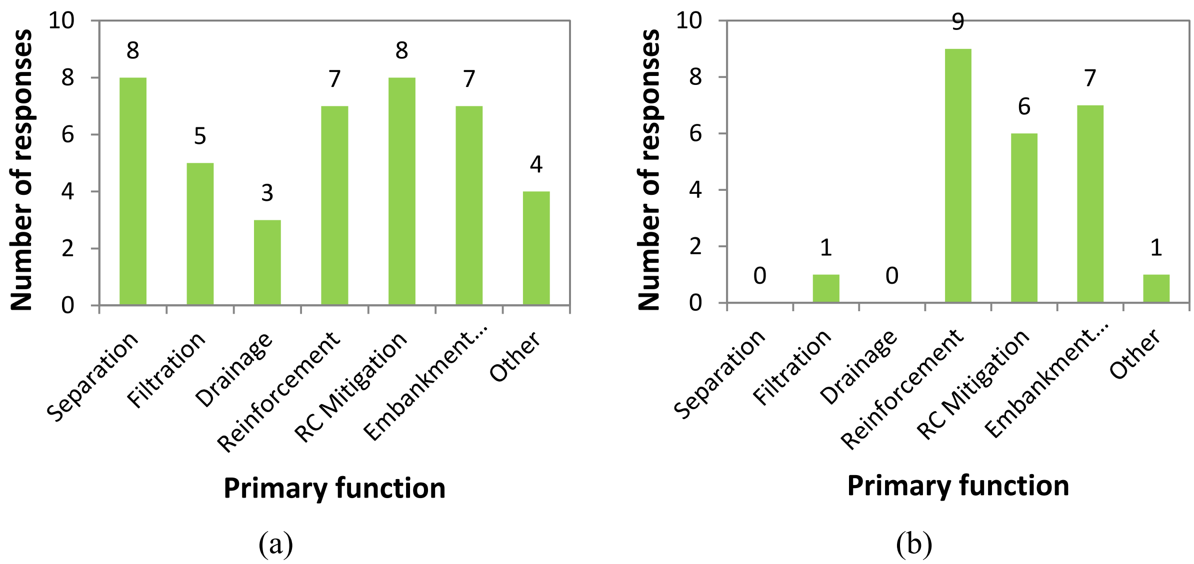


Figure 3.8: Primary function data: (a) "good" TxDOT responses; (b) "confused" TxDOT responses

3.4 Summary

Results from both the national and TxDOT surveys indicate widespread use of geotextiles for various applications in roadway design. Both sets of results indicate that some confusion remains regarding geotextiles and their applications; however, TxDOT responses indicated a major lack of understanding. This result is important in reinforcing the importance of developing the deliverables targeted with this project—guidelines for including geotextiles in design and an educational program to get the information to working engineers.

The national survey results also highlighted the prevalence of AASHTO M288 as the dominant national source for material properties. While this dominance was suspected after conducting the literature review, as most state and other national agencies reference and directly make use of M288, survey confirmation from working engineers is important.

Confusion related to the reinforcement application is prevalent through both sets of survey results, highlighting the need for clarification on the controlling mechanisms and quantifiable benefits in future research. Also visible in the survey analyses is confusion related to the nomenclature associated with drainage—as discussed in Chapters 1 and 2, the drainage function and application are very different. Loose use of nomenclature results in confusion, highlighting the need for rigid, standardized nomenclature in all geosynthetics design documents.

Chapter 4. Application Overview

Slight variations are present in how different geotextile applications are both identified and addressed in the literature. This chapter is presented as a means of identifying and clearly defining relevant applications and associated terminology covered in the documents developed in this study.

4.1 Subsurface Drainage

Geotextiles are commonly installed in roadway systems as part of subsurface drainage structures. Fluctuating moisture content in pavement sections is detrimental to pavement performance, as it results in volumetric changes in the subgrade and/or base. These shrink/swell effects are of particular concern to many areas in Texas characterized by highly active clays. As a result, adequate drainage is critical for roadway performance. Subsurface drainage is commonly provided with trench-like structures located around the edge of the pavement structural section, commonly referred to as "trench drains," containing coarser material than the adjacent pavement section. Coarse material may also be included directly beneath the pavement, often termed a "blanket drain," to collect infiltrating moisture and route it down-gradient to trench drains. A structure similar to a trench drain but typically characterized by a deeper excavation may be constructed to prevent the water table from rising to a level that would be highly detrimental to the pavement structural section.

Regardless of the specific structure, in order to prevent clogging and maintain adequate water flow into the drain, a filter should be included at the interface. Geotextiles are often an economical alternative to graded granular filters due to several factors (Holtz et al. 1998):

- the use of less costly drainage aggregate;
- the possible use of smaller sized drains;
- the possible elimination of collector pipes;
- expedient construction;
- lower risk of contamination and segregation of drainage aggregate during construction; and
- reduced excavation.

The following sections further describe the most common applications related to subsurface drainage.

Trench Drain: a drainage system installed parallel to the centerline of a roadway, typically along its edge, used to control base and surface water drainage. In this system, the primary function of the geotextile is filtration. Figure 4.1 illustrates a typical trench drain.

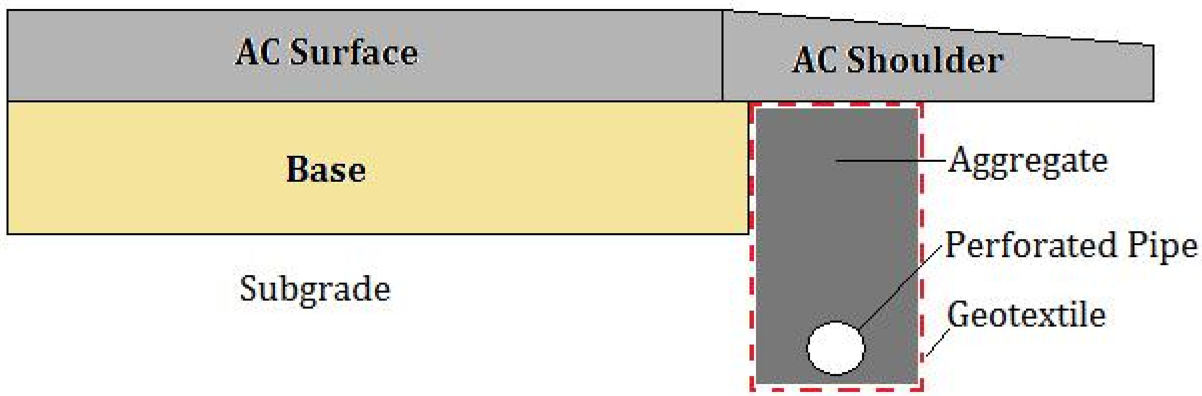


Figure 4.1: Typical trench drain

Underdrain: a drainage system located below or adjacent to a roadway, used to prevent the water table from rising above a certain level. In this system, the primary function of the geotextile is filtration. Figure 4.2 illustrates a typical underdrain.

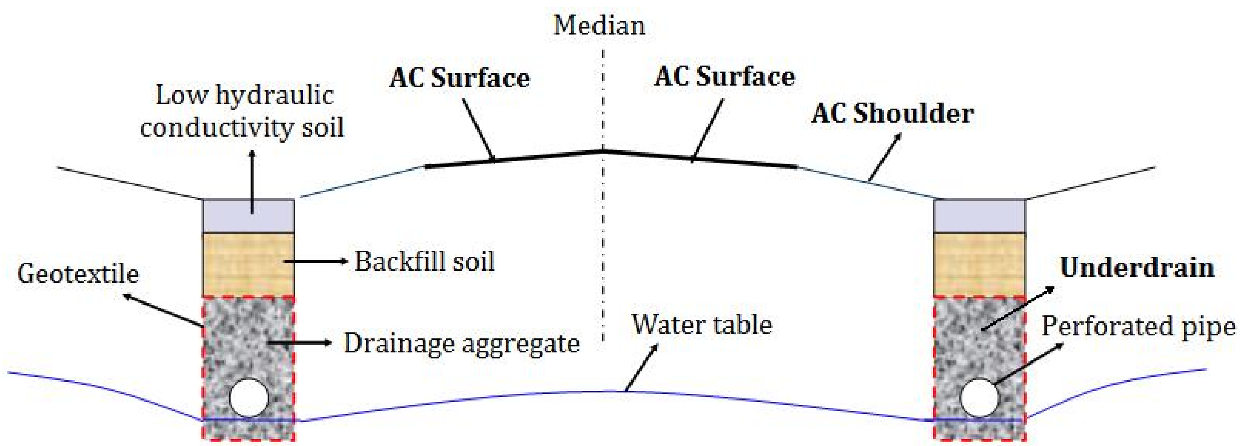


Figure 4.2: Typical underdrain

4.2 Pavement Structural Section

Geotextiles may be installed within the pavement structural section itself to perform a number of applications. Typically, the most effective placement of the geotextile occurs at the interface between two adjacent layers.

***Base or Subbase Separation*:** installation of a geotextile between base or subbase and underlying layer (e.g., subgrade) to perform the separation function. This installation preserves the integrity of each respective layer, reducing migration of fines and aggregate intrusion, and therefore extending the effective life of a pavement system. Figure 4.3 illustrates a typical section with a geotextile installed between base and subgrade. Design for the separation function alone assumes no appreciable amount of moisture will develop within the roadway system for the design life of the project. Presence of migrating moisture requires more stringent design of hydraulic properties, addressed in the following application.

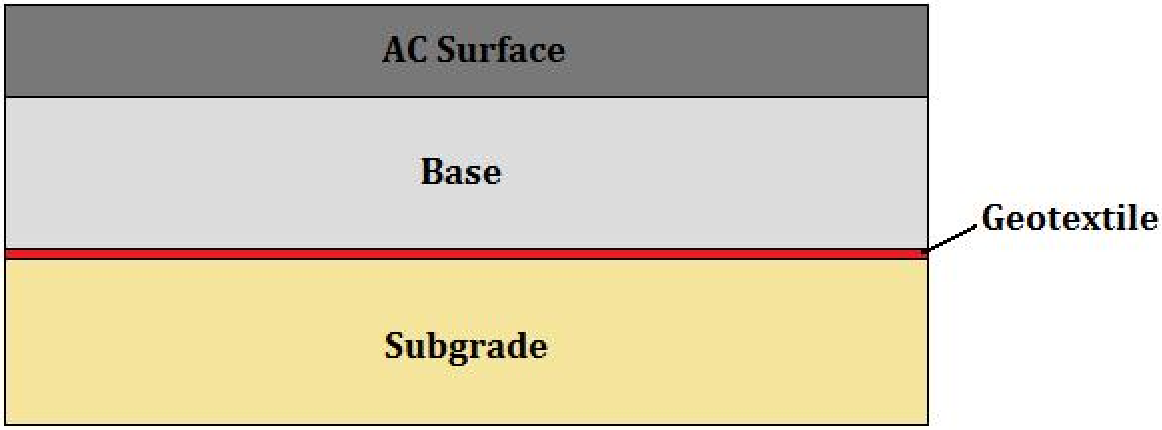


Figure 4.3: Typical section with geotextile used as separator between base and subgrade
Note: The same layout corresponds to a geotextile used as a stabilizer.

Base or Subbase Stabilization: installation of a geotextile between base or subbase and underlying layer to concurrently perform both the separation and filtration functions. Figure 4.3 also illustrates a typical configuration for a geotextile used for base or subbase stabilization. In this case, water is expected to migrate from the subgrade to the base, requiring the use of a filter to prevent migration of subgrade soil into the base. Note that the term "stabilization" is not used to imply reinforcement benefit from placement of a geotextile. This application includes only the separation and filtration functions. No reinforcement benefit should be included in design.

Base or Subbase Capillary Barrier: A geotextile installed between base or subbase and underlying layer to promote movement of water out of the roadway system and toward an edge drain is typically said to perform the primary function of drainage, or lateral transmission. While this application is mentioned in geotextile design guidelines and the in-plane flow capacity of a geotextile is a standard inclusion in manufacturers' product specifications, it is rarely the focus of design. The in-plane flow capacity of a geotextile is typically too low to warrant inclusion specifically for in-plane drainage—a geocomposite, with flow capacities orders of magnitude higher, is more appropriate. Current research, however, indicates that a nonwoven geotextile may indeed contribute to lateral transmission of water by forming a capillary break and inducing flow down-gradient toward the edge of the roadway.

A capillary break refers to the tendency, under unsaturated conditions, of coarser materials to be less conducive to flow than finer materials. Capillary forces in the finer material increase with suction, making flow across an interface between fine and coarse materials less likely. A coarse material placed adjacent to a fine material to prevent flow forms a capillary break. This coarse material does not have to be soil—indeed, research has shown that nonwoven geotextiles may function properly as a geosynthetic capillary break.

Placement of a nonwoven geotextile to create a capillary break is most commonly referred to as a "capillary barrier" in the literature. Secondary functions include separation and filtration, applicable when the barrier breaks down due to excess moisture. While there are currently no established guidelines, the research team proposes to identify and include the application in anticipation of future advances leading to a more complete set of design guidelines. Use of a geotextile to create a capillary break is currently the focus of research aimed at improving subsurface drainage within a roadway structure (Christopher et al. 2000, Henry et al. 2002). The configuration illustrated in Figure 4.3 also applies to the capillary break application.

Base or Subbase Reinforcement: installation of a geotextile between the base or subbase and an underlying layer to provide mechanical reinforcement in the roadway system. Secondary functions include separation and, depending on moisture conditions, filtration. A geotextile may also be installed wholly within the base layer for this application, rather than at the interface, in which case the secondary functions do not apply. The specific mechanisms by which a geotextile may contribute reinforcement benefit are documented in the literature, but there is controversy as to the governing mechanism. The geotextile may contribute through lateral reinforcement, increased bearing capacity, or membrane-type support (see Figure 2.4). There is also confusion related to which geotextile properties are most important for reinforcement. However, field and lab studies show that geotextiles may indeed be a viable option for reinforcement benefit in pavements. The research team proposes to include the application in anticipation of future incorporation of appropriate testing methods and property values.

4.3 Construction Access

Subgrade Restraint*:* installation of a geotextile at the interface between subgrade and adjacent material to increase the support of construction equipment over very low strength subgrade. The primary functions are separation and filtration. Reinforcement is generally recognized as a secondary function, although a quantification of actual reinforcement benefit is difficult to obtain. Reinforcement benefit becomes more significant with increasing depth of rutting. The primary mechanism contributing to load carrying capacity is increased bearing capacity, as shown in Figure 4.4. Subgrade restraint is applicable when addressing the potential for localized bearing failure, most commonly presenting itself in the form of "stuck" construction equipment, and should not be confused with an application that addresses any form of global stability or deep-seated rotational failure.

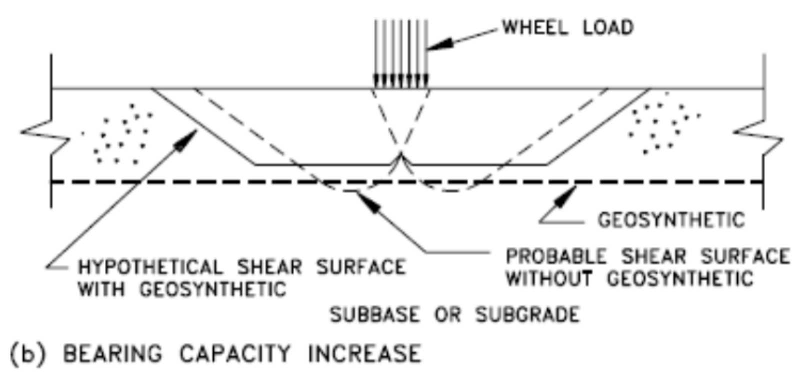


Figure 4.4: Increased load carrying capacity via bearing capacity increase with subgrade restraint (Holtz et al. 1998)

4.4 Summary

To summarize, the researchers focused on these applications:

- Trench Drain
- Underdrain
- Base or Subbase Separation
- Base or Subbase Stabilization
- Base or Subbase Capillary Barrier
- Base or Subbase Reinforcement
- Subgrade Restraint

Note the existence of ***mitigation of reflective cracking***, an important application not focused on in this report. Mitigation of crack propagation is performed by a nonwoven geotextile used immediately beneath a pavement overlay. Under normal conditions, an asphalt layer is subjected to thermal cracking (due to environmental stresses) and reflection cracking (due to load-induced stresses). The geotextile acts as a stress relieving interlayer, dissipating stresses before the crack induces stresses in the overlay. In addition, when a geotextile is impregnated with asphalt or other polymeric mixes, it becomes relatively impermeable to both cross-plane and in-plane flow. As shown in Figure 4.5, the nonwoven geotextile is placed on the existing pavement surface following the application of an asphalt tack coat. The geotextile has been reported to not only prevent cracks in the overlay but also act as a waterproofing layer, minimizing migration of water into the pavement structure. (Mitigation of reflective crack propagation is the focus of TxDOT Project No. 0-1777 and is therefore not a focus of this project.)

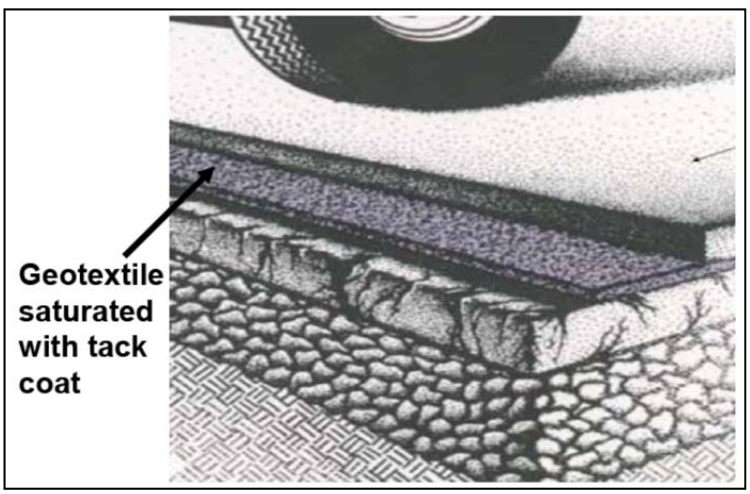


Figure 4.5: Geotextile used for mitigation of crack propagation into the pavement overlay

Another common application for high strength geotextiles is global reinforcement. A geotextile placed for this application helps to prevent deep-seated, rotational failures. Determination of an appropriate geotextile for global reinforcement is highly project- and material-specific, and requires a rigorous design procedure. Multiple layers of geotextile may be required. Due to the nature of the application, a simplified set of selection guidelines does not apply. Therefore, reinforcement for global stability is not addressed in this project.

Chapter 5. Departmental Material Specification (DMS) for Geotextiles in Roadway Applications

The design and selection guidelines reviewed in Chapter 2 help outline the process of including geotextiles in roadway design. Essential in selecting an appropriate geotextile is an understanding of relevant properties and methods of assessing these properties for a given product. The research team has developed a Departmental Material Specification (DMS) that presents baseline material requirements for each application, based primarily on previous TxDOT specifications and accepted national standards.

The proposed DMS, *DMS 6000—Geotextiles*, is provided in Appendix B. This chapter is presented to clearly define and rationalize the properties selected from a review of relevant literature and included in the DMS. Also included in this chapter are instructions on how to most effectively utilize the proposed DMS.

5.1 Document Overview

The format of the DMS developed through this project is based on that used for current *DMS 6200*: Filter Fabrics (TxDOT 2004). Proposed Section 6200.1 provides a brief description of the purpose of the proposed DMS. The proposed Material Producer List is introduced in proposed Section 6200.2. Additional discussion on the proposed Material Producer List is provided later in this chapter.

The most significant change in formatting lies in proposed Section 6200.4. Material requirements are broken into two sections. Tables 5.1 and 5.2, reproduced from the proposed DMS 6200, provide a framework for determining adequate strength property values based on required survivability.

Table 5.1, adopted from FHWA *Geosynthetic Design and Construction Guidelines* (Holtz et al. 1998), defines the three survivability classes based on relevant site conditions—subgrade soil strength, pressure placed on the geotextile due to construction equipment, initial cover thickness, and presence of angular aggregate. Subgrade soil strength is addressed in terms of the soil's California Bearing Ratio (CBR)—however, as CBR may not always be measured in TxDOT projects, footnote 4 allows an engineer to substitute an equivalent measure of strength, per his/her judgment. Pressure due to construction equipment is defined in terms of ground contact pressure, the pressure placed at the ground surface. Initial cover thickness refers to the compacted thickness of the first layer of fill placed atop the geotextile, on which construction equipment operates. Metcalfe and Holtz (1994) showed that angular aggregate controls survivability when placed next to a geotextile—Table 5.1 requires a Class 1 geotextile for this case. Survivability requirements are largely based on years of collective design experience rather than systematic research (Holtz et al. 1998). As a result, footnote 2 allows a lower survivability geotextile to be specified based on an engineer's judgment—this judgment should be based on applicable personal experience or project-specific lab and field results.

Table 5.2, adopted from AASHTO M288 (AASHTO 2006), provides strength requirements for each survivability class. Elongation criteria (>/< 50% elongation at ASTM D-4632 failure) is introduced to differentiate between required properties for woven (<50%) and nonwoven (>50%)

geotextiles. Results from ASTM D-6241 are required for determining puncture strength. In the past, ASTM D-4833 has been the standard test for puncture strength; however, the test is sometimes problematic for both nonwoven and woven geotextiles due to its small probe size. As a result, the industry is currently transitioning to ASTM D-6241, which uses a probe size that is approximately six times the diameter of that used in ASTM D-4833.

Table 5.1: Survivability classes

Site Soil CBR at Installation[3,4]	< 1		1 to 3		> 3	
Equipment Ground Contact Pressure (psi)	> 50	< 50	> 50	< 50	> 50	< 50
Initial Cover Thickness[5] (compacted, inches)						
4[6,7]	NR[8]	NR	1	1	2	2
6	NR	NR	1	1	2	2
12	NR	1	2	2	2	2
18	1	2	2	2	2	2

Notes:
1. If angular aggregate (crushed stone) is placed adjacent to geotextile, use Class 1.
2. Engineer may specify a lower survivability class if (a) the engineer has found the class of geotextile to have sufficient survivability based on field experience, or (b) the engineer has found the class of geotextile to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field test section constructed under anticipated field conditions.
3. Assume saturated CBR unless construction scheduling can be controlled.
4. Equivalent measure of strength may be substituted for CBR per engineer's judgment.
5. Maximum aggregate size not to exceed one-half the compacted cover thickness.
6. For low-volume, unpaved roads (ADT < 200 vehicles).
7. The 4-in. minimum cover is limited to existing road bases and is not intended for use in new construction.
8. NR = Not Recommended.

Table 5.2: Survivability requirements by class

			Geotextile Class					
			Class 1		Class 2		Class 3	
	Test Method	Units	Elongation <50%[2]	Elongation >50%[2]	Elongation <50%[2]	Elongation >50%[2]	Elongation <50%[2]	Elongation >50%[2]
Grab Strength	ASTM D4632	lbf	315	205	250	160	180	115
Sewn Seam Strength[3]	ASTM D4632	lbf	280	180	220	140	160	100
Tear Strength	ASTM D4533	lbf	115	80	90	60	70	40
Puncture Strength	ASTM D6241	lbf	620	435	495	310	375	225

Notes:
1. All numeric values represent minimum requirements in the weaker principle direction.
2. As measured in accordance with ASTM D 4632.
3. When sewn seams are required.

Additional property requirements are selected based on the purpose of placing the geotextile, or the functions the geotextile is expected to perform. Permittivity and AOS, hydraulic properties discussed in Chapter 2 of this report, are important properties based on whether or not the geotextile must act as a filter. For the *Base or Subbase Capillary Barrier* application, these hydraulic properties may have an additional relevance, but this factor has yet to be determined. Ultraviolet stability is an important degradation property for any geotextile that may be stored or placed in the sunlight for any significant amount of time.

5.2 Material Requirements

Material requirements are separated into two groups. Strength requirements are given in terms of survivability, while other requirements are application-based. As the rationale for selection of adequate properties and test methods has already been given, the follow sections provide the rationale behind the selection of actual property values. This project is entirely based on a review of standards and publications currently in use and lacks an experimental aspect; therefore, property requirements were set based on the most relevant information found. Much of the basis lies in AASHTO M288 and the FHWA Geosynthetics Design and Construction Manual (AASHTO 2006, Holtz et al. 1998).

Survivability requirements are taken directly from AASHTO M288. This adoption is standard procedure nationally—there is little variability from state to state. While the basis for the prescribed survivability property values is largely based on engineering experience, rather than systematic research and sound test data, this system has now been successfully used for decades. Strength values increase with increasing severity of construction conditions (i.e., Class 1 strength requirements are higher than Class 3). Strength requirements are lower for geotextiles failing at elongation greater than 50% (traditionally, nonwoven geotextiles)—presumably because more ductile geotextiles can absorb more strain and accordingly, more severe installation conditions, without losing their integrity.

Most of the basis for application-based property requirements is also found in AASHTO M288 (AASHTO 2006). The UV degradation requirement is taken directly from AASHTO M288. Hydraulic property requirements for Base or Subbase Separation are adopted from M288; requirements for Trench Drain, Underdrain, and Base or Subbase Stabilization are adopted from the M288 section on subsurface drainage, where the geotextile is expected to act as a filter. M288 does not require the same hydraulic properties of a geotextile acting in stabilization as it does for one acting in subsurface drainage. However, by our definitions, both applications are expected to provide filtration—therefore, both should fulfill the same hydraulic property requirements. Because no experimental program was conducted as part of this study, this investigation cannot provide specific threshold values that depart from those adopted in AASHTO M288.

Hydraulic property requirements for base or subbase barrier for lateral flow and base or subbase reinforcement are listed as “Report Only.” Proper requirements are not known at this time; however, requiring design engineers to report the hydraulic properties of the selected geotextile product will enable more effective review of the geotextile’s performance later in its design life. This will help determine the effect of the hydraulic properties on geotextile performance and result in a better understanding of appropriate values.

5.3 Material Producer List

The research team noted early in the project that the Material Producer List for the current *DMS 6200* is badly out of date. Few products are covered in the list, and many products on the list were found to be out of production. Many states are making use of the National Transportation Product Evaluation Program (NTPEP) for testing various geotextile products. The program uses only testing facilities certified by the Geosynthetics Accreditation Institute/Laboratory Assessment Program (GAI/LAP) located at Drexel University and covers an extensive amount of products currently on the market. The NTPEP runs all the tests required by the proposed DMS and publishes a quarterly report (AASHTO NTPEP 2008) containing test results for various geotextile products. In addition to publishing the quarterly report, testing results are kept up-to-date in the NTPEP DataMine, the program's searchable online test results database.

The project team recommends that the NTPEP geotextile test results be used in place of or in conjunction with a traditional Material Producer List. If used as a substitute, qualification of a proposed product could be based on published NTPEP testing results. NTPEP test results could also be used in conjunction with a traditional Material Producer List, allowing TxDOT to maintain a more user-friendly, up-to-date list of qualified geotextile products.

5.4 DMS Usage Notes

This DMS is intended to be a general document covering baseline material requirements for the targeted roadway applications involving placement of a geotextile. Projects will often require a special specification, either due to special site conditions or an attempt to focus on only one application and geotextile product. In this case, the DMS may be viewed as an all-encompassing document from which applicable property requirements, depending on project-specific goals and site conditions, may be selected. Additionally, project-specific concerns may often result in the need for more extensive design procedures.

Chapter 6. Installation Guidelines

The proposed Installation Guidelines are provided in Appendix C. Recommendations for installation do not vary for each proposed application. The terminology used throughout this report to characterize related groups of applications is also applicable for installation. As a result, three sets of installation guidelines are proposed: *Subsurface Drainage*, *Pavement Structural Section*, and *Construction Access*. The guidelines are intended to serve as a baseline set of considerations, subject to change, whether through the addition of more material or removal of existing material, based on particular site conditions and project requirements. Consistent with the scope of this project, the basis for the information provided herein was obtained from documented installation guidelines (either federal or state guidelines). While this information is limited, expanding beyond available documents is beyond the scope of this project and would require collecting undocumented best practice information or performance monitoring of constructed projects.

Chapter 7. Selection Guidelines

7.1 Introduction

The design guidelines produced as the major product of TxDOT Project 0-5812 are intended to guide the engineer through the selection, specification, and placement of geotextiles in roadway design. This process includes identifying and understanding relevant applications, understanding the design methodology behind each application, choosing an appropriate material/product, and properly installing the product on-site. The design guidelines follow this basic sequence: background, design, selection, specification, and installation.

The initial approach followed to define selection guidelines in this project included a review of available literature, complemented with information collected from the surveys conducted at the state and national levels. However, and upon recommendation of the Project Director, the proposed document was compiled following an application-based approach (rather than function-based approach, which has been typically documented). This is because the use of function-based design approach was reported to have caused confusion due to issues associated with discrepancies in the terminology. For example, perhaps the most common use for a geotextile in roadway applications is in subsurface drainage systems—while this application typically has "drainage" in its name, the function of the geotextile is indeed filtration, not drainage. Furthermore, installation guidelines *must* be application-based, as different applications may perform the same functions. Taking an application-based approach allows for complete continuity between the documents provided to TxDOT engineers for design involving geotextiles.

Figure 7.1 provides a flow chart outlining the design process for a TxDOT engineer utilizing a geotextile in roadway design. The schematic is a big picture view, giving a general view of the major steps in design and showing how each step is addressed by the deliverables of this project. The Design and Selection Guidelines will provide an engineer with the background information necessary to understand how to effectively incorporate geotextiles in roadway design. From this information, the engineer will select an application of focus.

The next step is to determine the appropriate geotextile type. Some applications may be addressed by a wide variety of geotextiles. Others may require a specific type—Base or Subbase Reinforcement, for example, typically calls for a high-strength, woven geotextile. The engineer should consult the Design Guidelines for information on appropriate geotextiles for the specific application.

After getting a general idea of the type of geotextile required for effective design, the engineer should consult the DMS to determine relevant properties, tests, and adequate property values in order to select an adequate geotextile product. The research team proposes that a Material Producer List be eventually tied into the DMS, giving property values for many leading geotextile products. These property values would be obtained from nationally certified testing completed under the geotextile division of the National Transportation Product Evaluation Program (NTPEP). An engineer may select an appropriate geotextile product by ensuring that the product meets testing requirements provided in the DMS.

After a product has been selected, the remaining step is to draft construction/installation guidelines. A general guide is given as a product of this project, providing engineers with a basis of information on proper installation of geotextiles on-site. Site-specific issues not covered in the guidelines should be incorporated in the project specifications.

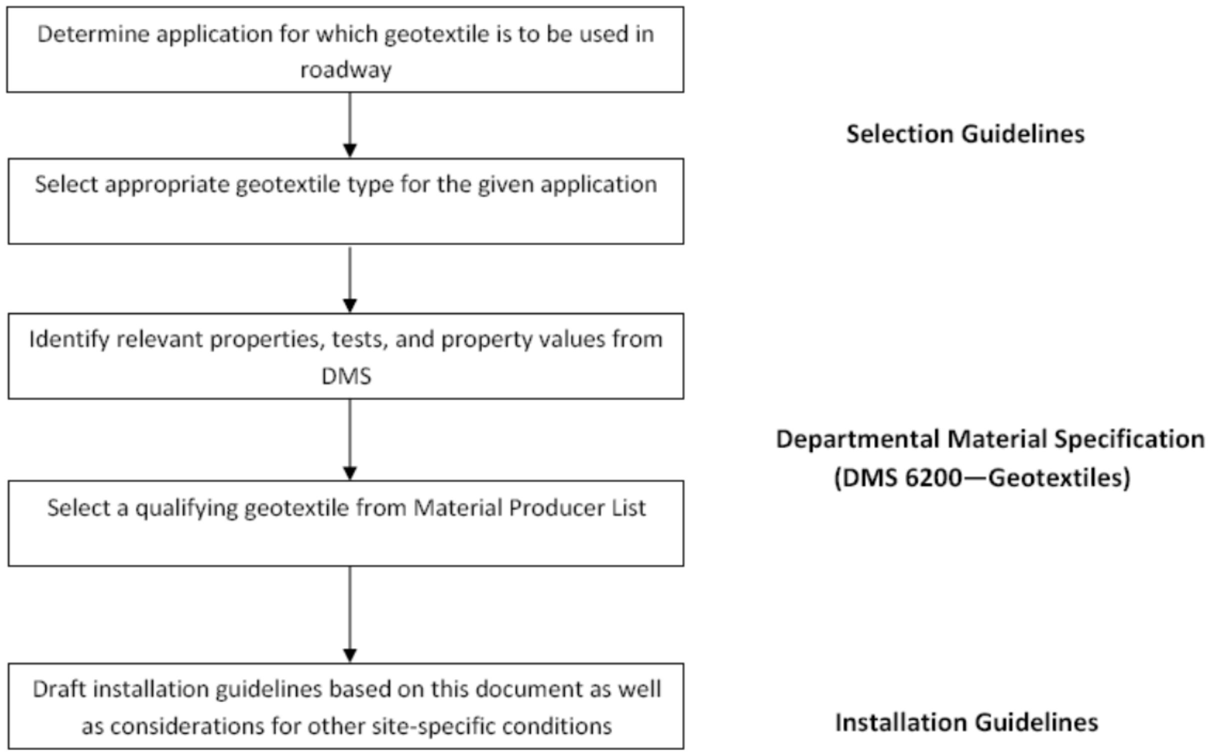


Figure 7.1: Design process flow chart

7.1.1 Definition of Terms

Nomenclature used in sources focused on design with geotextiles is highly inconsistent. For example, "drainage" may refer to the drainage function or the drainage application, which address two different objectives. The following definitions, in logical order, are provided to clearly define the nomenclature used in this document. These may be referenced throughout the design process.

Geosynthetics: a planar product manufactured from polymeric material used with soil, rock, **earth, or other geotechnical engineering-related material as an integral part of a man-made** project, structure, or system.

Geotextile: A permeable geosynthetic comprised solely of polymeric textiles.

> *Woven geotextile*: a planar geotextile structure produced by interlacing two or more sets of elements such as yarns, fibers, or rovings of filaments where the elements pass each other usually at right angles and one set of elements is parallel to the fabric axis.

Nonwoven geotextile: a textile structure produced by bonding or interlocking fibers, or both, accomplished by mechanical, thermal, or chemical means.

Polymer: a macromolecular material formed by the chemical combination of monomers having either the same or different chemical composition. Plastics, rubbers, and textile fibers are all high-molecular-weight polymers. Geotextiles are most commonly made of polypropylene, polyethylene, and/or polyester.

Polyolefin: a family of polymeric materials which includes polyethylene and polypropylene, two common polymers used for geotextiles.

Polyester (PET): generic name for a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of an ester of a dihydric alcohol and terephthalic acid.

Function: fundamental process performed by a geotextile. Geotextiles may perform multiple functions simultaneously. Functions most applicable to roadway applications addressed with this project are separation, filtration, drainage, and reinforcement.

Separation: placement of a flexible porous textile between dissimilar materials so that the integrity and functioning of both materials can remain intact or be improved.

Filtration: the equilibrium soil-to-geotextile system that allows for adequate liquid flow with limited soil loss *across the plane of the geotextile* over a service lifetime compatible with the application under consideration.

Drainage: equilibrium soil-to-geotextile system that allows for adequate liquid flow with limited soil loss *within the plane of the geotextile* over a service lifetime compatible with the application under construction.

Reinforcement: improvement of a total system's strength created by the introduction of a geotextile (that is good in tension) into a soil (that is good in compression but poor in tension) or other disjointed and separated material.

Protection: placement of a geotextile to act as a stress relief layer.

Fluid Barrier: placement of a geotextile to prevent the passage of fluid. A geotextile is typically placed as a fluid barrier in roadways in one of two ways: when saturated with a bituminous material and placed beneath a pavement overlay, and when placed adjacent to a finer material under unsaturated conditions.

Application: purpose for which a geotextile is placed—often a combination of multiple functions.

Edge Drain: drainage system installed along the edge of a roadway, used to control base and surface water drainage. In this system, the primary function of the geotextile is filtration.

Underdrain: drainage system located below and adjacent to a roadway, used to prevent the water table from rising to a certain level. In this system, the primary function of the geotextile is filtration.

Base or Subbase Separation: geotextile installed between base and underlying layer to perform the separation function.

Base or Subbase Stabilization: geotextile installed between base and underlying layer to concurrently perform the separation and filtration functions.

Base or Subbase Capillary Barrier: geotextile installed between base and underlying layer for the primary function of fluid barrier. In this case, the barrier is created via placement adjacent to a finer material under unsaturated conditions. Creation of the barrier is intended to promote lateral flow along the interface. Secondary functions include separation and potentially filtration.

Base or Subbase Reinforcement: geotextile installed between base and underlying layer for the primary function of reinforcement. Secondary functions include separation and, possibly, filtration. A geotextile may also be installed within the base layer for this application, in which case the secondary functions do not apply.

Subgrade Restraint: placement of a geotextile over areas of excessively soft subgrade to prevent localized bearing capacity failures. This application is appropriate for providing temporary construction access or a "working platform" over wet, very soft existing site material.

Survivability: ability of a geotextile to maintain structural integrity through construction/installation stresses. Survivability requirements are based on AASHTO M288-06. The class system is widely utilized for survivability specifications—Class 1 is the strongest, Class 3 the weakest. Survivability requirements are based on construction conditions: subgrade soil strength, pressure due to construction equipment, thickness of soil layer over geotextile, and presence of angular aggregate.

7.2 Identification of Appropriate Application

As discussed in Chapter 4, the following applications are covered in the selection guidelines:

1. Trench Drain
2. Underdrain
3. Base or Subbase Separation
4. Base or Subbase Stabilization
5. Base or Subbase Capillary Barrier
6. Base or Subbase Reinforcement
7. Subgrade Restraint

A notable application (consisting of the function having the same name) not addressed in these guidelines is mitigation of crack propagation. This application is covered extensively in TxDOT Project No. 0-1777 (Cleveland et al. 2002) and, as a result, is not included in this document. In addition, global stability issues (foundation failure, deep-seated global stability, etc.) are not addressed. Placement of a geotextile to aid in global stability requires a rigorous, highly project- and material-specific engineering design and could not be covered with a generalized set of specifications.

The nomenclature used in the literature to describe roadway applications varies significantly, but the applications themselves are consistent. For example, the application we call "Trench Drain" is also seen in the literature as "Edge Drain" or "French Drain," among other names. To assist the engineer in understanding and selecting an appropriate application, background information is provided in the selection guide (Appendix A) in addition to Chapter 4 of this report.

7.3 Geotextile Selection: Decision Criteria and Justification for Recommendations

After an engineer determines an application of interest, the next step is to understand the important principles of design. Strength requirements of a geotextile installed in a roadway are independent of the specific application and are governed by survivability. Other properties vary depending on the targeted application.

7.3.1 Survivability

In a typical roadway project, the most extreme conditions to which a geotextile is subjected occur during construction. In order to perform as designed during a project's lifetime, the geotextile must maintain its integrity through the duration of the construction process—the ability of a given geotextile to do so is termed its "survivability." Required survivability, a function of a number of project- and site-specific variables, controls the required strength properties of a geotextile.

Several strength properties—tensile (grab), tear, puncture, and seam—are typically used to determine a geotextile's survivability. Seam strength is included even though instances of seaming in actual projects are uncommon. These properties are chosen as representative index properties rather than models of conditions actually seen in the field. For example, the grab tensile test (ASTM D4632) is typically specified even though a geotextile used in the applications relevant to roadway design will probably never be strained to tensile failure. This approach is taken in an effort to characterize a geotextile's relative strength and ability to survive construction stresses and is currently the industry standard. Table 7.1 gives the standard tests for each strength property and associated units.

Table 7.1: Standard tests associated with survivability

Property	Test	Units
Grab Strength	ASTM D4632	lbf
Sewn Seam Strength	ASTM D4632	lbf
Tear Strength	ASTM D4533	lbf
Puncture Strength	ASTM D6241	lbf
	ASTM D4833	lbf

Tests prescribed for determining survivability were chosen to represent the national standard, in agreement with AASHTO M288 (AASHTO 2006), a vast majority of state specs, and NTPEP, which is discussed in more detail in Chapter 5. Two tests are given as alternatives for determining puncture strength. ASTM D4833 has been most commonly used in the past; however, ASTM D6241 is more appropriate for woven geotextiles and lightweight nonwoven geotextiles, and is quickly becoming the test of choice. Both tests use a cylindrical probe to determine the puncture resistance of a geotextile. ASTM D6241 uses a larger diameter "CBR probe," which is less likely to slip between fibers or yarns in woven geotextiles or be affected by major variations in thickness and localized strength in a lightweight nonwoven geotextile.

7.3.2 Application-based Properties

Other properties important in the selection of an adequate geotextile for a given application vary based on the application itself. Hydraulic properties—permittivity and apparent opening size (AOS)—are specified for the Edge Drain, Underdrain, Base or Subbase Separation, and Base or Subbase Stabilization applications. Hydraulic properties are also expected to be of significant importance for a geotextile placed to create a capillary barrier as part of the Base or Subbase Capillary Barrier application. The effectiveness of a capillary barrier is largely dependent upon the porosities of the two adjacent materials—under unsaturated conditions, a more porous material placed adjacent to a less porous material may act as a barrier to water flow, termed a "capillary barrier." Geotextiles acting as capillary barriers are shown in the literature to be effective in minimizing unwanted moisture flow through roadway systems (Christopher et al. 2000, Henry et al. 2002). However, the geotextile properties most important in capillary barrier design have yet to be addressed. The research team believes that permittivity and AOS may also be related to a geotextile capillary barrier's effectiveness.

The selection of permittivity and AOS as the controlling hydraulic properties is consistent with practice across the nation. Adequate design of a geotextile acting as a filter requires that the geotextile

1. retain soil particles;
2. allow passage of water; and
3. perform items 1 and 2 for the design life of the structure.

The ability of the geotextile to retain soil particles is determined by comparing the larger openings in the geotextile to the larger particles in adjacent soil. Generally, it is desired to have slightly smaller openings than soil particles, so that a bridge is formed at the soil/geotextile interface. The widely accepted measure of the opening size in a geotextile is the AOS, defined as the US Standard Sieve with sizes closest to that in the geotextile. A representative particle size is typically taken as D_{85}, or the particle size at which 85% of the soil is finer, obtained from a gradation curve of the adjacent soil. Permittivity identifies the geotextile's ability to allow passage of water. A geotextile's ability to retain soil particles while allowing passage of water long term (i.e., over the lifetime of the structure) depends on the geotextile's clogging resistance. Clogging occurs when finer soil particles are washed into the geotextile during normal passage of water and fail to wash out, becoming trapped in the geotextile. Clogging reduces the flow capacity of the geotextile. The most common test to estimate a geotextile's clogging resistance is the gradient ratio test, ASTM D5101. However, tests focusing on clogging resistance are necessarily long in duration and are not commonly run in practice. Clogging resistance is also highly project-specific, requiring long-term tests with materials and conditions similar to what is expected in the field. As a result, lab work to determine the clogging resistance of a soil/geotextile system is typically required only in highly critical situations.

Hydraulic property values specified in the DMS associated with this project should be viewed as starting points for design. Highly critical structures, judged based on the consequences of failure, should be designed with respect to the entire soil-geosynthetic system. The most common example in roadway design where this may become an issue is related to the Edge Drain and Underdrain applications. Design of an underdrain is similar to that of an edge drain. However, critical differences exist between the two structures that require unique consideration. An edge drain is designed to address water coming from the surface, predominantly a result of precipitation events. The periodic nature of these events means that edge drains are only operational a portion of the time. An underdrain, on the other hand, is designed to control subsurface flow by keeping the water table at a desired level. This requires continuous operation from the underdrain. In addition, failure of an edge drain is easier to identify—water will typically pond up at the ground surface. Failure of an edge drain is less critical than that of an underdrain. The most efficient, cost-effective design may be obtained by specifying permittivity and AOS values based on a comparison with adjacent soil.

Ultraviolet stability is an important endurance property related to geotextile usage, and is specified based on expected exposure to ultraviolet degradation. Table 7.2 summarizes the tests and units associated with each important application-based property.

Table 7.2: Standard tests associated with application-based properties

Property	Test	Units
Permittivity	ASTM D4491	sec^{-1}
AOS	ASTM D4751	US Standard Sieve No.
Ultraviolet (UV) Stability	ASTM D4355	%

The important distinction for hydraulic property requirements of each application is whether the geotextile is expected to act as a filter. Geotextiles placed as a separator are beneficial even when placed over very stiff subgrade material, by preventing migration of fines and aggregate intrusion and maintaining the integrity of both layers over the project design life. Design should ensure that the geotextile does not act as a barrier to water flow, but hydraulic properties are not as critical. In the case that significant amounts of flow are expected throughout the pavement section, hydraulic properties are more critical and design should focus on the Base or Subbase Stabilization application. Geotextiles placed for the purpose of subsurface drainage, i.e., for an edge drain or underdrain, are also expected to act as filters. Also, as discussed in Chapter 4, a geotextile placed for Subgrade Restraint also acts as a filter.

7.4 Material Specification

After determining an appropriate application and developing a general understanding of the type and characteristics of an adequate geotextile, the next step is to find a geotextile product that has the properties of interest. Proposed *DMS 6200*—Geotextiles is presented to guide an engineer or designer to an appropriate product. Proposed *DMS 6200* is not presented directly in the Selection

Guidelines but is referenced. This approach allows the framework of the Selection Guidelines to remain steady, even while the DMS is periodically updated to reflect changes in required testing and property values, as changes are sure to arise continually with future research.

7.5 Installation Guidelines

As the Selection Guidelines are intended to be in the form of a convenient field handbook, the installation guidelines are a vital section of the overall document. In an attempt to minimize confusion, as the proposed *DMS 6200* is already being referenced and not directly included, the complete version of the proposed Installation Guidelines is included in the Selection Guidelines. Additionally, installation methods are not expected to change as drastically and/or as often as required testing and property values. Project- and site-specific variations not covered in the presented installation guidelines should be considered during the development of a specific set of construction specifications.

References

AASHTO (1990). *Guide Specifications and Test Procedures for Geotextiles*. AASHTO-AGC-ARTBA Task Force 25 Report. Subcommittee on New Highway Materials, American Association of State Transportation and Highway Officials, Washington, D.C.

AASHTO (2006). *Geotextile Specification for Highway Applications* - M288-06, Standard Specifications for Transportation Materials and Methods of Sampling and Testing. American Association of State Transportation and Highway Officials, Washington, D.C., 20pp.

AASHTO NTPEP (2008). *Laboratory Results of Evaluations on Geotextiles and Geosynthetics*. Report NTPEP 8001.32 (NTPEP 137, 32nd Edition), 57pp. <http://www.ntpep.org/ProfileCenter/Uploads/NTPEP8001.32Report-final(GTX).pdf>.

Benjamim, C.V.S., Bueno, B., Zornberg, J.G. (2007). *Field Monitoring Evaluation of Geotextile-Reinforced Soil Retaining Walls*. Geosynthetics International Journal, April, Vol. 14, No. 1.

Berg, R.R., Christopher, B.R., and Perkins, S. (2000). *Geosynthetic Reinforcement of the Aggregate Base/Subbase Courses of Pavement* Structures, GMA White Paper II, June 2000, 176pp.

Bueno, B.S., Benjamim, C.V., and Zornberg, J.G. (2005). "Field Performance of a Full-Scale Retaining Wall Reinforced with Non-woven Geotextiles," *Slopes and Retaining Structures Under Seismic and Static Conditions*. ASCE Geotechnical Special Publication No. 140, Gabr, Bowders, Elton, and Zornberg (Editors), January 2005, Austin, TX (CD-ROM).

Christopher, B.R. and Holtz, R.D. (1985). Geotextile Engineering Manual. FHWA Technical Report No. FHWA-TS-86/203, Federal Highway Administration, Washington, D.C., March 1985, 1044pp.

Christopher, B.R., Hayden, S.A., and Zhao, A. (2000). "Roadway base and subgrade geocomposite drainage layers." *Testing and Performance of Geosynthetics in Subsurface Drainage*, *ASTM STP 1390*, J.B. Goddard, L.D. Suits and J.S. Baldwin, Eds., American Society for Testing and Materials, West Conshohocken, PA.

Cleveland, G.S., Button, J.W., and Lytton, R.L. (2002). *Geosynthetics in Flexible and Rigid Pavement Overlay Systems to Reduce Reflection Cracking*, Report No. FHWA/TX02/1777-1, Texas Transportation Institute, College Station, Texas, October 2002, 298pp.

FHWA (2003). FHWA Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP-03). Federal Highway Administration, Federal Lands Highway, Washington, DC, 700pp.

Henry, K.S., Stormont, J.C., and Barna, L. (2002) "Geocomposite capillary barrier drain for limiting moisture changes in pavement subgrades and base courses." Final Report for NCHRP-IDEA Project 68, The National Academies, Washington, D.C. 24p.

Holtz, R.D., Christopher, B.R., Berg, R.R. (1998). *Geosynthetic Design and Construction Guidelines*. FHWA Technical Report No. FHWA-HI-95-038, Federal Highway Administration, Washington, D.C., updated April 1998, 460pp.

International Geosynthetics Society (2000). *Recommended Descriptions of Geosynthetics Functions, Geosynthetics Terminology, Mathematical and Graphical Symbols*, 17 p.

Koerner, R.M. (2005). *Designing with Geosynthetics*. 5th Edition. Upper Saddle River, NJ: Prentice Hall.

McCartney, J.S., Kuhn, J.A., and Zornberg, J.G. (2005). *Geosynthetic Drainage Layers in Contact with Unsaturated Soils*. Proceedings: 16th International Conference of Soil Mechanics and Geotechnical Engineering (ISSMGE), Osaka, Japan, September 12-17, pp. 2301-2305.

Metcalfe, R.C. and Holtz, R.D. (1994) *Performance of Geotextile Separators in Western Washington*. Final Technical Report, Washington State Department of Transportation, Report No. WA-RD 321.1, 265 pp.

TxDOT (2004). DMS-6200, "Filter Fabric."

Zornberg, J.G., and Christopher, B.R., Editors, 2000, *Advances in Transportation and Geoenvironmental Systems Using Geosynthetics*, ASCE Geotechnical Special Publication No. 103, ASCE Press, ISBN 0-7844-0515-8, 422 pp.

Zornberg, J.G. and Christopher, B.R., 2006, "Chapter 37: Geosynthetics." In: *The Handbook of Groundwater Engineering*, 2nd Edition, Jacques W. Delleur (Editor-in-Chief), CRC Press, Inc., Boca Raton, FL.

Zornberg, J.G., Prozzi, J., Gupta, R., Luo, R., McCartney, J.S., Ferreira, J.Z., Nogueira, C. (2008). *Validating Mechanisms in Geosynthetic Reinforced Pavements*. FHWA Technical Report No. FHWA/TX-08/0-4829-1. Austin, TX: Center for Transportation Research.

Appendix A: Guide for the Application and Selection of Geotextiles

0-5812-P1

Guide for the Application and Selection of Geotextiles

Authors:
Jorge Zornberg
Nathan Thompson

TxDOT Project 0-5812: Development of Application Guide and Specifications for Geotextiles in Soil and Base

FEBRUARY 2010; REVISED FEBRUARY 2012

Performing Organization:	**Sponsoring Organization:**
Center for Transportation Research The University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, Texas 78701	Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080
Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.	

1. Introduction

General

Geosynthetics use in roadway design and construction has increased steadily as innovative uses and new products continue to evolve. Geotextiles have the widest range in properties in the geosynthetics field, making them particularly well-suited for a range of potential applications. For many projects, inclusion of geotextiles in roadway design may prove advantageous when compared to traditional materials and methods. This guide is presented first as a means of understanding the various applications a geotextile may address in roadway design, and determining whether a geotextile presents an economic design alternative for a specific project. For the case in which a geotextile is appropriate, information regarding selection of an appropriate product and proper installation during construction is provided.

Background

A ***geosynthetic*** is a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering-related material as an integral part of a man-made project, structure, or system. A ***geotextile*** is defined as a permeable geosynthetic made of textile materials. Among the different geosynthetic products, geotextiles present the widest range of properties and may be used to fulfill the widest variety of functions for transportation applications.

The ***polymers*** used in the manufacture of geotextile fibers include the following, listed in order of decreasing use: polypropylene (≈85%), polyester (≈12%), polyethylene (≈2%), and polyamide (≈1%). The most common types of ***filaments*** used in the manufacture of geotextiles include *monofilament, multifilament, staple filament* and *slit-film.* If fibers are twisted or spun together, they are known as a *yarn*.

The filaments, fibers, or yarns are formed into geotextiles using either ***woven*** or ***nonwoven*** methods. Figure A1 shows a number of typical geotextiles. A w*oven geotextile* is a planar geotextile structure produced by interlacing two or more sets of elements—yarns, fibers or filaments. The elements pass each other, usually at right angles, and one set of elements is parallel to the fabric axis. Woven geotextiles are manufactured using traditional weaving methods. A n*onwoven geotextile* is a textile structure produced by bonding or interlocking fibers, or both, accomplished by mechanical, thermal, or chemical means. Nonwoven geotextiles are manufactured by placing and orienting the filaments or fibers onto a conveyor belt, which are subsequently bonded by needle punching or melt bonding. Nonwoven geotextiles have significantly different engineering properties than woven geotextiles. In addition to the manufacturing approach, polymer type also influences the engineering properties of these products.

Common terminology associated with geotextiles includes machine direction, cross machine direction, and selvage. ***Machine direction*** refers to the direction in the plane of the fabric in line with the direction of manufacture. Conversely, ***cross machine direction*** refers to the direction in the plane of fabric perpendicular to the direction of manufacture. The ***selvage*** is the finished area on the sides of the geotextile width that prevents the yarns from unraveling.

Figure A1: View of different types of geotextiles

A geotextile is installed for an *application*, but performs a *function*. This distinction is important for design. A ***function*** is a fundamental process performed by a geotextile. Geotextiles may perform multiple functions simultaneously. An ***application*** is the purpose for which a geotextile is placed, often incorporating multiple functions.

Geotextile Functions

In order to properly understand potential applications of geotextiles, it is first necessary to understand their functions. Those typically addressed in roadway applications are as follows:

Separation is the introduction of a flexible porous geotextile placed between dissimilar materials so that the integrity and the functioning of both materials remains intact for the life of the structure or is improved (Koerner 2005). In pavement applications, separation refers to the geotextile's role in preventing the intermixing of two adjacent layers. For example, a major cause of failure of roadways constructed over soft foundations is contamination of the aggregate base course with the underlying soft subgrade soil (Figure A2a). A geotextile placed between the aggregate and the subgrade acts as a separator, which minimizes contamination of the aggregate base by the subgrade (Figure A2b).

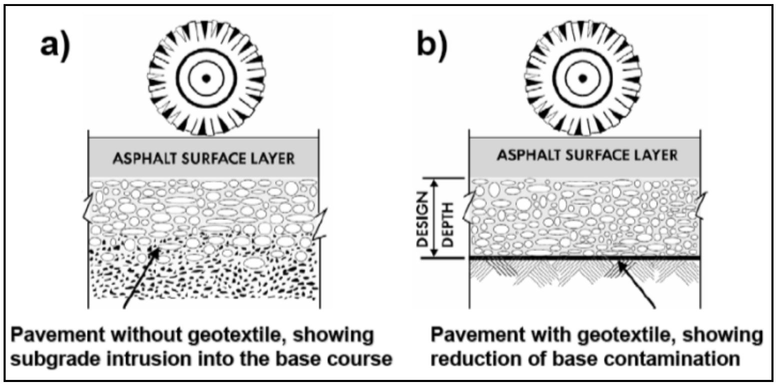


Figure A2: Separation function of a geotextile placed between base aggregate and a soft subgrade: (a) without geotextile; (b) with geotextile

Filtration is defined as the equilibrium geotextile-soil system that allows for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime compatible with the application under consideration (Koerner 2005). Properties of the filter material must be carefully chosen so that upstream particles are adequately retained without allowing excess downstream migration of fine particles, while maintaining adequate water flow across the interface. Adequate creation of a filter bridge is shown in Figure A3.

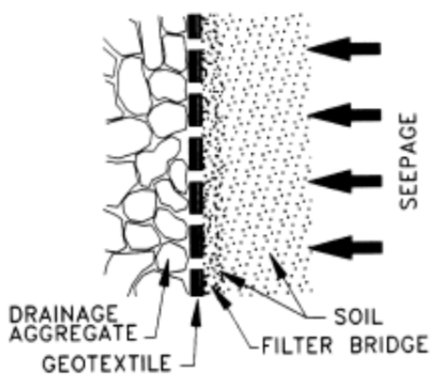


Figure A3: Creation of filter bridge using a geotextile (Holtz et al. 1998)

Drainage refers to the ability of geotextiles (typically thick, nonwoven geotextiles) to provide an avenue for flow of water within the plane of the geotextile. The important distinction between *drainage* and *filtration* is that drainage refers to in-plane flow of water, while filtration refers to cross-plane flow.

Reinforcement is the synergistic improvement in pavement strength created by the introduction of a geotextile into a pavement layer. The reinforcement function may be developed primarily through the following three mechanisms (Holtz et al. 1998):

1. *Lateral restraint* through interfacial friction between geotextile and soil/aggregate. When an aggregate layer is subjected to traffic loading, the aggregate tends to move laterally unless it is restrained by the subgrade or geosynthetic reinforcement. Soft, weak subgrade

soils provide very little lateral restraint, resulting in rutting. A geotextile with good frictional capabilities can provide tensile resistance to lateral aggregate movement (Figure A4a).

2. *Increased bearing capacity*, i.e., by forcing the potential bearing surface failure plane to develop at alternate higher shear strength surface (Figure A4b).

3. *Membrane-type support* of the wheel loads (Figure A4c).

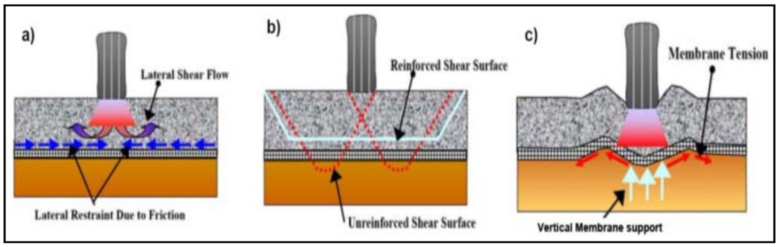


Figure A4: Reinforcement mechanisms induced by a geotextile used for base reinforcement: (a) lateral restraint; (b) increased bearing capacity; (c) membrane-type support

Protection refers to the ability of a nonwoven geotextile to act as a stress-relieving layer.

Fluid barrier refers to the ability of a geotextile, under certain conditions, to prevent the passage of fluid. Depending on the application, this effect may be either temporary, when used in unsaturated soils, or permanent, when coated with bituminous material in the field.

Potential Benefits of Geotextile Use

A geotextile placed for one of several roadway applications may increase pavement life, decrease construction costs, reduce required aggregate thickness, and/or provide construction access in areas of very soft subgrade conditions. In many cases, a geotextile may provide material advantages over the use of a more traditional construction material, i.e., granular soil or aggregate. In other cases, the benefit lies predominantly in reduced costs due to cheaper construction labor or materials.

2. Potential Applications

The seven applications covered in this manual are grouped according to the overall purpose for placement of the geotextile. Grouping the applications also helps highlight the similarities many of the applications share in terms of selection and/or installation guidelines.

Subsurface Drainage

A geotextile placed as part of a subsurface drainage structure acts as a filter between drainage aggregate and adjacent material. The geotextile may be placed in one of two applications, separated as a result of the source of water for which the filter is necessary.

Trench Drain: a drainage system installed parallel to the centerline of a roadway, typically along its edge, used to control base and surface water drainage. In this system, the primary function of the geotextile is filtration. Figure A5 illustrates a typical trench drain.

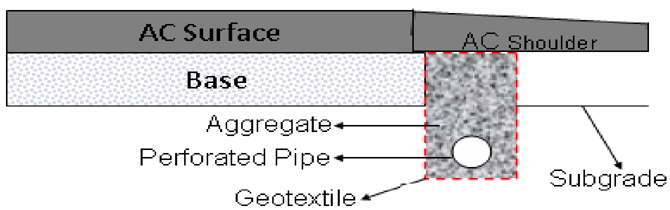


Figure A5. Typical trench drain

Underdrain: a drainage system located below or adjacent to a roadway, used to prevent the water table from rising above a certain level. In this system, the primary function of the geotextile is filtration. Figure A6 illustrates a typical underdrain.

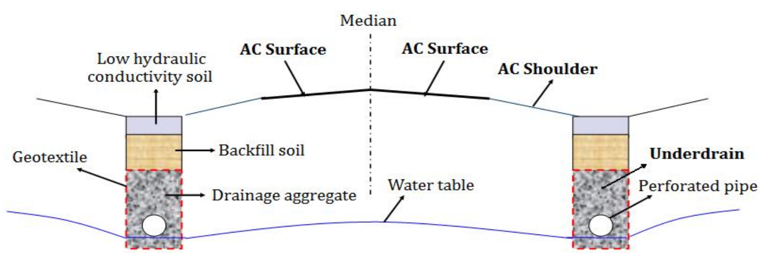


Figure A6. Typical underdrain

Pavement Structural Section

Many geotextile applications involve placement of a geotextile between two adjacent layers in a pavement structure. Figure A7 illustrates a typical location in the pavement section.

Base or Subbase Separation**:** installation of a geotextile between base or subbase and underlying layer (e.g. subgrade) to perform the separation function. This preserves the integrity of each respective layer, reduces migration of fines and aggregate intrusion, and therefore extends the effective life of a pavement system.

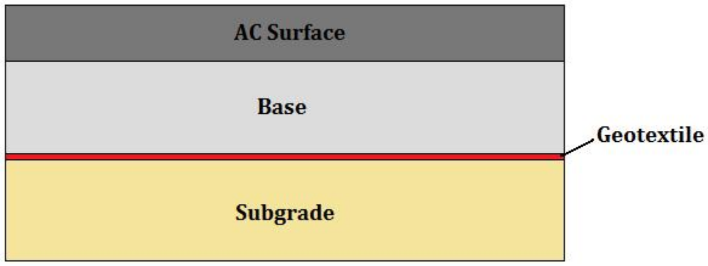


Figure A7. Typical section with geotextile used in Pavement Structural Section applications

Base or Subbase Stabilization: installation of a geotextile between base or subbase and underlying layer to concurrently perform both the separation *and* filtration functions. In this case, water is expected to migrate from the subgrade to the base, requiring the use of a filter to prevent migration of subgrade soil into the base. It is important to note that the term "stabilization" is not used to imply reinforcement benefit from placement of a geotextile.

Base or Subbase Capillary Barrier: installation of a geotextile between two adjacent layers in a pavement structural section to (a) act as a temporary barrier to water flow, and (b) encourage the movement of water in the overlying layer towards drainage structures at the pavement perimeter. The capillary barrier will only be effective if the overlying soil has significant fines content and is under unsaturated conditions. This application could also be contained in the *Subsurface Drainage* group, but for installation reasons is more suited in the *Pavement Structural Section* group.

Base or Subbase Reinforcement: installation of a geotextile between the base or subbase and an underlying layer to provide mechanical reinforcement in the roadway system. Secondary functions include separation and, depending on moisture conditions, filtration. A geotextile may also be installed wholly within the base layer for this application, rather than at the interface, in which case the secondary functions do not apply.

Construction Access (Road Embankment Stabilization)

Often, existing conditions prior to construction of a roadway are too soft for construction equipment to safely and efficiently operate. In this case, a geotextile may be used to help increase the available capacity of existing subgrade and allow construction activities to proceed.

Subgrade Restraint: placement of a geotextile over areas of excessively soft subgrade to prevent localized bearing capacity failures (see Figure A8). This application is appropriate for providing temporary construction access or a "working platform" over wet, very soft existing site material.

Figure A8: Placement of woven geotextile for subgrade restraint (Mirafi 2008)

3. Geotextile Selection

Geotextile properties required for selection of an adequate product are provided in proposed *TxDOT DMS 6200 – Geotextiles*. If a geotextile is to be placed for the *Base or Subbase Capillary Barrier* application, a nonwoven geotextile should be used. For every other application, either a woven or nonwoven geotextile may be selected as long as it meets the property requirements set forth in proposed DMS 6200. Property requirements are broken down into two main sections—strength and performance. Strength requirements do not depend on the application for which the geotextile is placed, while performance property requirements vary based on the individual applications.

Strength Requirements—Survivability

The strength of any geotextile placed in a roadway application should be sufficient to maintain its integrity through the most severe stress conditions experienced over its lifetime. This is termed "survivability." For roadway applications, the most extreme stress conditions for a geotextile are expected during installation. As a result, survivability requirements are not dependent upon the application for which a geotextile is placed.

Expected stress conditions during installation are a function of the strength of the existing subgrade, construction equipment used, thickness of the initial soil layer over which the construction equipment will operate, and characteristics of the cover material. A "worst case" scenario, resulting in the most extreme installation stresses, would include operating heavy construction equipment on a thin initial layer of angular aggregate placed over a geotextile atop very soft subgrade material.

A framework for determining required survivability requirements for a geotextile is presented in Section 6200.4.A, found in proposed *DMS 6200 – Geotextiles*. Class 1 geotextiles have the most stringent strength requirements and are appropriate for more extreme construction conditions, while Class 3 geotextiles are characterized by the most relaxed requirements. It is important to note that this approach is based on a widely recognized national document, AASHTO M288—Geotextile Specification for Highway Applications. As a result, many manufacturers include compliance with Class 1, 2, and 3 in product literature.

Based on expected construction conditions, an appropriate geotextile class should be selected from Table 1 found in proposed DMS 6200. Required geotextile strength values are provided in Table 2 of the DMS 6200.

Performance Requirements

In order to perform effectively, a geotextile should also meet certain application-based performance requirements. If a geotextile is expected to perform the filtration function, i.e., if it is placed for a *Trench Drain*, *Underdrain*, *Base or Subbase Stabilization*, or *Subgrade Restraint*, it must retain soil particles while allowing an adequate amount of flow across its plane (see Figure A3). Selection of a geotextile that will adequately retain soil particles is based on a comparison of the average geotextile pore size, or apparent opening size (AOS), with a measure of particle size in the adjacent soil. A finer soil, with smaller soil particles, requires a smaller maximum AOS, and vice versa for a coarser soil. Adequate flow is ensured by specifying a minimum geotextile permittivity, a measure of the cross-plane flow capacity of a geotextile (permeability divided by geotextile thickness). The geotextile permeability should be high enough so that a barrier is not created to water flowing through the adjacent soil. Therefore, a coarser adjacent soil results in a higher minimum geotextile permeability, and vice versa.

A geotextile placed for *Base or Subbase Separation* is not expected to perform the filtration function. It is only placed to prevent soil migration and aggregate intrusion. As a result, the required maximum AOS is lower than those for a geotextile performing filtration. Similarly, the minimum required permittivity is significantly lower than that for a geotextile performing filtration.

4. Installation Guidelines

Following appropriate installation procedures is essential to ensuring that a geotextile survives installation and performs as intended over its life cycle. Installation procedures are slightly different for each of the three groups of applications: *Subsurface Drainage*, *Pavement Structural Section*, and *Subgrade Restraint*.

Subsurface Drainage

These installation guidelines are related to placing a geotextile around the perimeter of a trench as part of a subsurface drainage system (see Figures A5 and A6), i.e., for the following applications:

- *Trench Drain*
- *Underdrain*

The geotextile shall not be placed when weather conditions, in the opinion of the engineer, are not suitable to allow placement or installation. This will normally be at times of wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat.

Materials. Geotextile shall meet the material requirements of proposed *TxDOT DMS 6200*. The geotextile shall be covered while in storage to minimize potential damages before installation. Cover and elevate geotextile rolls during storage to protect them from the following:

- Site construction damage (tearing, excessive mud, wet cement, epoxy, etc.);
- Precipitation;
- Extended ultraviolet radiation including direct sunlight;
- Chemicals that are strong acids or strong bases;
- Temperatures above 160 °F and below -22 °F.

Geotextiles which have not been ultraviolet stabilized shall not remain uncovered for longer than 7 days after the installation. Ultraviolet stabilized materials shall not remain exposed longer than 14 days after installation.

Installation. Figure A9 shows the six basic steps in the construction of a *Trench Drain* or *Underdrain*: excavate the trench, place the geotextile along the perimeter, add bedding for drainage, place drainage aggregate and compact, wrap the geotextile over the top of the drainage aggregate, and backfill and compact the top.

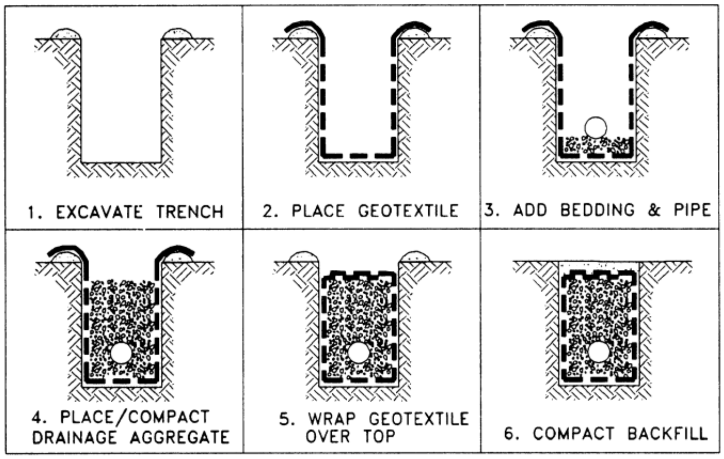


Figure A9. Geotextile placement for subsurface drainage (Holtz et al. 1998)

1. **Excavating and preparing the trench.** Excavate trenches using a wheel or chain trencher or other trenching method approved by the Engineer. Grade trench bottoms to the shape of the underdrain pipe. Ensure that trench is wide enough so that backfill may be properly placed and compacted.

   Prepare the bottom and sides of the trench so that no damage will occur to the geotextile upon placement. To minimize the damage, the bottom and the sides of the trench shall be smooth and free of stones, sticks, and other debris or irregularities that might puncture or damage the geotextile during placement. Material with defects, rips, holes, flaws, deterioration, or other damage should not be used. Construction equipment should never be operated directly on the geotextile under any circumstances.

   See Figure A9-1 for excavated trench illustration.

2. **Geotextile Placement.** The graded surface of the bottom shall be smooth and free of debris. When placing the geotextile, it shall be unrolled in line with the placement of the new aggregate. The geotextile shall be placed free of tension, stress, or wrinkles, and with minimal void space between the geotextile and the ground surface. See Figure A9-2 for illustration.

   The geotextile shall be inspected periodically during construction, and should be repaired immediately whenever any damage is founded. Place a sufficient width of geotextile to entirely cover the perimeter of the trench and allow for the required overlap. Successive sheets of geotextiles shall be overlapped a minimum of 12 inches, with the upstream sheet overlapping the downstream sheet. The geotextiles shall not be dragged across the site and the backfilled aggregate should not be dropped from a height greater than three feet.

3. **Damage Repairs.** If the geotextile is damaged during installation or drainage aggregate placement, a geotextile patch shall be placed over the damaged area extending beyond the

damaged area a distance of 3 feet.

4. **Aggregate backfill.** Placement of drainage aggregate should proceed immediately following placement of the geotextile. The geotextile should be covered with a minimum of 12 inches of loosely placed aggregate prior to compaction. If a perforated collector pipe is to be installed in the trench, a bedding layer of drainage aggregate should be placed below the pipe, with the remainder of the aggregate placed to the minimum required construction depth (Figure A9-3 and A9-4).

5. **Overlapping.** In trenches equal to or greater than 12 inches wide, after placing the drainage aggregate the geotextile shall be folded over the top of the backfill material in a manner to produce a minimum overlap of 12 inch. In trenches less than 12 inches but greater than 4 inches wide, the overlap shall be equal to the width of the trench. Where the trench is less than 4 inches wide the geotextile overlap shall be sewn or otherwise bonded. All seams shall be subject to the approval of the engineer. See Figure A9-5 for illustration.

6. **Compaction.** The aggregate should be compacted with vibratory equipment to the density requirement of TxDOT. If higher compactive effort is required, a higher survivability geotextile should be considered (Figure A9-6).

Pavement Structural Section

These installation guidelines are related to placing a geotextile between base or subbase and subgrade (see Figure A10 for the illustration) for any of the following applications:

- *Base or Subbase Separation*
- *Base or Subbase Stabilization*
- *Base or Subbase Capillary Barrier*
- *Base or Subbase Reinforcement*

The geotextiles shall not be placed when weather conditions, in the opinion of the engineer, are not suitable to allow placement or installation. This will normally be at times of wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat.

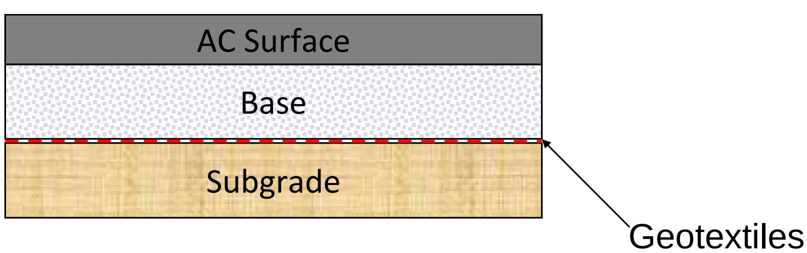


Figure A10. Location of geotextile in Pavement Structural Section applications

Materials. Geotextile shall meet the material requirements of proposed *TxDOT DMS 6200*. The geotextile shall be covered while in storage to minimize potential damages before installation. Cover and elevate geotextile rolls during storage to protect them from the following:

- Site construction damage (tearing, excessive mud, wet cement, epoxy, etc.);
- Precipitation;
- Extended ultraviolet radiation including direct sunlight;
- Chemicals that are strong acids or strong bases;
- Temperatures above 160 °F and below -22 °F.

Geotextiles which have not been ultraviolet stabilized shall not remain uncovered for longer than 7 days after the installation. Ultraviolet stabilized materials shall not remain exposed longer than 14 days after installation.

Equipment. Mechanical or manual laydown equipment shall be capable of handling full rolls of fabric and laying the fabric smoothly, without wrinkles or folds. The equipment shall be in accordance with the fabric manufacturer's recommendations or as approved by the engineer.

Installation. Placement of a geotextile in the pavement structural section should generally consist of the following steps:

1. Surface Preparation. The installation site shall be prepared by clearing, grubbing, and excavating or filling the area to the design grade. This includes the removal of topsoil and vegetation. Soft spots and unsuitable areas identified during site preparation shall be excavated and backfilled with select material and compacted using normal procedures, as directed.

2. Geotextile Placement. The geotextile shall be unrolled and placed in intimate contact with the subgrade soil, without wrinkles or folds, on the prepared subgrade in the direction of construction traffic. Wrinkles and folds in the geotextile (not associated with roadway curves) shall be removed by stretching and staking as required. Adjacent geotextile rolls shall be overlapped, sewn or joined as required in the plans (see Table A1 for overlap requirements).

Table A1. Overlap Requirements (AASHTO 2006)

Soil CBR	Minimum overlap
Greater than 3	300–450 mm
1–3	0.6–1 m
0.5–1	1 m or sewn
Less than 0.5	Sewn
All roll ends	1 m or sewn

On curves, the geotextile may be folded or cut to conform to the curve. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock. See Figure A11 for illustration.

3. Seaming. If a sewn seam is to be used, the thread used shall consist of high strength polypropylene or polyester. Nylon thread shall not be used. For seams that are sewn in the field, the contractor shall provide at least a two-meter length of sewn seam for sampling by the engineer before the geotextile is installed. The sample must be sewn using the same equipment and procedures as will be used in production. The contractor shall submit the seam assembly description, including the seam type, stitch type, sewing thread and stitch density, along with the sample of the seam. For seams that are sewn in the factory, the engineer shall obtain samples of the factory seams at random from any roll of geotextile that is used on the project.

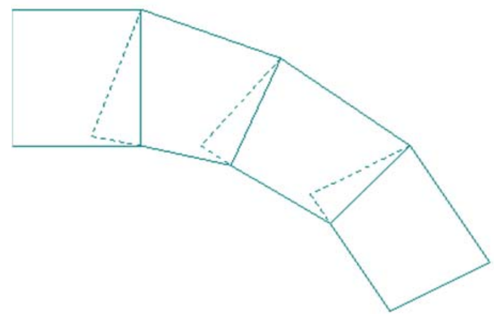


Figure A11. Appropriate direction of overlap when placing geotextile in curve

4. Geotextile Inspection. Prior to covering, the geotextile shall be inspected to ensure that the geotextile has not been damaged (i.e., holes, tears, rips) during installation. The inspection shall be performed by the engineer or the engineer's designated representative. It is recommended that the designated representative be a certified inspector.

Damaged geotextiles, as identified by the inspector, shall be repaired immediately. Cover the area with a geotextile patch that covers entirely and extends beyond the damaged area approximately 3 feet (100mm). Placement procedures should then be modified to eliminate further damage from taking place (i.e., increase initial lift thickness, decrease equipment loads, etc.). Repair of all damaged geotextile should be at contractor's expense.

5. Soft Ground Requirement. Where geotextiles are to be placed over soft ground, typically characterized by a CBR less than or equal to 3, construction vehicles shall be limited in size and weight such that rutting in the initial lift above the geotextile is not greater than 3 inches (75 mm) deep. Turning of vehicles on the first lift above the geotextile is not permitted. Compaction of the first lift above the geotextile over soft ground shall be limited to placing and spreading equipment only. No sheep-foot type equipment will be allowed on the first lift. Subsequent lifts will be closely observed during compaction, and if any subgrade failures occur during compaction operations, lightweight compaction equipment shall be used.

6. Base or Subbase Placement. The geotextile may be held in place prior to placement of cover by pins, staples or piles of fill or rocks. The subbase shall be placed by end dumping onto the geotextile from the edge of the geotextile, or over previously placed base or subbase aggregate. Place base or subbase material in a manner to minimize slippage of the geotextile. If excessive slippage occurs, use steel securing pins 18 inch (460 mm) long, 3/16 inch (4.75 mm) in diameter, pointed at one end, and with a 1.5 inch (40 mm) washer head at the other end at a maximum spacing of 6 feet (1.8m). If permitted, alternate securing devices may be used.

Direct traffic on the geotextile, along with any sudden stops, starts, or turns on the subbase material by construction equipment, shall not be allowed. Place the backfill material in uniform layers so that there is the minimum specified lift thickness between the geotextile and equipment tires or tracks at all times. A minimum thickness of 8 inches (200 mm) is recommended. On subgrade having a CBR less than 1, the subbase aggregate shall be spread simultaneously with dumping to minimize the potential of a localized subgrade failure. The initial lift thickness shall be 12 inch (300 mm) or more, and no vibratory compaction will be allowed on the first lift.

7. Compaction. A smooth drum roller shall be used to achieve the required density. Any ruts occurring during construction shall be filled with additional subbase material and compacted to the specified density. The use of vibratory compaction will not be allowed, as it may cause damage to the geotextile. Under no circumstances shall cover material be dropped on unprotected geotextiles from a height greater than 3 feet (100 mm) above the surface of the geotextile.

Construction Access (Road Embankment Stabilization)

These installation guidelines are related to placing a geotextile between a weak subgrade and adjacent fill material for *Subgrade Restraint*.

The geotextiles shall not be placed when weather conditions, in the opinion of the engineer, are not suitable to allow placement or installation. This will normally be at times of wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat.

Materials. Geotextile shall meet the material requirements of *proposed TxDOT DMS 6200*. The geotextile shall be covered while in storage to minimize potential damages before installation. Cover and elevate geotextile rolls during storage to protect them from the following:

- Site construction damage (tearing, excessive mud, wet cement, epoxy, etc.);
- Precipitation;
- Extended ultraviolet radiation including direct sunlight;
- Chemicals that are strong acids or strong bases;
- Temperatures above 160 °F and below -22 °F.

Geotextiles which have not been ultraviolet stabilized shall not remain uncovered for longer than 7 days after the installation. Ultraviolet stabilized materials shall not remain exposed longer than 14 days after installation.

Equipment. Mechanical or manual laydown equipment shall be capable of handling full rolls of fabric and laying the fabric smoothly, without wrinkles or folds. The equipment shall be in accordance with the fabric manufacturer's recommendations or as approved by the engineer.

Installation. Placement of a geotextile in the pavement structural section should generally consist of the following steps:

1. Surface Preparation. The installation site shall be prepared to the extent possible, depending on site and equipment access, by clearing, grubbing, and excavating or filling the area to the design grade. This includes the removal of topsoil and vegetation.

2. Geotextile Placement. The geotextile shall be unrolled and placed in intimate contact with the subgrade soil, without wrinkles or folds, on the prepared subgrade in the direction of construction traffic. Wrinkles and folds in the geotextile (not associated with roadway curves) shall be removed by stretching and staking as required. Adjacent geotextile rolls shall be overlapped, sewn or joined as required in the plans (again, see Table A1 for overlap requirements).

On curves, the geotextile may be folded or cut to conform to the curve. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock. See Figure A11 for illustration.

3. Seaming. If a sewn seam is to be used, the thread used shall consist of high strength polypropylene or polyester. Nylon thread shall not be used. For seams that are sewn in the field, the contractor shall provide at least a two-meter length of sewn seam for sampling by the engineer before the geotextile is installed. The sample must be sewn using the same equipment and procedures as will be used in production. The contractor shall submit the seam assembly description, including the seam type, stitch type, sewing thread and stitch density, along with the sample of the seam. For seams that are sewn in the factory, the engineer shall obtain samples of the factory seams at random from any roll of geotextile that is used on the project.

4. Geotextile Inspection. Prior to covering, the geotextile shall be inspected to ensure that the geotextile has not been damaged (i.e., holes, tears, rips) during installation. The inspection shall be performed by the engineer or the engineer's designated representative. It is recommended that the designated representative be a certified inspector.

Damaged geotextiles, as identified by the inspector, shall be repaired immediately. Cover the area with a geotextile patch that covers entirely and extends beyond the damaged area approximately 3 feet (100mm). Placement procedures should then be modified to eliminate further damage from taking place (i.e., increase initial lift thickness, decrease equipment loads, etc.). Repair of all damaged geotextile should be at contractor's expense.

5. Base or Subbase Placement. The geotextile may be held in place prior to placement of cover by pins, staples or piles of fill or rocks. The subbase shall be placed by end dumping onto the geotextile from the edge of the geotextile, or over previously placed base or subbase aggregate. Construction equipment should be limited in size and weight such that rutting in the initial lift above the geotextile is not greater than 3 inches (75 mm) deep. Construction equipment shall not operate directly on exposed geotextile. Compaction of first lift above the geotextile shall be limited to placing and spreading equipment only. No sheep-foot type equipment will be allowed on the first lift. Place base or subbase material in a manner to minimize slippage of the geotextile. If excessive slippage occurs, use steel securing pins 18 inch (460 mm) long, 3/16 inch (4.75 mm) in diameter, pointed at one end, and with a 1.5 inch (40 mm) washer head at the other end at a maximum spacing of 6 feet (1.8m). If permitted, alternate securing devices may be used.

Direct traffic on the geotextile, along with any sudden stops, starts, or turns on the subbase material by construction equipment, shall not be allowed. Place the backfill material in uniform layers so that there is the minimum specified lift thickness between the geotextile and equipment tires or tracks at all times. A minimum thickness of 8 inches (200 mm) is recommended. On subgrade having a CBR less than 1, the subbase aggregate shall be spread simultaneously with dumping to minimize the potential of a localized subgrade failure. The initial lift thickness shall be 12 inch (300 mm) or more, and no vibratory compaction will be allowed on the first lift.

6. Compaction. A smooth drum roller shall be used to achieve the required density. Any ruts occurring during construction shall be filled with additional subbase material and compacted to the specified density. The use of vibratory compaction will not be allowed, as it may cause damage to the geotextile. Under no circumstances shall cover material be dropped on unprotected geotextiles from a height greater than 3 feet (100 mm) above the surface of the geotextile.

Appendix B: Departmental Material Specification

DMS – 6XXX (*)
GEOTEXTILES

EFFECTIVE DATE: XXXX

(*) Note : This DMS is referred in Report 0-5812-1 as « proposed DMS6200 »

6XXX.1. Description This specification governs for the material certification, sampling and testing, and material requirements of geotextiles used for roadway applications.

6XXX.2. Material Producer List. There is currently no TxDOT Material Producer List for this DMS. Products may be checked for approval by consulting published results from tests performed through the National Transportation Product Evaluation Program (NTPEP). These results are contained in the most recent version of NTPEP Publication 137: *Laboratory Results of Evaluations on Geotextiles & Geosynthetics*.

6XXX.3. Sampling and Testing Requirements. Sample in accordance with Tex-735-I. Perform tests in accordance with the test methods listed in Tables 2 and 3.

6XXX.4. Material Requirements. Strength requirements for geotextiles used in transportation applications are governed by installation stresses—the highest stresses the geotextile will be subjected to over a project's lifetime. These strength properties represent a geotextile's survivability. In addition to survivability requirements, each specific application requires different engineering properties from the geotextile.

A. Survivability Requirements. The required survivability of a geotextile is governed by construction conditions. Tables 1 and 2 provide a framework for determining applicable strength requirements.

Table 1
Survivability Classes[1,2]

Site Soil CBR at Installation[3,4]	< 1		1 to 3		> 3	
Equipment Ground Contact Pressure (psi)	> 50	< 50	> 50	< 50	> 50	< 50
Initial Cover Thickness[5] (compacted, inches)						
4[6,7]	NR[8]	NR	1	1	2	2
6	NR	NR	1	1	2	2
12	NR	1	2	2	2	2
18	1	2	2	2	2	2

1. If angular aggregate (crushed stone) is placed adjacent to geotextile, use Class 1.

2. Engineer may specify a lower survivability class if (a) the engineer has found the class of geotextile to have sufficient survivability based on field experience, or (b) the engineer has found the class of geotextile to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field test section constructed under anticipated field conditions.
3. Assume saturated CBR unless construction scheduling can be controlled.
4. Equivalent measure of strength may be substituted for CBR per engineer's judgment.
5. Maximum aggregate size not to exceed one-half the compacted cover thickness.
6. For low-volume, unpaved roads (ADT < 200 vehicles).
7. The 4-in. minimum cover is limited to existing road bases and is not intended for use in new construction.
8. NR = Not Recommended.

Table 2
Survivability Requirements by Class[1]

			Geotextile Class					
			Class 1		Class 2		Class 3	
	Test Method	Units	Elongation <50%[2]	Elongation >50%[2]	Elongation <50%[2]	Elongation >50%[2]	Elongation <50%[2]	Elongation >50%[2]
Grab Strength	ASTM D4632	lbf	315	205	250	160	180	115
Sewn Seam Strength[3]	ASTM D4632	lbf	280	180	220	140	160	100
Tear Strength	ASTM D4533	lbf	115	80	90	60	70	40
Puncture Strength	ASTM D6241	lbf	620	435	495	310	375	225

1. All numeric values represent minimum requirements in the weaker principle direction.
2. As measured in accordance with ASTM D 4632.
3. When sewn seams are required.

B. Application-based Property Requirements. Table 3 provides application-based property requirements.

Table 3
Geotextile Property Requirements

Property	ASTM Test Method	Units	Percent Passing #200 sieve[1]	Requirement by Application[2]						
				Edge Drain	Underdrain[3]	Base or Subbase Separation	Base or Subbase Stabilization	Base or Subbase Capillary Barrier	Base or Subbase Reinforcement	Subgrade Restraint
Survivability	*See Table 1*		N/A	*See Table 1*					Class 1	Class 1
			< 15	0.5	0.5		0.5			0.5
Permittivity[4]	D 4491	sec^{-1}	15 to 50	0.2	0.2	0.02	0.2	Report Only[5]	Report Only[5]	0.2
			> 50	0.1	0.1		0.1			0.1
			< 15	40	40		40			40
Apparent Opening Size (AOS)	D 4751	Sieve No.	15 to 50	60	60	30	60	Report Only[5]	Report Only[5]	60
			> 50	70	70		70			70
Ultraviolet Stability	D 4355	%	N/A	≥ 50% after 500 hours of exposure						

1. Based on particle size analysis of *in situ* soil in accordance with Tex-110-E.
2. Values for Apparent Opening Size (AOS) are maximum requirements. All other values are minimum requirements.
3. Due to critical nature of this application, performance testing should also be completed with qualified geotextile and site-specific soil to ensure long-term flow compatibility.
4. Default permittivity values. The geotextile permittivity should be greater than that of the soil.
5. Recommended values are expected to be developed with future research.

6XXX.5. Packaging. Provide fabric in the length and width specified on the plans, specified in the purchase order awarded by the State, or as approved.

Wind fabric onto suitable cylindrical forms or cores to aid in handling and unrolling.

Package fabric individually in a suitable container to protect the geotextile from damage due to ultraviolet light and moisture during normal storage and handling.

6XXX.6. Identification. Identify each roll with a tag or label affixed to the outside of the roll on one end. List the following information on the tag or label:

- Unique roll number, serially designated;
- Manufacturer’s lot number or control numbers, if any;
- Name of fabric manufacturer;
- Brand name of the product;
- Manufacturer’s style or catalog designation of the fabric, if any;
- Roll width in meters (inches);
- Roll length in meters (yards).

6XXX.7. Basis for Rejection. Should any individual sample selected at random from 100 rolls, or fraction thereof, fail to meet any specification requirement, then that roll will be rejected.

Two additional samples will be taken, one from each of two other rolls selected at random from the same 100-roll lot, or fraction thereof. If either of these two additional samples fails to comply with any portion of the Specification, then the entire quantity of rolls represented by that sample will be rejected.

Appendix C: Draft Construction Specifications

Part 1: Use of Geotextile in Subsurface Drainage System

1. Description. Construct a subsurface drainage system using a geotextile around the perimeter of a trench drain or underdrain in accordance with the procedures and requirements shown.

2. Definition of subsurface drainage system with geotextiles. Identify the type of subsurface drainage system to be constructed using geotextile. Subsurface drainage systems include trench drains and underdrains. A typical trench drain cross section is constructed as shown in Figure C1. A typical underdrain cross section is constructed as shown in Figure C2.

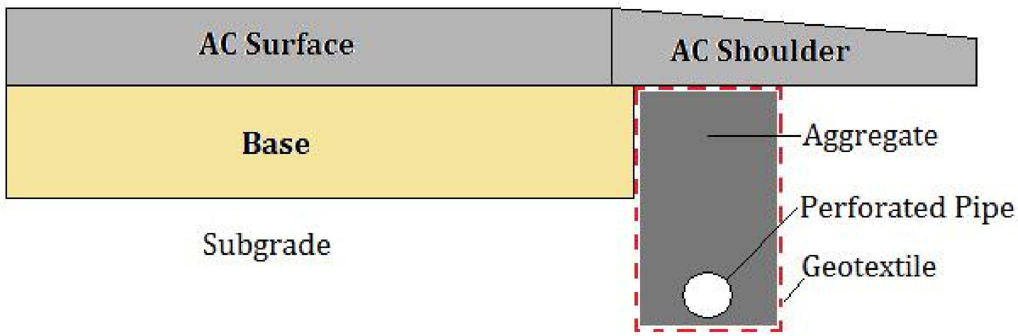


Figure C1: Typical trench drain

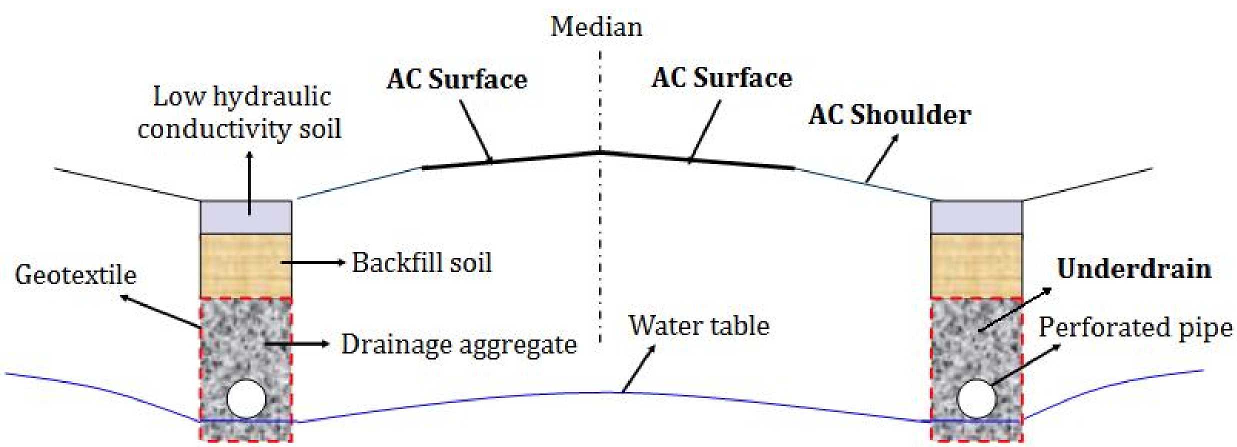


Figure C2. Typical underdrain

3. Materials and Storage Requirements. Geotextile shall meet the material requirements of proposed TxDOT DMS 6200. The geotextile shall be covered while in storage to minimize potential damages before installation. Cover and elevate geotextile rolls during storage to protect them from the following:

- Site construction damage (tearing, excessive mud, wet cement, epoxy, etc.);
- Precipitation;
- Extended ultraviolet radiation including direct sunlight;
- Chemicals that are strong acids or strong bases;

- Temperatures above 160 °F and below -22 °F.

Geotextiles that have not been ultraviolet stabilized shall not remain uncovered for longer than 7 days after the installation. Ultraviolet stabilized materials shall not remain exposed longer than 14 days after installation.

4. Construction.

A. General. Provide, produce, transport, furnish, and place the geotextile in accordance with these specifications and as approved. The trench drain or underdrain shall be constructed following the six basic steps as depicted in Figure C3: excavate the trench, place the geotextile along the perimeter, add bedding for drainage, place drainage aggregate and compact, wrap the geotextile over the top of the drainage aggregate and backfill and compact the top. Follow each step described in detail herein.

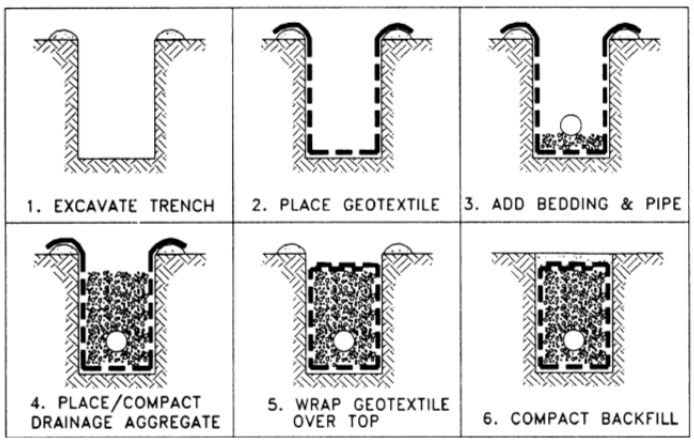


Figure C3. Geotextile placement for subsurface drainage (Holtz et al. 1998)

B. **Excavating and preparing the trench.** Excavate the trench using a wheel or chain trencher or other trenching method approved by the Engineer. Grade trench bottoms to the shape of the underdrain pipe. Ensure that trench is wide enough so that backfill may be properly placed and compacted.

Prepare the bottom and sides of the trench so that no damage will occur to the geotextile upon placement. To minimize damage of the geotextile, the bottom and the sides of the trench shall be smooth and free of stones, sticks, and other debris or irregularities that might puncture or damage the geotextile during placement. Reject material with defects, rips, holes, flaws, deterioration, or other damage. Do not operate construction equipment directly on the geotextile under any circumstances. See Figure C3.1 for illustration of trench excavation.

C. **Geotextile Placement.** Do not place the geotextile when weather conditions are not suitable to allow placement or installation such as wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat.

The graded surface of the bottom of the trench shall be smooth and free of debris. When placing the geotextile, unroll it in line with the placement of the new aggregate. The geotextile shall be placed free of tension, stress, or wrinkles, and with minimal void space between the geotextile and the ground surface. See Figure C3.2 for illustration.

The geotextile shall be inspected periodically during construction, and should be repaired immediately whenever any damage is founded. Place a sufficient width of geotextile to entirely cover the perimeter of the trench and allow for the required overlap. Successive sheets of geotextiles shall be overlapped a minimum of 12 inches, with the upstream sheet overlapping the downstream sheet. Do not drag the geotextiles across the site and do not drop the backfilled aggregate from a height greater than three feet.

D. **Damage Repairs.** If the geotextile is damaged during installation or drainage aggregate placement, a geotextile patch shall be placed over the damaged area extending beyond the damaged area a distance of 3 feet.

E. **Aggregate backfill.** Proceed with placement of drainage aggregate immediately following placement of the geotextile. Cover the geotextile with a minimum of 12 inches of loosely placed aggregate prior to compaction. Should a perforated collector pipe to be installed in the trench, then place a bedding layer of drainage aggregate below the pipe, with the remainder of the aggregate placed to the minimum required construction depth (See Figures C3.3 and C3.4).

F. **Overlapping.** In trenches equal to or greater than 12 inches wide, after placing the drainage aggregate, fold the geotextile over the top of the backfill material in a manner to produce a minimum overlap of 12 inch. In trenches less than 12 inches but greater than 4 inches wide, the overlap shall be equal to the width of the trench. Where the trench is less than 4 inches wide the geotextile overlap shall be sewn or otherwise bonded. All seams shall be subject to the approval of the engineer. See Figure C3.5 for illustration.

G. **Compaction.** Compact the aggregate with vibratory equipment to the density requirement of TxDOT. If higher compactive effort is required, use a higher survivability geotextile (See Figure C3.6).

Part 2: Use of Geotextile in Pavement Structural Sections

1. **Description**. Follow this installation guide for placing a geotextile between base or subbase or base and subgrade for any of the following applications (Figure C4):

   - *Base or Subbase Separation*
   - *Base or Subbase Stabilization*
   - *Base or Subbase Capillary Barrier*
   - *Base or Subbase Reinforcement*

   Do not place geotextiles when weather conditions, in the opinion of the engineer, are not suitable to allow placement or installation. This will normally be at times of wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat.

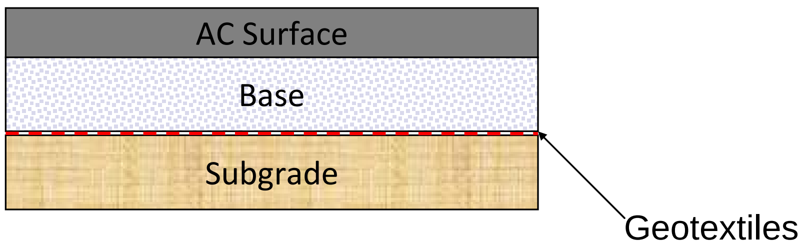


Figure C4. Location of geotextile in Pavement Structural Section applications

2. **Materials and Storage Requirements.** Geotextile shall meet the material requirements of proposed *TxDOT DMS 6200*. Cover and elevate geotextile rolls during storage to minimize potential damages before installation and to protect them from the following:

   - Site construction damage (tearing, excessive mud, wet cement, epoxy, etc.);
   - Precipitation;
   - Extended ultraviolet radiation including direct sunlight;
   - Chemicals that are strong acids or strong bases;
   - Temperatures above 160 °F and below -22 °F.

   Do not leave geotextiles which have not been ultraviolet stabilized uncovered for longer than 7 days after the installation. Do not expose ultraviolet stabilized materials longer than 14 days after installation.

3. **Equipment.** Use mechanical or manual laydown equipment capable of handling full rolls of fabric and laying the fabric smoothly, without wrinkles or folds. The equipment shall be in accordance with the fabric manufacturer's recommendations or as approved by the engineer.

4. **Installation.** Follow the following steps to place a geotextile in the pavement structural section:
   - **A. Surface Preparation.** Prepare the installation site by clearing, grubbing, and excavating or filling the area to achieve the design grade:
     - a. Remove topsoil and vegetation.

b. Identify soft spots and unsuitable areas.
c. Excavate and backfill the soft spots and unsuitable areas with select materials.
d. Compact the backfilled area using engineered procedures, as directed.

B. Geotextile Placement. Unroll the geotextile and place it in intimate contact with the subgrade soil, without wrinkles or folds, on the prepared subgrade. Place the geotextile in the direction of construction traffic. Remove wrinkles and folds not associated with roadway curves by stretching and staking as required. Overlap adjacent geotextile rolls. Secure the overlapped area by sewing or joining as required in the plans (see Table C1 for overlap requirements).

Table C1. Overlap Requirements (AASHTO 2006)

Soil CBR	Minimum overlap
Greater than 3	300–450 mm
1–3	0.6–1 m
0.5–1	1 m or sewn
Less than 0.5	Sewn
All roll ends	1 m or sewn

Fold or cut the geotextile to conform to the shape of the curves. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock. See Figure C5 for illustration.

C. Seaming. Should a sewn seam is to be used, use high strength polypropylene or polyester threads. Do not use nylon thread. Follow these guidelines for seams that are sewn in the field:

a. Ask the contractor to provide at least a two-meter length of the sewn seam for sampling by the engineer before the geotextile is installed.
b. Ask the contractor to sew the sample using the same equipment and procedures as will be used in production.
c. Ask the contractor to submit the seam assembly description, including the seam type, stitch type, sewing thread and stitch density, along with the sample of the seam.

For seams that are sewn in the factory obtain samples of the factory seams at random from any roll of geotextile that is used on the project.

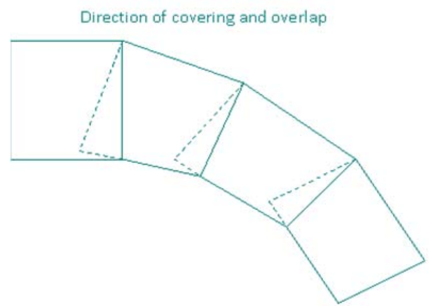


Figure C5. Appropriate direction of overlap when placing geotextile in curve

D. Geotextile Inspection. Inspect the geotextile prior to covering to ensure that the geotextile has not been damaged (i.e., holes, tears, rips) during installation. The inspection shall be performed by the engineer or the engineer's designated representative. It is recommended that the designated representative be a certified inspector.

Repair damaged geotextiles, as identified by the inspector, immediately. Cover the area with a geotextile patch that covers entirely and extends beyond the damaged area approximately 3 feet (100mm). Modify the placement procedures to eliminate further damage from taking place (i.e., increase initial lift thickness, decrease equipment loads, etc.). Repair of all damaged geotextile should be at contractor's expense.

E. Soft Ground Requirements. Identify soft grounds which are typically characterized by a CBR less than or equal to 3. Limit the size and the weight of the construction vehicles over the soft grounds such that rutting in the initial lift above the geotextile is not greater than 3 inches (75 mm) deep. Do not turn off vehicles on the first lift above the geotextile. Limit the compaction of the first lift above the geotextile over soft ground to placing and spreading equipment only. Do not use sheep-foot type equipment on the first lift. Observe subsequent lifts closely during compaction, and if any subgrade failures occur during compaction operations, use lightweight compaction equipment.

F. Base or Subbase Placement. Use pins, staples or piles of fill or rocks to secure the geotextile in place prior to placement of cover. Place the subbase by end dumping onto the geotextile from the edge of the geotextile, or over previously placed base or subbase aggregate. Place base or subbase material in a manner to minimize slippage of the geotextile. If excessive slippage occurs, use steel securing pins 18 inch (460 mm) long, 3/16 inch (4.75 mm) in diameter, pointed at one end, and with a 1.5 inch (40 mm) washer head at the other end at a maximum spacing of 6 feet (1.8m). If permitted, alternate securing devices may be used.

Do not allow direct traffic on the geotextile, along with any sudden stops, starts, or turns on the subbase material by construction equipment. Place the backfill material in uniform layers so that there is the minimum specified lift thickness between the geotextile and equipment tires or tracks at all times. A minimum thickness of 8 inches (200 mm) is recommended. On subgrade having a CBR less than 1, spread the subbase aggregate simultaneously with dumping to minimize the potential of a localized subgrade failure. Use 12 inch (300 mm) or more for the initial lift thickness. Do not use any vibratory compaction on the first lift.

G. Compaction. Use a smooth drum roller to achieve the required density. Fill any ruts occurring during the construction with additional subbase material and compact them to the specified density. Do not use vibratory compaction as it may cause damage to the geotextile. Under no circumstances drop the cover material on unprotected geotextiles from a height greater than 3 feet (100 mm) above the surface of the geotextile.

Part 3: Use of Geotextile for Construction Access in Unpaved Sections

1. **Description**. Follow this installation guide for placing a geotextile between a weak subgrade and adjacent fill material for *Subgrade Restraint*.

   Do not place geotextiles when weather conditions, in the opinion of the engineer, are not suitable to allow placement or installation. This will normally be at times of wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat.

2. **Materials and Storage Requirements.** Geotextile shall meet the material requirements of proposed *TxDOT DMS 6200*. Cover and elevate geotextile rolls during storage to minimize potential damages before installation and to protect them from the following:

   - Site construction damage (tearing, excessive mud, wet cement, epoxy, etc.);
   - Precipitation;
   - Extended ultraviolet radiation including direct sunlight;
   - Chemicals that are strong acids or strong bases;
   - Temperatures above 160 °F and below -22 °F.

   Do not leave geotextiles which have not been ultraviolet stabilized uncovered for longer than 7 days after the installation. Do not expose ultraviolet stabilized materials longer than 14 days after installation.

3. **Equipment.** Use mechanical or manual laydown equipment capable of handling full rolls of fabric and laying the fabric smoothly, without wrinkles or folds. The equipment shall be in accordance with the fabric manufacturer's recommendations or as approved by the engineer.

4. **Installation.** Follow the following steps to place a geotextile in the pavement structural section:

   A. **Surface Preparation.** Prepare the installation site by clearing, grubbing, and excavating or filling the area to achieve the design grade:

      a. Remove topsoil and vegetation.
      b. Identify soft spots and unsuitable areas.
      c. Excavate and backfill the soft spots and unsuitable areas with select materials.
      d. Compact the backfilled area using engineered procedures, as directed.

   B. **Surface Preparation.** Prepare the installation site to the extent possible, depending on site and equipment access, by clearing, grubbing, and excavating or filling the area to the design grade. Remove the topsoil and vegetation.

   C. **Geotextile Placement.** Unroll the geotextile and place it in intimate contact with the subgrade soil, without wrinkles or folds, on the prepared subgrade. Place the geotextile in the direction of construction traffic. Remove wrinkles and folds not associated with roadway curves by stretching and staking as required. Overlap adjacent geotextile rolls.

Secure the overlapped area by sewing or joining as required in the plans (see Table C1 for overlap requirements).

Fold or cut the geotextile to conform to the shape of the curves. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock. See Figure C5 for illustration.

D. Seaming. Should a sewn seam is to be used, use high strength polypropylene or polyester threads. Do not use nylon thread. Follow these guidelines for seams that are sewn in the field:

a. Ask the contractor to provide at least a two-meter length of the sewn seam for sampling by the engineer before the geotextile is installed.
b. Ask the contractor to sew the sample using the same equipment and procedures as will be used in production.
c. Ask the contractor to submit the seam assembly description, including the seam type, stitch type, sewing thread and stitch density, along with the sample of the seam.

For seams that are sewn in the factory obtain samples of the factory seams at random from any roll of geotextile that is used on the project.

E. Geotextile Inspection. Inspect the geotextile prior to covering to ensure that the geotextile has not been damaged (i.e., holes, tears, rips) during installation. The inspection shall be performed by the engineer or the engineer’s designated representative. It is recommended that the designated representative be a certified inspector.

Repair damaged geotextiles, as identified by the inspector, immediately. Cover the area with a geotextile patch that covers entirely and extends beyond the damaged area approximately 3 feet (100mm). Modify the placement procedures to eliminate further damage from taking place (i.e., increase initial lift thickness, decrease equipment loads, etc.). Repair of all damaged geotextile should be at contractor’s expense.

F. Base or Subbase Placement. Use pins, staples or piles of fill or rocks to secure the geotextile in place prior to placement of cover. Place the subbase by end dumping onto the geotextile from the edge of the geotextile, or over previously placed base or subbase aggregate. Limit the size and the weight of the construction equipment such that rutting in the initial lift above the geotextile is not greater than 3 inches (75 mm) deep. Do not operate the construction equipment directly on exposed geotextile. Limit the compaction of the first lift above the geotextile to placing and spreading equipment only. Do not use sheep-foot type equipment on the first lift. Place base or subbase material in a manner to minimize slippage of the geotextile. If excessive slippage occurs, use steel securing pins 18 inch (460 mm) long, 3/16 inch (4.75 mm) in diameter, pointed at one end, and with a 1.5 inch (40 mm) washer head at the other end at a maximum spacing of 6 feet (1.8m). If permitted, alternate securing devices may be used.

Do not allow direct traffic on the geotextile, along with any sudden stops, starts, or turns on the subbase material by construction equipment. Place the backfill material in uniform layers so that there is the minimum specified lift thickness between the geotextile and equipment tires or tracks at all times. A minimum thickness of 8 inches (200 mm) is recommended. On subgrade having a CBR less than 1, spread the subbase aggregate simultaneously with dumping to minimize the potential of a localized subgrade failure. Use 12 inch (300 mm) or more for the initial lift thickness. Do not use any vibratory compaction on the first lift.

G. Compaction. Use a smooth drum roller to achieve the required density. Fill any ruts occurring during the construction with additional subbase material and compact them to the specified density. Do not use vibratory compaction as it may cause damage to the geotextile. Under no circumstances drop the cover material on unprotected geotextiles from a height greater than 3 feet (100 mm) above the surface of the geotextile.