TECHNICAL REPORT GL-91-18

US Army Corps of Engineers

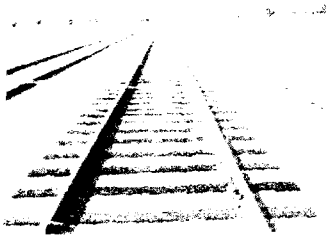
ENGINEERING USE OF GEOTEXTILES IN RAILROAD TRACK CONSTRUCTION AND REHABILITATION

by

David M. Coleman, Hugh M. Taylor

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

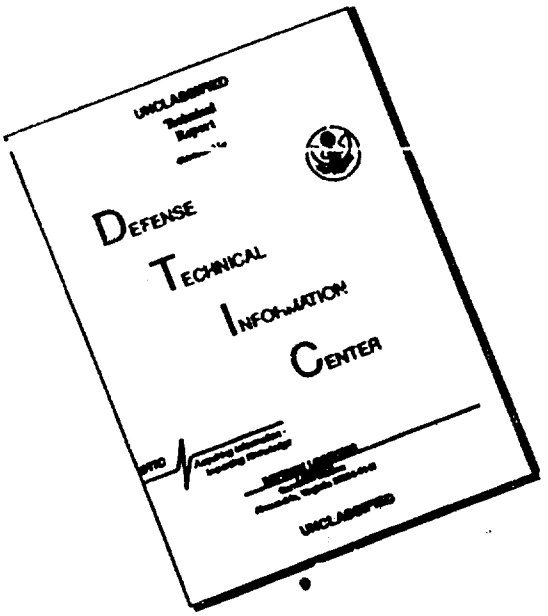


September 1991
Final Report

GEOTECHNICAL LABORATORY

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Destroy this report when no longer needed. Do not return it to the originator

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1991	Final report

4. TITLE AND SUBTITLE

Engineering Use of Geotextiles in Railroad Track Construction and Rehabilitation

5. FUNDING NUMBERS

6. AUTHOR(S)

David M. Coleman, Hugh M. Taylor

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

USAE Waterways Experiment Station,
Geotechnical Laboratory, 3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

Technical Report
GL-91-18

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report presents recommendations for the use of geotextiles in railroad track construction and rehabilitation projects. In order to provide the reader with a comprehensive package, the use of geotextiles for in-track applications, drainage applications, and erosion control applications is presented. For each of these general areas, recommended geotextile property requirements, design criteria, and installation considerations are presented. Recommended guide specifications are also given for each application.

14. SUBJECT TERMS

Drainage
Erosion control
Geotextiles
Railroads
Railroad construction

15. NUMBER OF PAGES
126

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

PREFACE

The information presented in this report has been developed through several different research projects and engineering studies over a number of years. Most of the work was performed as a part of the development of a technical manual that covers the engineering usage of geotextiles. The guide specifications presented herein were developed during a project to develop a series of guide specifications for various geotextile applications. Both of these projects were sponsored by the Huntsville Division, Corps of Engineers. Additional work was performed and this work was published in FY 1991 under the RDT&E project "Improved Design For Military Railroads." Technical Monitor was Mr. Paige Johnson, US Army Corps of Engineers.

This report was written by Messrs. H. M. Taylor, Soil and Rock Mechanics Division (S&RMD) and D. M. Coleman, Pavement Systems Division (PSD), Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES). Information concerning the use of geotextiles in filtration and drainage applications and erosion control applications was adapted from unpublished work that was performed by Messrs. S. P. Miller, S&RMD and S. L. Webster, PSD. Drafting and other technical support was performed by Mr. W. L. Hanks, S&RMD. This work was conducted under the general supervision of Dr. W. F. Marcuson III, Chief, GL, and under the direct supervision of Mr. H. H. Ulery, Jr., Chief, PSD, and Dr. A. J. Bush III, Chief, Criteria Development and Application Branch, PSD.

The Commander and Director of WES during the preparation and publication of this report was COL Larry B. Fulton, EN. The Technical Director was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic decimetres
inches	2.54	centimetres
ounces (mass) per square yard	33.90575	grams per square metre
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square feet	0.09290304	square metres
square inches	6.4516	square centimetres

ENGINEERING USE OF GEOTEXTILES IN RAILROAD TRACK CONSTRUCTION AND REHABILITATION

PART I: INTRODUCTION

Background

1. Limited use of geotextiles on commercial railroads in the United States began about 1970. The earliest installations were lightweight fabric with the most common being 4 to 6 oz/sq yd.* These applications were generally limited to highway-railroad grade crossings, turnouts, and rail crossings. In recent years the installations have included areas having problem subgrades in addition to the above applications. Heavier weight geotextiles are being used in the newer installations.

2. Past performance of railroad track having been built or rehabilitated using geotextiles has varied. A number of factors influence the performance of a geotextile in a railroad environment. Among these are the physical properties of the geotextile such as material type, weight, and strength characteristics; depth of installation; installation techniques; subgrade conditions upon placement; type and size of ballast material; amount of traffic; axle loadings; and environmental factors. Construction and performance data on many geotextile installations in the railroad industry have not been well documented in the published literature. Poor performance of geotextiles in railroad applications is often due to puncturing as a result of the extremely harsh conditions that exist at the ballast-subgrade interface. This puncturing and subsequent poor geotextile performance appear to result from improper geotextile selection for existing conditions, inadequate depth of placement, improper installation or construction practices, inadequate provision for drainage away from the track, or a combination of the above.

3. The selection of a geotextile for a railroad track application is dependent upon many factors including traffic, existing track structure, existing subgrade conditions, existing drainage conditions, and previous

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

maintenance requirements. In railroad applications geotextiles are primarily used to perform the functions of separation, filtration, and lateral drainage. Based on current knowledge, little is known of any reinforcement effect geotextiles may have on soft subgrades under railroad tracks. Therefore, geotextiles in railroad applications should not be counted on to produce any reinforcement benefits and should not be used to reduce the ballast or subballast design thickness. Geotextiles are used in railroad applications for both new construction and track rehabilitation. Geotextiles have found their greatest railroad use in those areas of commercial railroads where a large amount of track maintenance has been required due to poor drainage conditions, soft subgrade conditions, and/or high impact loadings.

Purpose

4. This report presents recommended use of geotextiles in railroad construction and rehabilitation. The use of geotextiles for in-track (between ballast and subgrade) applications, drainage applications, and erosion control applications is presented. The criteria and recommendations presented herein represent information that will be included in future revisions of the appropriate Army/Air Force technical manuals and Corps of Engineer Guide Specifications. This report is intended to fill a gap that exists in the criteria and guidance documents that are currently available to designers concerning the use of geotextiles in railroad track.

5. It must be noted that the amount of research upon which the design and use of geotextiles in railroad, and many other, applications is based upon is relatively small. To some extent this is due to the fact that marketing and use of geotextiles in these applications proceeded establishment of the engineering requirements for the particular application. Many of the index properties and specification requirements have been developed based on observations of test installations and are empirical. The information provided in this report is based upon the current (1990) state of the practice. Future research, improvements in and standardization of test methods, detailed laboratory testing programs, and other advances will at some time in the future result in changes in the recommendations presented herein.

Scope

6. This report covers physical properties and functions of geotextiles for use in railroad construction and rehabilitation. Recommended procedures are included for design and installation of geotextile systems for in-track, drainage, and erosion control applications. Recommended guide specifications covering the material selection and installation requirements for geotextiles for each of these applications are provided in Appendixes A through D.

PART II: IN-TRACK APPLICATIONS

Geotextile Use and Selection

7. The use of a geotextile under track (in-track applications) is dependent upon traffic, subgrade conditions, and environmental factors. Geotextiles are used in track when it is necessary to provide for filtration, separation of ballast and subgrade or ballast and subballast, or drainage. Geotextiles can be used beneath the ballast and/or subballast in both new track construction and the rehabilitation of existing track. An analysis of the existing or proposed conditions must be performed to determine if a geotextile is required. Table 1 provides information on soil types, soil properties, soil behavior and general recommendations for use of a geotextile. Table 1 is based on the Unified Soil Classification System (USCS), as given in American Society for Testing and Materials (ASTM) D 2487 (ASTM 1990) and can be used for preliminary decisions regarding the use of geotextiles in track. Specific decisions and designs for the use of geotextiles must be made based upon determination of the actual conditions and field testing and not determined solely from Table 1.

8. Geotextiles are normally placed between the subgrade and ballast layer or between the ballast and subballast layers if one is present. A common geotextile application is found in what is commonly known as "pumping track" and "ballast pockets" areas.

9. Under traffic the transient vertical stresses at the ballast or subballast interface are sufficient to cause the subgrade and ballast or subballast materials to intermix if the subgrade is weak. As the intermixing continues, the ballast becomes fouled by excessive fines contamination, and a loss of free drainage through the ballast occurs as well as a loss of shear strength. The ballast is pushed down into the subgrade and mixes with it. As this process continues, ballast is forced deeper and deeper into the subgrade, forming a pocket of fouled and ineffective ballast, resulting in the loss of track surface. These ballast pockets tend to collect water, further reducing the strength of the roadbed around them and result in continual track maintenance problems. Installation of geotextiles during rehabilitation of these areas provides separation, filtration, and drainage functions and can prevent

Major Divisions (1)	(2)	Classification (3)	Soil Group Name (4)	Field Identification (5)	Drainage (6)	Erosion in Exposed Slopes (7)
COARSE-GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded GRAVELS and GRAVEL-SAND mixtures, trace to some clay	Wide range in grain sizes, substantial amounts of all intermediate sizes, no dry strength	Excellent	None
		GP	Poorly graded GRAVELS and GRAVEL-SAND mixtures, trace to no silt or clay	Predominantly one size or a range of sizes with some missing, no dry strength	Excellent	None
		GM	GRAVEL some SILT, GRAVEL-SAND-SILT mixtures	Fines with low to no plasticity, slight to no dry strength	Fair to very poor	None to slight
		GC	GRAVEL some CLAY GRAVEL-SAND-CLAY mixtures	Plastic fines, medium to high dry strength	Poor to very poor	None to slight
	SAND AND SANDY SOILS	SW	Well-graded SANDS and SAND-GRAVEL mixtures, trace to no silt or clay	Wide range in grain sizes, substantial amounts of all intermediate sizes, no dry strength	Excellent	Slight to high with decreasing gravel content
		SP	Poorly graded SANDS and SAND-GRAVEL mixtures, trace to no silt or clay	Predominantly one size or a range of sizes with some missing, no dry strength	Excellent	High
		SM	SAND-SILT mixtures	Fines of low to no plasticity, slight to no dry strength	Fair to very poor	High
		SC	SAND-CLAY mixtures	Plastic fines, medium to high dry strength	Very poor	Slight
FINE-GRAINED SOILS	SILTS AND CLAYS LL < 50 LOW PLASTICITY	ML	SILTS, very fine SANDS, ROCK FLOUR	Fine-grained, slight to no dry strength	Fair to very poor	Very high
		CL	CLAYS of low to medium plasticity, CLAY-GRAVEL-SAND-SILT mixtures	Medium to high dry strength	Very poor	None to slight
		OL	ORGANIC silts and clays of low plasticity	High smell, dark color, mottled appearance, slight to high dry strength	Poor to very poor	Variable
	SILTS AND CLAYS LL > 50 HIGH PLASTICITY	MH	SILTS, SILT-SAND mixtures of high plasticity	Slight to medium dry strength	Poor to very poor	None to slight
		CH	CLAYS of high plasticity	Sticky when wet, high dry strength	Very poor	None
		OH	ORGANIC silts and clays of high plasticity	High smell, dark color, mottled appearance, slight to high dry strength	Very poor	Variable
HIGHLY ORGANIC SOILS		Pt	MUSKEG, PEAT	Dark color, spongy feel and fibrous texture	Fair to poor	Not applicable

NOTES

Columns 1-4. Unified Soil Classification System (ASTM D 2487).

Column 4. Soil types in capitals and underlines make up more than 50 percent of sample. Other soil types in capitals make up more than 10 percent.

Column 6. Ability of soil to drain water by gravity. Drainage ability decreases with decreasing average grain size.

Column 7. Ability of natural soil to resist erosion on an exposed slope.

Column 8. Value as stable subgrade for roadbed when protected by suitable ballast and subballast materials and not subjected to frost action. Good soil

Column 9. Tendency of soil to pump up and foul ballast under traffic.

Column 11. Stability of soil against bulging and subsidence when used in compacted fill. Cross check with column 7 on tendency to erode.

Column 12. Equipment listed will usually produce the desired densities with a reasonable number of passes when moisture conditions and lift thickness are

Column 13. Value of soil as filter backfill around subdrain pipes to prevent clogging with fines and as a filter to prevent migration of fines from below.

Column 14. Use is dependent upon existing or proposed subgrade and drainage depth. Geotextile will not improve the soil strength or change its classification, primarily span weak subgrade soil.

Table 1

Engineering Use of Soils and Geotextiles for Railroad Applications

Erosion on Exposed Slope (7)	Value as Subgrade (8)	Pumping Action (9)	Potential Frost Action (10)	Stability in Compacted Fills (11)	Compaction Characteristics (12)	Value as a Filter Layer (13)	Geotextile Use (14)
None	Excellent	None	None to very slight	Very stable	Good, crawler-type tractor, rubber-tired roller, steel-wheeled roller	Fair	None required
None	Good to excellent	None	None to very slight	Reasonably stable	Good, crawler-type tractor, rubber-tired roller, steel-wheeled roller	Fair to poor	None required
None to slight	Good	None	Slight to medium	Reasonably stable	Good, with close control, rubber-tired roller, sheepsfoot roller	Very poor	None required
None to slight	Good	Slight	Slight to medium	Fairly stable	Fair, rubber-tired roller, sheepsfoot roller	Not suitable	None required
Slight to high with decreasing gravel content	Good	None	None to very slight	Very stable	Good, crawler-type tractor	Excellent	None required
High	Fair to good	None	None to very slight	Reasonably stable with flat slopes	Good, crawler-type tractor	Fair to poor	None required
High	Fair	None to slight	Slight to high	Fairly stable	Good, with close control, rubber-tired roller, sheepsfoot roller	Very poor	Possibly
Slight	Poor to fair	Slight	Slight to high	Fairly stable	Fair, sheepsfoot roller, rubber-tired roller	Not suitable	Possibly
Very high	Poor to fair	Slight to bad	Medium to very high	Poor	Good to poor, close control essential, rubber-tired roller, sheepsfoot roller	Not suitable	Yes
None to slight	Poor to fair	Bad	Medium to high	Stable	Fair to good, sheepsfoot roller, rubber-tired roller	Not suitable	Yes
Variable	Poor	Very bad	Medium to high	Not suitable	Fair to poor, sheepsfoot roller	Not suitable	Yes
None to slight	Poor	Very bad	Medium to very high	Poor	Poor to very poor, sheepsfoot roller	Not suitable	Yes
None	Poor to fair	Very bad	Medium	Fairly stable with flat slopes	Fair to poor, sheepsfoot roller	Not suitable	Yes
Variable	Poor to very poor	Very bad	Medium	Not suitable	Poor to very poor, sheepsfoot roller	Not suitable	Yes
Not applicable	Not suitable	Very bad	Slight	Not suitable	Compaction not practical	Not suitable	Yes

...n 10 percent

...t action. Good soil may be used to protect poorer subgrade [illegible]

...ode

...and lift thicknesses are properly controlled

...s from below

...change its classification [illegible] subballast, or stabilized material [illegible]

bility in acted Fills (11)	Compaction Characteristics (12)	Value as a Filter Layer (13)	Geotextile Use (14)	Classification (15)
y stable	Good, crawler-type tractor, rubber-tired roller, steel-wheeled roller	Fair	None required	GW
sonably table	Good, crawler-type tractor, rubber-tired roller, steel-wheeled roller	Fair to poor	None required	GP
sonably table	Good, with close control, rubber-tired roller, sheepsfoot roller	Very poor	None required	GM
Fairly table	Fair, rubber-tired roller, sheepsfoot roller	Not suitable	None required	GC
Very table	Good, crawler-type tractor	Excellent	None required	SW
sonably ble with slopes	Good, crawler-type tractor	Fair to poor	None required	SP
Fairly stable	Good, with close control, rubber-tired roller, sheepsfoot roller	Very poor	Possibly	SM
Fairly stable	Fair, sheepsfoot roller, rubber-tired roller	Not suitable	Possibly	SC
Poor	Good to poor, close control essential, rubber-tired roller, sheepsfoot roller	Not suitable	Yes	ML
Stable	Fair to good, sheepsfoot roller, rubber-tired roller	Not suitable	Yes	CL
Not uitable	Fair to poor, sheepsfoot roller	Not suitable	Yes	OL
Poor	Poor to very poor, sheepsfoot roller	Not suitable	Yes	MH
rly stable flat slopes	Fair to poor, sheepsfoot roller	Not suitable	Yes	CH
Not uitable	Poor to very poor, sheepsfoot roller	Not suitable	Yes	OH
Not uitable	Compaction not practical	Not suitable	Yes	Pt

allast, or stabilized material to

the reoccurrence of pumping track. Common locations for the installation of a geotextile in railroad track are as follows:

a. Locations of excessive track maintenance resulting from poor subgrade/drainage conditions.

b. Highway-railroad grade crossings.

c. Railroad crossings.

d. Turnouts.

e. Bridge approaches.

If a geotextile is installed in track without provision made for adequate drainage, water will be retained in the track structure, and the instability of the track will be worsened. In any track construction or rehabilitation project, adequate drainage must be incorporated in the project design.

10. The basic functional requirements for geotextiles that are placed in a railroad track are to:

a. Separate two types of soils of different particle sizes and gradings that would readily mix under the influence of repeated loading and water migration through the track.

b. Filter or hold back soil particles while allowing the passage of water without clogging.

c. Drain water away from the track roadbed on a long-term basis both laterally and by gravity along the plane of the geotextile without a buildup of excessive hydrostatic pressures.

d. Withstand the abrasive forces of moving aggregate caused by the tamping process during initial construction and cyclic maintenance as well as those resulting from the passage of trains over the geotextile.

e. Have the ability to elongate around protruding large gravel-sized particles without puncture or rupture.

11. Based on current knowledge, woven geotextiles are not recommended for use in railroad track applications. Test installations have shown that woven geotextiles tend to blind and act as a plastic sheet preventing water from draining out of the subgrade. Geotextiles selected for use in the track structure should be nonwoven, needle-punched materials that meet the requirements listed in Table 2. Appendix A is a guide specification entitled "Geotextiles in Railroad Track" which covers furnishing and installing geotextiles beneath the ballast and/or subballast in a railroad track.

12. At this time no satisfactory test is available to measure the abrasion resistance of a geotextile for use in railroad applications. Indications are that abrasion is greater for geotextiles placed during track

Table 2

Geotextile Property Requirements for In-Track Applications

Property	Minimum Requirements*	Test Method
Weight**	15 oz/sq yd	ASTM D 3776 Option B
Color†	Grey or tinted	--
Grab tensile strength	350 lb	ASTM D 4632
Elongation at failure	20 percent	ASTM D 4632
Burst strength	620 psi	ASTM D 3786
Puncture strength	185 lb	ASTM D 4833
Trapezoidal tear strength	150 lb	ASTM D 4533
Apparent opening size (AOS) (maximum required value)	Less than 0.22 mm (No. 70 sieve)	ASTM D 4751
Normal permeability (k)††	0.1 cm/sec	ASTM D 4491

(Continued)

* All numerical values listed in Table 1, except AOS, represent minimum average roll values and are the value in the weaker principal direction. The minimum average roll value is the lowest of the average roll values determined from testing a small number of rolls.

** The minimum weight listed herein is based on the experience that geotextiles with weights less than 15 oz/sq yd tend to show greater abrasion and wear than do heavier weight materials.

† Color should be grey or tinted to prevent "snow blindness" of personnel during installation.

†† The permeability of the geotextile should be at least five times greater than the permeability of the subgrade soil but not less than the specified value. The pressure used to measure the nominal thickness (necessary to calculate the permeability) in ASTM D 1777 should be based on the pressure expected to be placed on the geotextile in the installation.

Table 2 (Concluded)

Property	Minimum Requirements	Test Method
Permittivity	0.2 cm/sec	ASTM D 4491
Planar water flow/transmissivity at i = 1 and normal stress = 3.5 psi	0.006 sq ft/min	ASTM D 4716
Ultraviolet degradation at 150 hr	70 percent strength retained	ASTM D 4355
[Seam strength]‡	[350 lb]	[ASTM D 1683]

‡ Most railroad applications use overlap as a method of joining separate pieces of geotextile. But in some applications seaming may be specified. Delete this requirement if seaming is not used. ASTM D 1683 is used to specify seam strengths, but ASTM D 4632 should be used for strength testing instead of ASTM D 1682 as given in ASTM D 1683. If seams are specified, see Federal Standard 751a. If the geotextile is expected to perform a reinforcement function, the seam may require testing by ASTM D 4595.

rehabilitations where the rail remains in-place than for geotextiles placed during new construction or in track rehabilitation where the existing rail, ties, and ballast are removed and the subgrade reworked. This may be due to the differences in the surface upon which the geotextile is placed. In new construction the subgrade surface is normally graded, compacted, and free from large stones. During in-place rehabilitation the old ballast may be removed by undercutting or ploughing which leaves ballast particles loose or protruding from the surface thereby creating a rough surface for placement of the geotextile. Although there is no satisfactory abrasion test currently available, the abrasion resistance of a geotextile as determined from currently available index-type tests should be considered in light of the condition of the surface on which the geotextile is to be placed.

Installation Considerations

13. Geotextiles are typically used to separate the ballast or subballast from the subgrade (or ballast from subballast) in a railroad track section where the subgrade soil (or subballast) contains more than 25 percent by weight of particles passing the No. 200 sieve (i.e. silt or clay particles). These soils will generally classify as SM, SC, ML, CL, MH, or CH in the USCS as defined in ASTM D 2487 (ASTM 1990a).

Depth of placement

14. Technical Manual TM 5-850-2/AFM 88-7, Chapter 2 (Headquarters, Departments of the Army and the Air Force 1980) is currently being revised to specify a minimum ballast/subballast thickness of 10 in. for track without geotextiles. The actual total ballast/subballast thickness required is a function of the maximum wheel load, rail weight, tie size, tie spacing, and allowable subgrade bearing pressure. In the design of new track construction or track rehabilitation using geotextiles, the geotextile should be placed at the deepest of the following:

a. At least 12 in. below the bottom of the tie.

b. At the bottom of the new ballast layer in the case of rehabilitation by plowing.

c. At the interface between the ballast (or subballast) and the subgrade when used in new construction or during rehabilitation where the track in removed.

In no case should the geotextile be placed less than 12 in. below the bottom of the ties. This placement depth will help ensure the survivability and efficient function of the geotextile as well as preventing interference with normal track maintenance activities.

Protective sand layer

15. Studies by commercial railroads worldwide have shown the benefit of using a protective sand layer in conjunction with a geotextile in the track. Indications are that the sand plays a dual role of both protecting the geotextile and providing an additional filtration layer. A 2-in.-thick sand layer placed over the geotextile will assist in reducing the abrasion forces caused by the ballast as well as provide an additional filtration layer. In track rehabilitation where undercutting or a ballast plowing type of ballast removal operation is used, there may be many large gravelly particles remaining on the surface of the subgrade prior to the placement of the geotextile. A sand layer placed beneath the geotextile will assist in providing a smooth surface for placing the geotextile and will help protect the geotextile from punctures and abrasion.

16. While the use of protective clean sand (less than 5 percent passing the No. 200 sieve) layers with a geotextile will increase the service life of a geotextile, there are also several disadvantages. These disadvantages include the extra cost of the sand, the increase in rail height resulting from the extra thickness in the track structure, and the difficulty and cost in placing the sand layer in the track during construction or rehabilitation.

17. The sand used in a protective layer should be a clean, free-draining sand. Table 3 presents a suggested sand gradation; however, other gradations may be used to meet the necessary filtration requirements.

Provision for drainage

18. Provision for adequate drainage is the key to a stable railroad track structure. During the design of a new track or a track rehabilitation project, particular attention must be directed to improving both internal and external track drainage. Drainage provisions that should be considered include adequately sized side ditches to handle surface runoff, sufficient crown in both the subgrade and subballast layers to prevent water from ponding on the top of the subballast or subgrade, and installation of subdrains and/or lateral drains to prevent water accumulation in the track and to assist in the removal of water from the track structure.

Table 3

Suggested Sand-Layer Gradation

Sieve Size	Percent Passing by Weight*
1/2 in.	100
No. 4	90-100
No. 10	75-100
No. 40	40-70
No. 200	0-5

* Gradation determined by ASTM C 117 and ASTM C 136 (ASTM 1990h, 1990i).

Care should be taken to avoid the creation of bathtub or canal effects during track rehabilitation by assuring that the ground level outside the shoulders of the track is below the level of the ballast/geotextile/subgrade interface. Proper maintenance of railroad drainage facilities is described in TM 5-627/ MO-103/AFM 91-33 (Headquarters, Departments of the Army, the Navy, and the Air Force 1980). Lightweight geotextiles for use in subdrains and other drainage applications are discussed in Part III of this report.

Typical Sections

19. Figures 1 and 2 present typical cross sections of a railroad track structure showing the recommended use of a geotextile in the track.

Special Applications

20. The previous section presented design guidelines for track rehabilitation or new construction where geotextiles are applicable. This section presents recommendations for the use of geotextiles in special applications such as those listed below.

a. Locations where the geotextile is at or below the local ground level.

b. Highway-railroad grade crossings.

c. Rail crossings.

d. Bridge abutments.

e. Turnouts.

Installation of geotextile
below natural ground level

21. In some locations the elevation of the track structure may be such that the geotextile must be placed below the level of the natural ground. In these cases steps should be taken to prevent the influx of water from the ground surface on the sides of the track. A subdrain that is lined with or completely encapsulated in a geotextile and installed along the edge of the track to filter the inflow of surface water may be used to direct water away from the track structure. In extremely flat areas it may be necessary to construct perpendicular side ditches, lateral drains, and/or soak-away pits away from the track to allow the drains to remove the water from the track structure. Slotted pipes placed in the trenches will facilitate movement of the water away from the track. Figure 3 presents an example of a typical section with the geotextile installed below the ground surface.

Highway-railroad grade crossings

22. Highway-grade crossings have traditionally been the location of extensive track maintenance activities. Factors that contribute to the maintenance problem of highway crossings are:

a. High impact loads generated by trains entering and leaving the more rigid track structure of the crossings.

b. Difficulty in providing adequate drainage.

c. Ballast fouling that occurs from fine material that falls from passing cars and trucks on the highway.

d. Ballast fouling from winter sanding and salting operations in the colder climates.

Figure 4 presents a typical geotextile installation in a highway-grade crossing.

23. Drainage in a grade crossing is generally parallel to the rails until the pavement and road shoulder have been cleared. Once clear of the crossing itself, the drainage should be turned perpendicular to the track and discharged away from the track structure. Figure 5 presents a typical section of a grade crossing showing one method of using a geotextile and a subdrain system in the track structure to promote drainage. A perforated drain pipe, either wrapped with a geotextile during installation or purchase prewrapped, may be placed in the trench with sufficient fall to move the water from within

the crossing to the ditches outside of the crossing area. Such drain pipes should be placed in the trench with the line of perforations facing down. The ends of the perforated drain pipes and the geotextile under the crossing should be laid with sufficient fall towards the side ditches to prevent water from ponding in the crossing area. Whether perforated pipes are used or not used, the shoulders at the corner of the crossing should be removed, and the ends of the geotextile should be turned down so that the geotextile facilitates drainage under gravity towards the side ditches as shown in Figure 5.

24. In cold climates it is common to salt and sand highways, including grade crossings. This can lead to fouling of the ballast in the grade crossing. One method of preventing or minimizing this ballast fouling is to encapsulate the ballast in a geotextile as shown in Figure 6. The provision for drainage in this type of installation would be the same as discussed above.

Turnout applications

25. The installation of a geotextile under a turnout is basically the same as installation in any other segment of track. In the vicinity of a turnout, drainage of the ballast/subballast is more difficult to achieve because horizontal distances for subsurface flow is about doubled, and gradients are about halved. This along with the additional wheel impact that occurs in the turnout area are reasons for using geotextiles under a turnout where none is necessary in adjacent track sections. Where geotextiles are used in a turnout, they should extend at least 25 ft away from the turnout itself to provide a transition section. As with road crossings, particular attention should be given to the removal of surface water from the turnout area. Figure 7 shows one possible way of providing improved drainage in the turnout area when a geotextile is used.

26. Some geotextile manufacturers produce specially packaged units ready-made for quick installation under turnouts. These turnout package systems are available in different sizes ranging from No. 8 to No. 20 turnouts. These systems are said to reduce the time and labor requirements for installing a geotextile under a turnout.

Rail crossings

27. The use of a geotextile in the track under a rail crossing is very similar to the road crossing and turnout applications. During the design and

installation process, care must be taken to provide for adequate drainage away from the track.

Bridge abutments

28. Geotextiles can be used at bridge abutments to decrease pumping, assist in the removal of water from the track structure adjacent to the abutment, and provide an overall increase in track stability in an area known to experience high impact loads. Figure 8 presents a typical bridge abutment application that incorporates both a geotextile and a subdrain. The geotextile should extend at least 50 ft from the abutment to provide a transition section onto the bridge.

Geotextile Installation Procedures

New track construction and rehabilitation

29. For new construction, the subgrade should be prepared, compacted, and shaped to the lines and grades as directed by the project plans and specifications prior to the placement of the geotextile. Any rutting, caving, erosion, or sag-pockets in the roadbed should be eliminated, and provisions should be made for drainage away from the track center line. In track rehabilitation using undercutting or ploughing, the large aggregate ballast remaining on the undercut surface should be removed to the maximum extent possible or a 2-in.-thick sand blanket provided between the subgrade and geotextile to protect the geotextile. Detailed specifications for the installation of geotextiles in track are given in Appendix A.

Placement

30. The geotextile should be carefully placed on the prepared surface with the long dimension parallel to the prepared surface. During placement, the geotextile should be stretched free of wrinkles, folds, creases, and be free of tension both longitudinally and transversely. In some situations it may be necessary to hold the geotextile in place using pins, small aggregate piles, or ballast bags until the backfilling is complete. The geotextile should be completely covered immediately after placement in the track. The maximum exposure time for the geotextile, from removal of the protective shipping cover to placement of the granular materials sufficient to prevent exposure to sunlight, should be no more than seven consecutive days.

31. Care should be taken to prevent damage to the geotextile during the placement and backfilling process. Contamination from mud, dust, sediment, and debris that will impair the function of the geotextile should be prevented. Any contamination that occurs must be removed without damaging the geotextile. A section of geotextile that is damaged or has its function impaired must be replaced. Once installed, equipment should not be allowed to operate directly on the geotextile, and surface drainage should be directed away from the material to help prevent contamination. A minimum depth of 6 in. of ballast or subballast cover is recommended before equipment operations are allowed over the geotextile. Equipment operations over the geotextile should be limited to the minimum necessary for track construction. In no case should equipment turning be allowed over a covered geotextile.

Joining/splicing

32. The geotextile may be joined by overlapping or sewing (splicing). Most railroad applications use overlap alone for joining separate pieces of geotextile. The minimum overlap distance in the longitudinal and transverse directions shall be 3 ft. Sealed or sewn seams are rarely used, but they may be necessary in some applications. If used, seams should conform to the strength requirements of Table 2. Any small rips or tears in the geotextile should be repaired by the contractor and approved by the project engineer.

Ballast placement and cover depth

33. A minimum distance of 12 in. is required between the bottom of the tie and the geotextile. A minimum 6-in. layer of coarse subballast or 2-in. layer of free draining sand may be used above the geotextile to help protect the geotextile from the high abrasive and puncture forces produced by the ballast. Placement of the ballast/subballast cover material should be performed in a manner to ensure intimate contact of the geotextile with the prepared surface and with the cover material. The placement should be performed in a manner that will not damage the geotextile including tears, punctures, or abrasion.

Tamping

34. Tamping of the ballast materials should be performed by setting the tamper feet to the minimum depth required to adequately tamp the track and using the minimum tamping pressure required to compact the ballast. The tamper operator and inspector should monitor the depth of tamping and limit the depth to prevent detrimental effects of the tamper foot on the geotextile.

Spoil

35. During track rehabilitation using geotextiles, any existing shoulder material that would impede free drainage of the track structure should be removed. Where complete shoulder removal or reconstruction is not practical, a trench drain or other subdrainage system should be used. Only clean ballast or granular material should be used in the drainage trenches to ensure the free flow of water away from the track. During undercutting operations, the fouled spoil removed from the track should be deposited away from drains or completely removed from the area. Fouled spoil should not be used in or deposited near drainage trenches.

Double layers

36. Double layers of geotextile should not be used, except for splicing overlaps and seams. Soil fines can accumulate between the two geotextiles and result in a weak slippage plane when wet.

Protection during construction

37. The geotextile should be protected against moisture, extended ultraviolet exposure, and damage by vandals prior to placement. After placement, the geotextile should be completely covered within 7 days to prevent potential damage or impaired function.

PART III: RAILROAD DRAINAGE APPLICATIONS

General

38. The use of subdrains, geotextiles, and other subsurface drainage in or adjacent to a railroad track is dependent on the existing topographic, environmental, and subgrade conditions. As used in this report, the term "drainage applications" refers to the use of granular and geotextile filters/drains to assist in draining water away from the track structure, and "drainage geotextile" refers to a geotextile used primarily for both filtration and drainage that is placed adjacent to the track but not within the track structure itself (e.g. at the ballast-subgrade interface). Drainage may be accomplished by edge drains, interceptor drains, wall drains, and relief wells, or by the water moving laterally through the plane of a geotextile. Geotextiles should be used for drainage applications when it is necessary to provide for adequate filtration and/or separation of the drainage aggregates and subgrade soils.

Design Criteria

39. A properly functioning drain must allow the passage of water while retaining the surrounding soil. This is true regardless of whether a granular or geotextile filter is used. In order to provide comprehensive documentation of railroad drainage applications, design criteria for both granular drains and geotextiles will be presented in this section.

Granular drains

40. To assure proper performance of granular drains, the drain materials must meet grain-size requirements based on the grain size of the surrounding soils. There are two principal granular filter criteria that have been developed empirically based on laboratory testing and field experience. These are the piping criterion and the permeability criterion.

a. Piping criterion. The ability of a drain to retain the surrounding soil is defined by the stability or piping criteria. This criterion limits the D_{15} size (the particle size at which 15 percent of the sample is finer) of the drain based on the D_{85} size (the particle size at which 85 percent of the sample is finer) of the surrounding soil as shown in Equation 1.

$$\frac{D_{15F}}{D_{85S}} \leq 5 \quad (1)$$

where

D_{15F} = the D_{15} size of the drain or filter material

D_{85S} = the D_{85} size of the surrounding soil to be retained or protected

b. Permeability criterion. The permeability of a soil is generally controlled by the smaller (D_{10} or D_{15}) grain sizes. The filter criterion which assures the ease of water flow into and through the drain is:

$$\frac{D_{15F}}{D_{15S}} \geq 5 \quad (2)$$

where

D_{15F} = the D_{15} of the drain or filter material

D_{15S} = the D_{15} of the surrounding soil

41. If a perforated pipe is placed within a granular drain to rapidly carry away the water collected by the drain, the perforation (hole) size must be related to the grain size of the material used in the drain. To prevent movement of the drain material into the pipe, the maximum hole diameter or slot width should not exceed the D_{85} size of the surrounding drain material.

Drainage geotextiles

42. The primary geotextile characteristics influencing filtration/drainage functions are opening size, number of openings per unit area, and tortuosity. These properties can be indirectly measured by the AOS test in ASTM D 4751, the permittivity test in ASTM D 4491 (ASTM 1990d, 1990m), and hydraulic gradient ratio tests for specific soil-geotextile combinations. At this time various procedures for the gradient ratio test are available, but the test procedure has not been standardized. Two other important performance factors are the geotextile's strength and durability. These are necessary for the geotextile to survive construction operations and long-term field conditions. As with granular filters/drains, the construction methods used in installing the geotextile has a critical influence on the performance of the geotextile drain.

43. The geotextile used in drainage applications must allow the passage of water while retaining the in situ material (soil or granular drainage materials). Design criteria for drainage and filtration are specified in

43. The geotextile used in drainage applications must allow the passage of water while retaining the in situ material (soil or granular drainage materials). Design criteria for drainage and filtration are specified in Table 4. Geotextiles that meet the filtration requirements in Table 4 should also satisfy the property requirements for survivability in Table 5. Certain applications may require that the criteria be verified or refined by laboratory testing as described in the following paragraphs.

Piping

44. The piping criterion given in Table 4 is based on granular drain criteria for preventing drain material from entering openings in drain pipes. If flow through the geotextile drain installation will be reversing and/or under high gradients (especially if reversals are very quick and involve large changes in head), tests that model prototype conditions should be performed to determine the actual geotextile requirements.

45. There is limited evidence (Giroud 1982) that the degree of uniformity and density of granular soils, in addition to the D_{85} size, influences the ability of geotextiles to retain the drained soil. For very uniform soils (C_u 2 to 4, where C_u is the uniformity coefficient = D_{60}/D_{10}), the maximum AOS may not be as critical as for more well graded soils (indicated by C_u greater than 5). A gradient ratio test with observation of the material passing through the geotextile may be necessary to determine the proper AOS for well-graded soils. In normal soil-geotextile filter systems, detrimental blinding or clogging only occurs when there is migration of fine soil particles through the soil matrix to the geotextile surface or into the geotextile. For most natural soils, minimal internal migration will take place. However, internal migration may take place under sufficient gradient if the soil is very widely graded (has a C_u greater than 20) or if the soil is gap graded.

Permeability

46. The permeability criterion for nonwoven geotextile given in Table 4 requires a geotextile permeability at least five times the permeability of the surrounding soil. The permeability of the geotextile is determined by the permittivity test given in ASTM D 4491 (ASTM 1990m) with measurement of the geotextile thickness given in ASTM D 1777 (ASTM 1990p). The most critical soils as related to the permeability criterion are the cleaner and coarser sands. This is because of their ability to pass large volumes of water which the geotextile must also pass.

Table 4

Geotextile Filtration Properties for Drainage Applications

Protected Material* (Percent Passing No. 200 Sieve)	Piping**	Permeability Criterion Woven†	Permeability Criterion Nonwoven††
Less than 5	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 10%	$k_G \geq 5k_s$
5 to 50	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 4%	$k_G \geq 5k_s$
50 to 85	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 4%	$k_G \geq 5k_s$
	Upper limit on AOS is AOS (mm) $\leq$ 0.212 mm (No. 70 US Standard Sieve)		
Greater than 85	AOS (mm) $\geq$ 0.125 mm (No. 120 US Standard Sieve)		$k_G \geq 5k_s$

* Protected material is the material that is to be prevented from moving in the direction of the drainage flow (e.g., at the subgrade soil/drainage trench interface with water moving into the trench, the soil would be the protected material).

** When the protected material contains appreciable quantities of material retained on the No. 4 sieve, use only the soil passing the No. 4 sieve in selecting the AOS of the geotextile.

† POA, percent open area, is the net area of a geotextile that is not occupied by filaments. POA is normally determined only for woven and nonwoven geotextiles having distinct visible and measurable openings that continue directly through the geotextile.

†† k_G is the permeability of the nonwoven geotextile, and k_s is the permeability of the protected soil.

Table 5

Geotextile Survivability Properties for Drainage Applications

Property	Minimum Requirements* Condition Class A**	Class B†	Test Method
Grab strength lb	180	80	ASTM D 4632
Elongation, %	NA	NA	ASTM D 4632
Sewn seam strength†† lb	180	80	ASTM D 4884
Puncture strength lb	80	25	ASTM D 4833
Burst strength psi	290	130	ASTM D 3786
Trapezoid tear lb	50	25	ASTM D 4533
Ultraviolet degradation at 150 hr	70% strength retained	70% strength retained	ASTM D 4355

* Minimum Average Roll Value. Use value in weaker principle direction. All numerical values represent minimum average roll value (i.e., test results from any sampled roll in a lot shall meet or exceed the minimum values in the table). Stated values are for noncritical, nonsevere applications. Lots sampled according to ASTM D 4354 (ASTM 1990f).

** Class A installation conditions for geotextile are where installation stresses are more severe than Class B conditions (i.e., very coarse, sharp angular aggregate is used, a heavy degree of compaction (ASTM 1990e) is specified, depth of trench is greater than 10 ft, or where geotextile is in contact with ballast or subballast materials.

† Class B installation conditions are those where geotextile conditions are used with smooth graded surfaces having no sharp angular projections, no sharp angular aggregate is used; compaction requirements are light (< ASTM D 698), and trenches are less than 10 ft in depth.

†† Values apply to both field and manufactured seams, if used.

Other filter considerations

47. Most drain installations do not depend on flow in the plane of the geotextile. If this is a consideration in the design, ASTM D 4716 (ASTM 1990c) should be used to determine the in-plane permeability of the geotextile. Appropriate loads (consistent to those expected in the completed project) should be applied perpendicular to the plane of the geotextile during the permeability test.

48. To prevent clogging or blinding of the geotextile, intimate contact between the soil and the geotextile should be assured during construction. Voids between the soil and geotextile can expose the geotextile to a slurry or muddy water mixture during seepage. This condition promotes erosion of soil behind the geotextile and clogging of the geotextile.

49. Very fine-grained noncohesive soils such as rock flour present a special problem, and design of drain installations in this type of soil should be based on tests using the expected hydraulic conditions, soils, and candidate geotextiles.

50. As a general rule, slit-film geotextiles are unacceptable for drainage applications. They may meet AOS criteria but generally have a very low POA or permeability. The wide filament in many slit films is prone to move relative to the cross filaments during handling, thereby changing the AOS and POA values.

51. The designer must consider that in certain areas an ochre formation may occur on the geotextile. Ochre is an iron deposit usually a red or tan gelatinous mass associated with bacterial slimes. It can under certain conditions form on and in subsurface drains. The designer may be able to determine the potential for ochre formation by reviewing local experience with highway, agricultural, embankment, or other drains with local or state agencies. Ford (1982a) provides water and soil test methods for determining potential for ochre formation. If there is reasonable expectation for ochre formation, the use of a geotextile is discouraged since geotextiles may be prone to clog (Ford 1982b). Once ochre clogging occurs, removal from the perforated pipes or geotextile is generally very difficult or impossible, since the chemicals or acids used for ochre removal can damage the geotextile and high pressure jetting through the perforated pipe is relatively ineffective.

Strength and survivability requirements

52. Unless geotextiles used in drainage applications have secondary functions (separation, reinforcement) that require high strength, the requirements shown in Table 5 will provide adequate strength. When specifying strengths for a specific project, consideration must be given to the severity of the installation conditions and whether any unique stresses will be applied to the geotextile. Table 5 provides two classes of installation conditions for geotextiles used in drainage applications. Class A installation conditions are for installations where the stresses imposed on the geotextile are more severe. Such applications include places where very coarse, sharp angular aggregate is used, where the compaction of the material adjacent to the geotextile is specified as ASTM D 698 (ASTM 1990e) or greater, or where the geotextile is installed in a trench greater than 10 ft deep. Installation of drainage geotextiles in or adjacent to railroad track where the geotextile is in contact with either ballast or subballast material is considered a Class A installation condition. Class B installation conditions are less severe than Class A conditions and are those where the geotextile is installed on smooth graded surfaces having no sharp or angular projections, no sharp or angular aggregate in contact with the geotextile, compaction requirements light (generally less than ASTM D 698), or the geotextile installed in a trench less than 10 ft deep.

Installation Considerations

53. Prior to placement of the geotextile the drainage trench or other excavation should be shaped to the final lines and grades as required by the project specifications. All surfaces upon which a geotextile is to be placed should be free from large stones, roots, and other debris. Any ruts, holes, or depressions should be filled in so that the geotextile can be placed in intimate contact with the prepared ground surface.

54. The geotextile should be placed with care to prevent the occurrence of folds or wrinkles in the material and to ensure intimate contact between the geotextile and the soil. Geotextile pins may be used to hold the geotextile in place on vertical or steeply sloping surfaces. When possible, the geotextile should be covered the same day that it is placed, and in no case should the geotextile remain exposed for more than seven consecutive days

after removal of its protective cover. During placement of aggregate backfill in drainage structures containing a geotextile, care should be taken to prevent damage to the geotextile and to ensure intimate contact between the granular material and the geotextile. In trench drains and other applications where a geotextile is used to line the trench, the backfill should be carefully placed in the trench and the geotextile folded over the top of the backfill to produce a minimum overlap of 12 in. In trenches less than 12 in. wide an overlap equal to the width of the trench is recommended. After the geotextile has been folded over in the trench, the subsequent layers of material can be installed. In applications where successive sheets of geotextile are required the sheets may be joined by either sewing or overlapping. Where overlapping is used, the minimum overlap should be 12 in. or the width of the trench, whichever is greater. Where seaming or sealing is used to join the geotextile sheets, the joints should meet the minimum seam strength requirements of Table 5.

Summary

55. Adequate drainage is the key to a stable railroad track structure thereby reducing maintenance. This is especially true when a geotextile is used in the track. During the design of a new track or a track rehabilitation project, provisions for improving both internal and external drainage should be included. Drainage provisions that should be considered include adequate side ditches to handle surface runoff, sufficient crown in both the subgrade and subballast layers to prevent water from ponding on the top of the subballast or subgrade, installation of perpendicular drains to prevent water accumulation in the track, and subdrains where required to assist in the removal of water away from the track structure. During track rehabilitation the creation of bathtub or canal effects should be avoided by ensuring that any fouled ballast or other spoil is removed from the vicinity of the track and that the ballast shoulders are free to drain onto the subgrade shoulders. Geotextiles should not be placed in a railroad track until existing drainage problems are corrected. While not a panacea for all railroad drainage problems, geotextiles used in conjunction with other drainage structures can help to improve track drainage and therefore track performance. Appendix B presents a recommended guide specification for geotextiles used in drainage applications.

PART IV: RAILROAD EROSION CONTROL APPLICATIONS

General

56. The use of geotextiles for erosion control applications is also dependent on environmental and subgrade conditions. Geotextiles may be used to provide for improved filtration and separation of the armor material and the subgrade soil. Geotextiles have application in railroad erosion control problems such as cut and fill slope protection, protection of small drainage structures and ditches, wave protection for causeways and shoreline railway embankments, and scour protection for structures such as bridge piers and abutments. An additional application is temporary erosion control during construction using geotextile silt fences. Appendixes C and D present guide specifications that are recommended for use in erosion control and silt fence applications, respectively. The following paragraphs provide additional detail on the use of geotextiles in these applications.

Design Criteria

Piping and permeability

57. The geotextile used for erosion control applications should be designed to allow the passage of water while retaining the in situ soil. Table 6 presents the filtration properties required for geotextiles in erosion control applications. This is the same criterion that was previously presented for drainage geotextiles, and the piping, permeability, and other filter considerations given in paragraphs 44 through 51 are also valid for the erosion control geotextiles.

Strength and survivability

58. Table 7 presents the strength and survivability properties required for geotextiles used in erosion control applications. As with drainage geotextiles, the severity of the installation conditions must be considered when selecting the geotextile properties. Class A applications are those where the geotextile is exposed to the more severe installation and service conditions. This includes where the stone placement height is from 0 to 3 ft and the stone weight is less than 250 lb. Class B applications are those where the geotextile is

Table 6

Geotextile Filtration Properties for Erosion Control Applications

Protected Material* (Percent Passing No. 200 Sieve)	Piping**	Permeability Criterion	
		Woven†	Nonwoven††
Less than 5	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 10%	$k_G \geq 5k_s$
5 to 50	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 4%	$k_G \geq 5k_s$
50 to 85	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 4%	$k_G \geq 5k_s$
	Upper limit on AOS is AOS (mm) $\leq$ 0.212 mm (No. 70 US Standard Sieve)		
Greater than 85	AOS (mm) $\geq$ 0.125 mm (No. 120 US Standard Sieve)		$k_G \geq 5k_s$

* Protected material is the material that is to be prevented from moving in the direction of the drainage flow (e.g., at the subgrade soil/drainage trench interface with water moving into the trench, the soil would be the protected material).

** When the protected material contains appreciable quantities of material retained on the No. 4 sieve, use only the soil passing the No. 4 sieve in selecting the AOS of the geotextile.

† POA, percent open area, is the net area of a geotextile that is not occupied by filaments. POA is normally determined only for woven and nonwoven geotextiles having distinct visible and measurable openings that continue directly through the geotextile.

†† k_G is the permeability of the nonwoven geotextile, and k_s is the permeability of the protected soil.

Table 7

Geotextile Survivability Properties for Erosion Control Applications

Property	Minimum Requirements* Application		Test Method
	Class A**	Class B†	
Grab strength lb	200	90	ASTM D 4632
Elongation, %	15	15	ASTM D 4632
Sewn seam strength†† lb	200	90	ASTM D 4884
Puncture strength lb	80	40	ASTM D 4833
Burst strength psi	320	140	ASTM D 3786
Trapezoid tear lb	50	30	ASTM D 4533
Ultraviolet degradation at 150 hr	70% strength retained	70% strength retained	ASTM D 4355

* Minimum average roll value. Use value in weaker principle direction. All numerical values represent minimum average roll value (i.e., test results from any sampled roll in a lot shall meet or exceed the minimum values in the table). Stated values are for noncritical, nonsevere applications. Lots sampled according to ASTM D 4354.

** Class A applications are those where geotextiles are under conditions where installation stresses are more severe than Class B applications; i.e., stone placement height should be less than 3 ft and stone weights should not exceed 250 lb, no sand cushion.

† Class B applications are those where geotextile is used in structures or under conditions where the geotextile is protected by a sand cushion or by "zero drop height" placement of stone.

†† Values apply to both field and manufactured seams.

protected by a sand blanket or where the stones are placed using "zero drop height." If unique stress conditions exist or if the installation and service conditions are more severe than those given by the Class A application, consideration must be given to increase the strength requirements of the geotextile.

Installation Considerations

59. The area where the erosion control geotextile is to be placed should be prepared and shaped to the specified lines and grades. In addition, the area should be clear of any large stones, roots, or other debris. During the surface preparation all ruts, holes, and other depressions should be filled so that the geotextile is placed in intimate contact with the ground surface.

60. The geotextile should be placed in intimate contact with the prepared surface without any folds or wrinkles prior to the placement of the riprap or other cover materials. It is not necessary to place the geotextile in tension before placement of the cover. If possible, the geotextile should be covered the same day that it is placed. If this is not possible, the geotextile should be covered within 7 days after removal of its protective wrapping. During placement of the riprap or cover material, extreme care must be taken to avoid damage to the geotextile. The geotextile may be joined either by sewing, sealing, or by overlapping. The minimum overlap distance should be at least 3 ft. Where sealed or sewn joint seams are used, there shall be a minimum overlap of 6 in., and the seam strength shall be at least equal to the minimum value of seam strength specified in Table 7. Overlapping should be accomplished so that the upstream sheet of geotextile is placed over the downstream sheet and/or the upslope sheet is over the downslope sheet.

61. The geotextile must be firmly anchored at the top of the slope on which the erosion control is being placed. One of the most effective methods of anchoring is accomplished by an anchor trench constructed at least 3 ft from the crest of the slope and at least 2 ft deep. The backfill for the anchor trench must be carefully compacted to ensure that good anchorage is achieved. If the erosion protection is along a river, stream, or location where strong water currents are expected, it is recommended that the toe of

the geotextile be similarly anchored to prevent scour at the base of the protection.

62. Riprap and backfill placement should begin at the toe and proceed up the slope. Riprap and heavy stones used for erosion protection should not be dropped onto the geotextile from a height of more than 1 ft. Slope protection materials and smaller stone filling should not be dropped onto the geotextile from a height greater than 3 ft. The use of a geotextile filter in erosion control applications does not supercede the normal criteria for the sizing and selection of riprap. It is recommended that an intermediate layer of smaller sized stones be placed directly on the geotextile if very large riprap materials (greater than 200 lb) are used.

Silt Fences

63. During new track construction or the major rehabilitation projects there may be a need for temporary erosion control using a silt fence or fences. The purpose of the silt fence is to intercept and detain sediment from unprotected areas before it leaves the construction site. The permeable geotextile allows water to flow through the fence while the sediment in the water is retained against the geotextile. The fence will also reduce the water velocity allowing some of the sediment to settle out of suspension. The use of silt fences is limited to situations where there is only sheet or overland flow. Silt fences generally cannot handle the volumes of water in stream channels.

64. The geotextile used for silt fences should be either a woven or nonwoven material specifically designed by the manufacturer for temporary erosion control. The geotextile should be attached to the support system with staples, wire, or other fasteners in accordance with the manufacture's recommendations. The bottom should be adequately buried in a trench cut in the ground to prevent sediment from escaping under the fence. In the event that a trench cannot be excavated, the geotextile toe should be backfilled with soil. The filtration and retention functions of a silt fence are illustrated schematically in Figure 9. Depending on the volume of flow expected and the filtration and retention characteristics of the geotextiles used, more than one silt fence may be required at a specific location to provide adequate retention of the soil as shown in Figure 10.

Silt Fence Design Concepts

65. A silt fence is a two-component barrier system consisting of a sheet of geotextile and a support component. The support component may be a wire or a plastic mesh support fence attached to fence posts or simple support posts. The minimum height of the silt fence, the geotextile properties (tensile strength, permeability), the slope of the site, the volume of water and suspended particles which are delivered to the silt fence, and the size distribution of the suspended particles are all considerations in the design. Referring to Figure 9, the total height of the silt fence must be greater than $h_1 + h_2 + h$, where h_1 is the height of geotextile necessary to allow water flowing into the basin to flow through the geotextile, considering the permeability of the geotextile; h_2 is the height of water necessary to overcome the threshold gradient of the geotextile and to initiate flow. For most expected conditions, $h_1 + h_2$ is approximately 6 in. or less. The silt fence accomplishes its purpose by creating a pond of relatively still water which serves as a sedimentation basin and collects the suspended solids from the runoff. The useful life of the silt fence is the time required to fill the triangular area of height, h in Figure 9, behind the silt fence with sediment. The height of the silt fence geotextile should not exceed 3 ft. The silt fence can be designed for the retention of a maximum amount of sediment or for a high flow efficiency over its design life as follows:

a. Design for maximum particle retention. The design for particle retention is based on the geotextile selection criteria for drainage discussed in Part III. Geotextiles selected for use as silt fences should have an AOS as determined by Equation 3 with a limiting value of the No. 120 (0.125 mm) sieve size.

$$\frac{D_{85S}\ (mm)}{AOS_G\ (mm)} \geq 1.0 \tag{3}$$

where

D_{85S} = the D_{85} size of the soil in mm

AOS_G = the AOS sieve size of the geotextile in mm

A minimum of 90-lb tensile strength determined in accordance with ASTM D 4632 (ASTM 1990o) is recommended with support posts spaced a maximum of 8 ft apart for nonsevere, noncritical installations. For severe, critical, or large-scale installations, the geotextile should be tested in trial installations prior to its adoption.

large-scale installations, the geotextile should be tested in trial installations prior to its adoption.

b. Design for filtration efficiency. The preferred method of silt fence design is the design based on optimum geotextile filtering efficiency. The basic concept of this design is that the geotextile should be capable of filtering most of the soil particles carried in the runoff from a construction site without unduly impeding the flow. A special laboratory test is used to determine the filtering efficiency and the flow rate of the sediment-filled water through the geotextile. The test is called the Virginia Test Method 51 (VTM-51) (Wyant 1980) and the test procedure is presented in Appendix E. The geotextile requirements for silt fences based on the VTM-51 test procedure are summarized in Table 8.

66. The selection of a geotextile for use in silt fences can best be illustrated by a silt fence design example which is presented in Appendix F.

Silt Fence Construction Considerations

67. Silt fences should be constructed before the initiation of any soil disturbing construction activity. Silt fences should be installed in drainage areas to prevent sediment-laden runoff from leaving the construction site and fouling local ditches and streams. The steps in construction of a silt fence, as shown in Figure 11, are:

a. Drive support posts in a row along the desired line. Typical post spacing is between 2 to 8 ft apart.

b. Excavate a small trench having a minimum width of 6 in. and a minimum depth of 6 in. on the upstream side of the fence. This trench is for burying and anchoring the lower end of the geotextile.

c. Securely fasten wire mesh to the upstream side of the support posts. The wire fence should extend into the trench a minimum of 2 in. and extend a maximum of 36 in. above the original ground surface.

d. Cut the geotextile to the required width.

e. Loosely attach the geotextile to the upstream side of the wire support fence with hog rings or tie wire. Allow the lower end of the geotextile to extend into the trench.

f. Bury the lower end of the geotextile a minimum of 6 in. in the upstream trench and compact the backfill to provide good anchorage.

Table 8

Geotextile Use for Silt Fences (after Wyant 1980)

Proposed Structure	Filtering Efficiency* %	Flow Rate* gal/ft²/min	Wide Width Tensile Strength** lb/lin in.
3-ft silt fence with reinforced backing	75	0.3	Reinforcing governs
3-ft silt fence without reinforced backing	75	0.3	50
18-in. silt barrier without reinforced backing and posts 10 ft apart	75	0.3	24
18-in. silt barrier without reinforced backing and posts 3 ft apart	75	0.3	7

* Tests results from Virginia Highway and Transportation Research Council (VHTRC) Laboratory Filtering Efficiency Test (see Appendix E).
** From ASTM 4595 (ASTM 1990g).

68. It is a good practice to construct the silt fence across a flat area in the shape of a horseshoe with the ends pointing upstream. This aids in the ponding of the runoff, facilitates sedimentation, and increases the strength of the fence. Prefabricated silt fence sections containing geotextile and support posts are commercially available. They generally are manufactured in heights of 18 and 36 in., and the geotextile at the lower portion of the fence is extended for burying anchorage. The prefabricated silt fence is cost effective because its installation does not require excessive hand labor. However, the designer must be careful to specify the desired geotextile properties in order to obtain predictable in-service performance.

Silt Fence Maintenance

69. Silt fences should be inspected immediately after each rainfall and at least daily during prolonged rainfall. Any deficiencies should be corrected immediately. Typical failure modes of silt fences are shown in Figure 12. The effectiveness of the silt fences should be reviewed

periodically, perhaps daily, particularly in areas where construction is changing the earth contour and drainage runoff patterns. Additional silt fences should be installed as required to address the changing conditions. Sediment deposits should be removed when the deposit reaches approximately one-half the height of the silt fence or when heavy runoff or high water is expected. When removing sediment depcsits, care must be taken not to tear the geotextile or to dig up the bottom of the geotextile and destroy the anchoring. Damaged silt fences should be repaired immediately. Silt fences should not be removed until adequate vegetation growth ensures no additional erosion in the construction area. Sediment deposits remaining in place after the silt fence is no longer required should be dressed to conform with the existing terrain and the area topsoiled, seeded, and fertilized as required.

PART V: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

70. This report presents recommendations for the use of geotextiles in railroad track construction and rehabilitation projects. In order to provide the reader with a comprehensive package, the use of geotextiles for in-track applications, drainage applications, and erosion control applications is presented. For each of these general areas, recommended geotextile property requirements, design criteria, and installation considerations are presented.

71. The information and recommendations given in this report is consistent with the recommendations of the American Railway Engineering Association (AREA) Manual For Railway Engineering Chapter 1, Part 10 "Geosynthetics" (AREA 1990). However, for the geotextile properties required for filtration and drainage in the drainage and erosion control applications, the AREA recommendations on geotextile material properties have been replaced with recently developed Corps of Engineers criteria.

Conclusions

72. The information presented in this report was developed during several different research projects and studies over the past several years. From this work it is concluded that:

a. Geotextiles can contribute to the improvement of a railroad track structure and assist in the performance of railroad related drainage and erosion control facilities.

b. There is a lack of understanding by many engineers/designers on the requirements for using geotextiles in railroad construction projects.

c. Where geotextiles are used in a railroad track, there will be some improvement in track performance. This improved performance usually is a result of improved drainage and separation and will be manifested in the form of reduced track maintenance requirements.

d. Geotextiles will assist in providing better performance of granular filters and granular drains in drainage and erosion control applications.

e. The most cost-effective use of geotextiles in railroad related applications is where the geotextile will extend the required

track maintenance cycle or improve the function of drainage and erosion control structures.

Recommendations

73. Based on the study presented herein, it is recommended that:

a. The criteria, guidance, and information presented in this report be used for selecting and specifying geotextiles for railroad construction/rehabilitation projects where a geotextile is needed.

b. The guide specification "Geotextiles in Railroad Track," provided in Appendix A be used for specifying the geotextile material and installation procedures to be used in railroad track construction or rehabilitation projects.

c. The guide specifications "Geotextiles for Filtration and Drainage", "Geotextiles Used in Erosion Control", and "Geotextiles for Sediment Control (Temporary Silt Fence)" presented in Appendixes B, C, and D, respectively, be used for specifying the geotextile material and installation procedures used in drainage and erosion control applications related to railroad track construction or rehabilitation projects.

d. The information presented herein be incorporated into future revisions of the appropriate DOD technical manuals.

REFERENCES

American Railway Engineering Association. 1990. Manual for Railway Engineering American, Railway Engineering Association, Washington, DC.

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1989. Standard Methods for the Examination of Water and Wastewater, 17th Ed., Washington, DC.

American Society for Testing and Materials. 1990a. "Classification of Soil for Engineering Purposes", ASTM D 2487 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990b. "Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products", ASTM D 4833, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990c. "Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products", ASTM D 4716, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990d. "Standard Test Method for Determining the Apparent Opening Size of a Geotextile", ASTM D 4751, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990e. "Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (304.8-mm) Drop", ASTM D 698, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990f. "Standard Practice for Sampling of Geotextiles for Testing", ASTM D 4354, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990g. "Standard Test Method for Determining the Tensile Properties of Geotextiles by the Wide-Width Strip Method", ASTM D 4595, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990h. "Standard Test Method for Material Finer than 75-mm (No. 200) Sieve in Mineral Aggregates by Washing", ASTM C 117, 1990 Annual Book of Standards, Vol 4.03, Philadelphia, PA.

_____. 1990i. "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates", ASTM C 136, 1990 Annual Book of Standards, Vol 4.03, Philadelphia, PA.

_____. 1990j. "Standard Test Methods for Mass per Unit Area (Weight) of Woven Fabric", ASTM D 3776, 1990 Annual Book of Standards, Vol 7.01, Philadelphia, PA.

_____. 1990k. "Standard Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method", ASTM D 3786, 1990 Annual Book of Standards, Vol 7.01, Philadelphia, PA.

_____. 19901. "Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)", ASTM D 4355, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

American Society for Testing and Materials. 1990m. "Standard Test Method for Water Permeability of Geotextiles by Permittivity", ASTM D 4491, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990n. "Standard Test Method for Trapezoid Tearing Strength of Geotextiles", ASTM D 4533, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990o. "Standard Test Method for Breaking Load and Elongation of Geotextiles (Grab Method)", ASTM D 4632, 1990 Annual Book of Standards, Vol 4.08, Philadelphia, PA.

_____. 1990p. "Standard Test Method for Measuring Thickness of Textile Materials", ASTM D 1777, 1990 Annual Book of Standards, Vol 7.01, Philadelphia, PA.

Ford, H. W. 1982a. "Estimating the Potential for Ochre Clogging Before Installing Drains", Transactions of the American Society of Civil Engineers, Vol 25, No. 6, pp 1597-1600, Washington, DC.

_____. 1982b. "Some Fundamentals of Iron and Slime Deposition in Drains", Proceedings of the Second International Drainage Workshop, pp 207-212, Washington, DC.

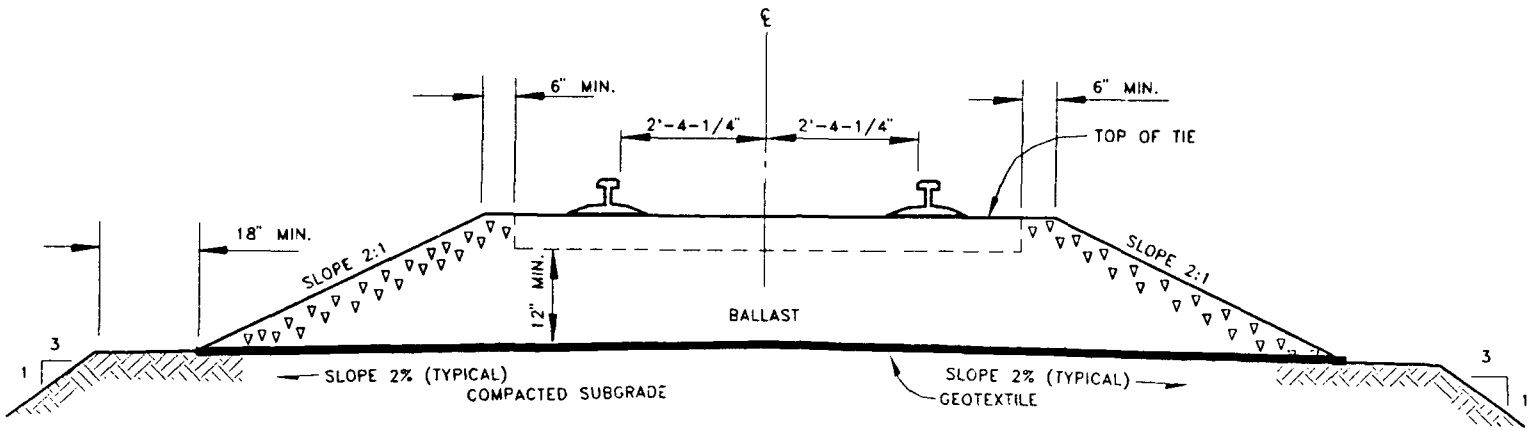
Giroud, J.P. 1982. "Filter Criteria for Geotextiles", Proceedings of the Second International Conference on Geotextiles, Vol I, pp 103-108. Industrial Fabrics Association International, St. Paul, MN.

Headquarters, Departments of the Army and the Air Force. 1980 (Jul). "Railroad Design and Construction at Army and Air Force Installations", Technical Manual TM 5-850-2/AFM 88-7, Chapter 2, Washington, DC.

Headquarters, Departments of the Army, the Navy, and the Air Force. 1980 (Jan). "Maintenance of Trackage", Technical Manual TM 5-627/MO-103/AFM 91-33, Washington, DC.

Raymond, G. P. 1986. "Installation Factors that Affect Performance of Railroad Geotextiles", Transportation Research Record 1071, Transportation Research Board, Washington, DC.

Wyant, David C. 1980. "Evaluation of Filter Fabrics for Use as Silt Fences", Report No. VHTRC 80-R49, Virginia Highway and Transportation Research Council, Charlottesville, VA.

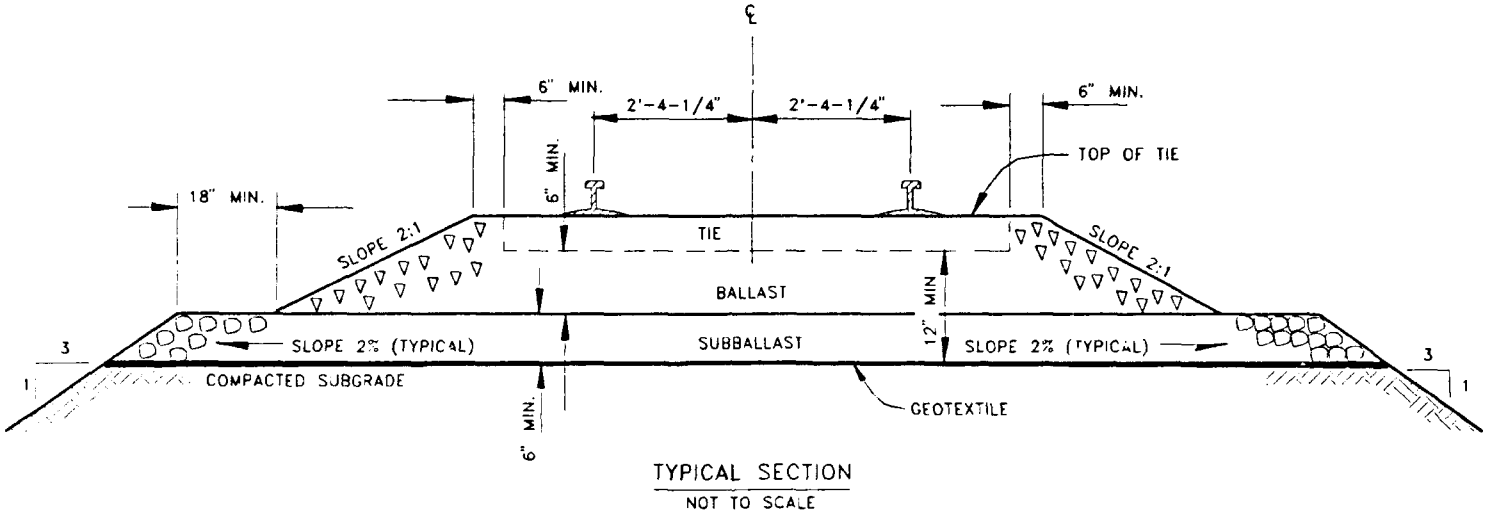


TYPICAL SECTION
NOT TO SCALE

NOTES:

1) DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS.
2) MINIMUM DEPTH OF BALLAST OVER GEOTEXTILE IS 12 INCHES BELOW BOTTOM OF TIE TO INSURE GEOTEXTILE SURVIVABILITY AND FUNCTION.
3) GEOTEXTILE TO MEET REQUIREMENTS OF CEGS 02274.
4) GEOTEXTILE INSTALLATION ON CURVES WILL BE SIMILAR.

Figure 1. Typical ballast section with geotextile



NOTES:

1) DEPTH OF BALLAST SECTION WILL DEPEND ON SUBGRADE STRENGTH, TRAFFIC DENSITY, AND WHEEL LOADS.
2) MINIMUM DEPTH OF BALLAST/SUBBALLAST OVER GEOTEXTILE IS 12-INCHES BELOW BOTTOM OF TIE TO INSURE GEOTEXTILE SURVIVABILITY AND FUNCTIONS. MAY PLACE GEOTEXTILE BETWEEN BALLAST AND SUBBALLAST DEPENDING UPON MATERIALS.
3) THICKNESS OF BALLAST AND SUBBALLAST MAY BE VARIED TO OBTAIN BEST STRUCTURAL AND ECONOMIC DESIGN WHILE MEETING MINIMUM THICKNESS REQUIREMENTS.
4) GEOTEXTILE TO MEET REQUIREMENTS OF CEGS-02274.
5) GEOTEXTILE INSTALLATION ON CURVES WILL BE SIMILAR.

Figure 2. Typical ballast/subballast section with geotextile

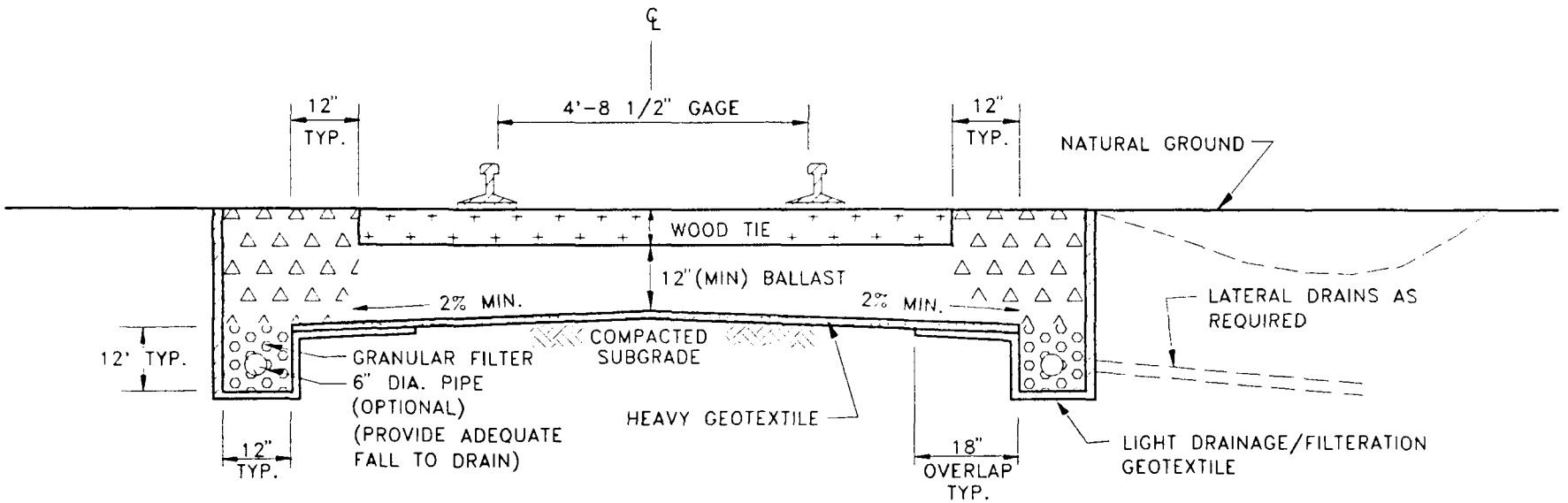
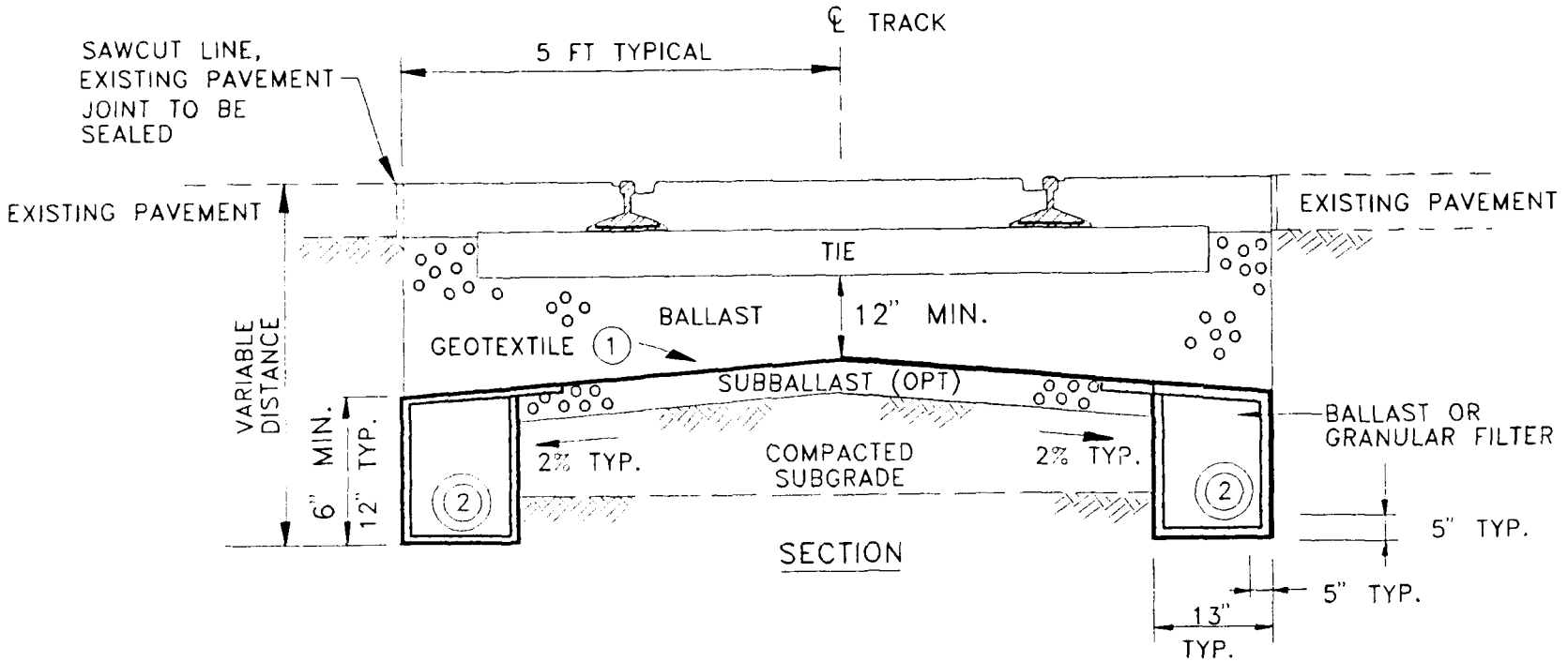


Figure 3. Geotextile installation below natural ground level



NOTE:

1) GEOTEXTILE. MINIMUM 15 OZ/YD MEETING REQUIREMENTS OF CEGS2274.
2) SUBDRAIN OF CORRUGATED, PERFORATED, POLYETHYLENE OR GALVANIZED STEEL PIPE. MINIMUM DIAMETER 6 INCHES.
3) PROVIDE ADEQUATE SLOPE TO DRAIN SUBDRAINS.

DRAWING NOT TO SCALE

Figure 4. Typical geotextile/subdrain installation for highway crossing

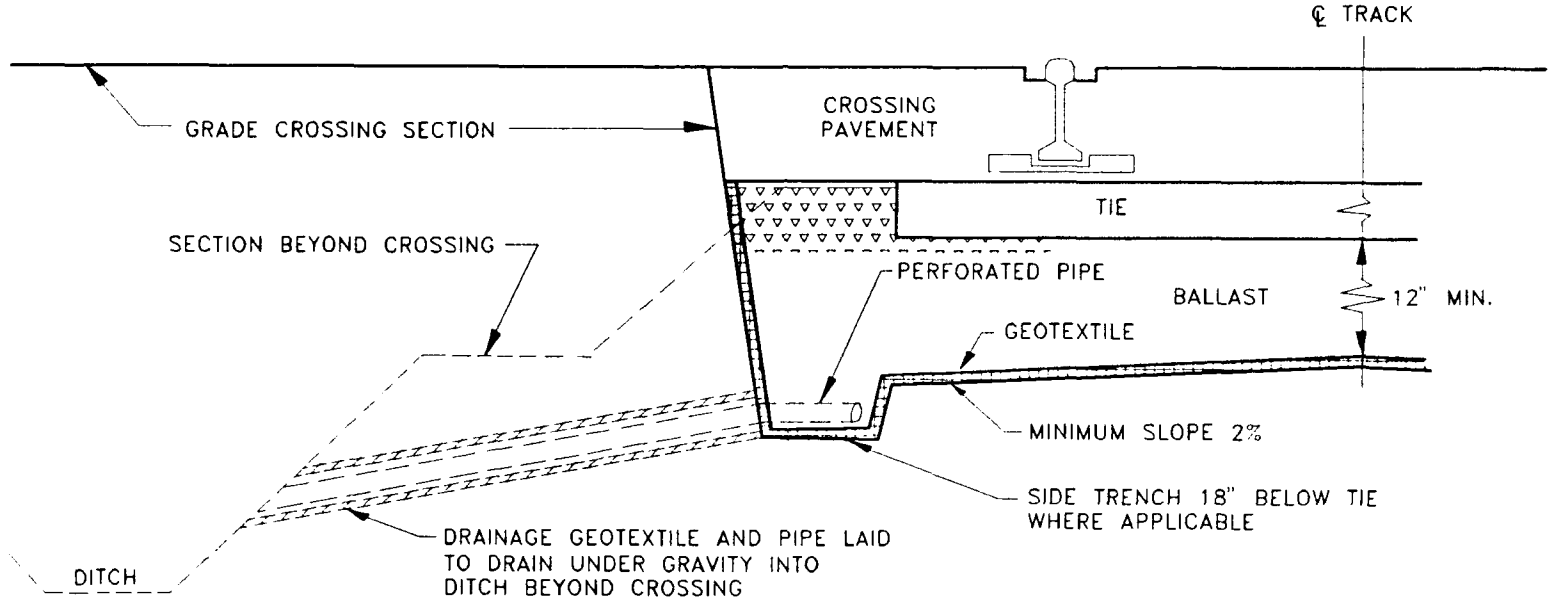


Figure 5. Typical highway grade crossing drainage provision

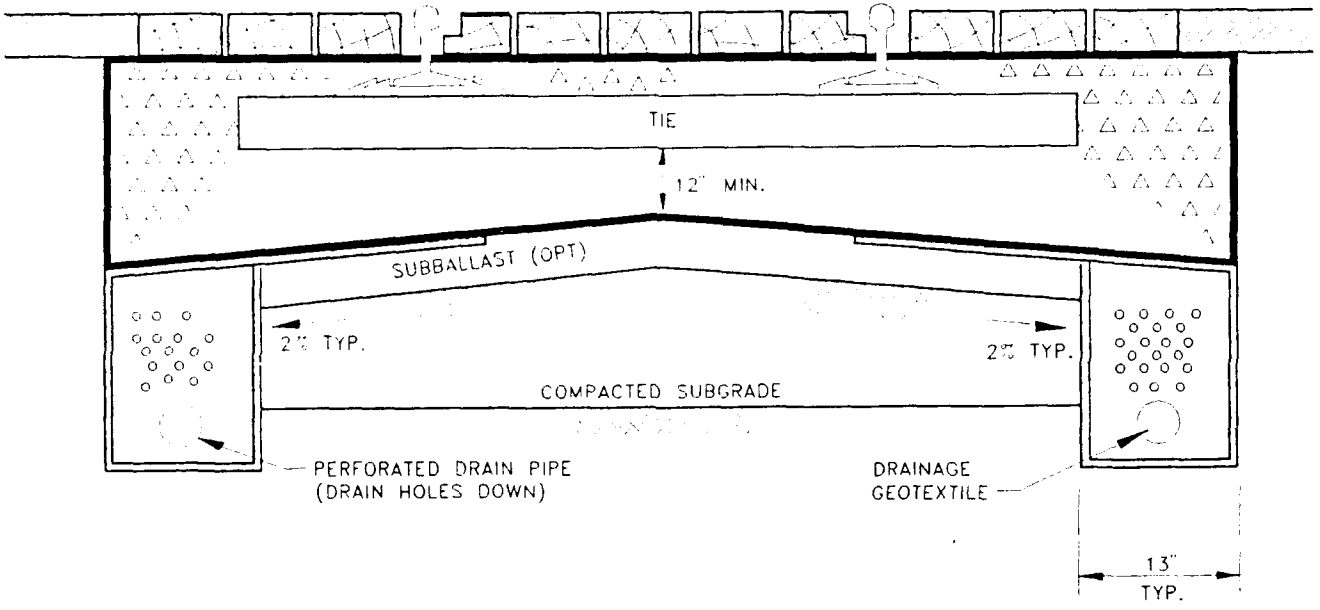


Figure 6. Typical geotextile encapsulated highway grade crossing

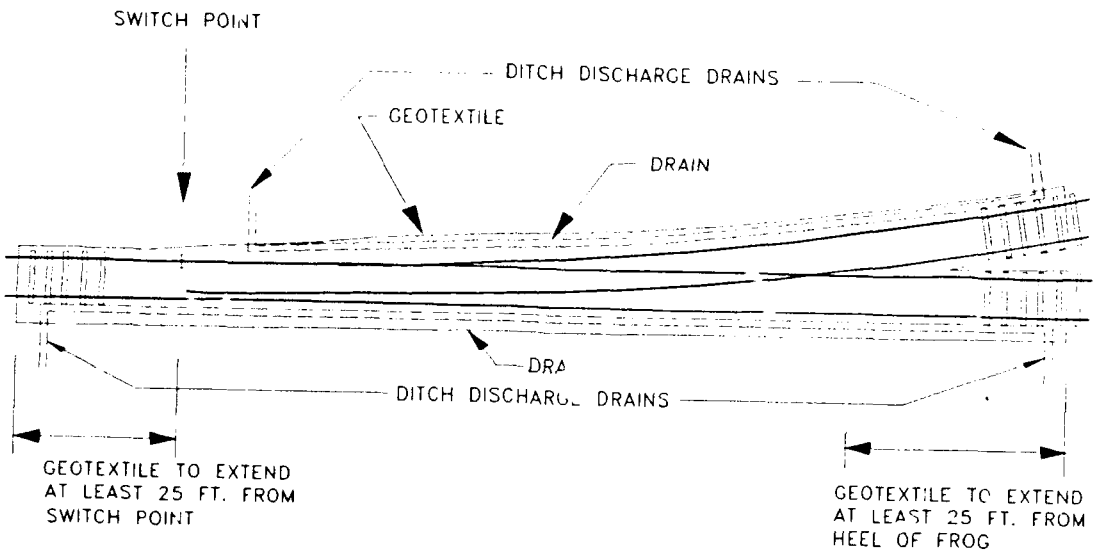


Figure 7. Plan view of geotextile installation and drainage provision in turnout area

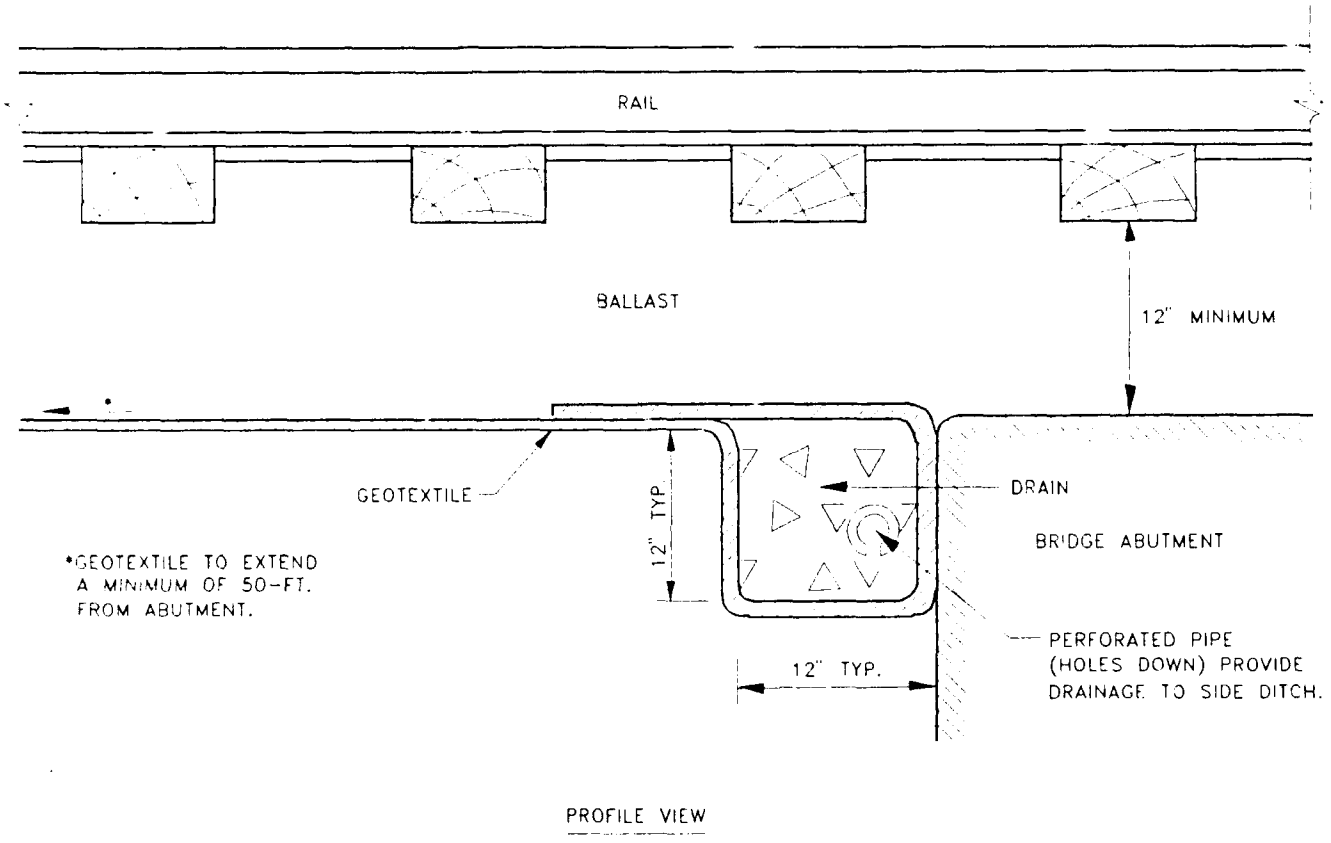


Figure 8. Application of geotextile and drain system at bridge abutment

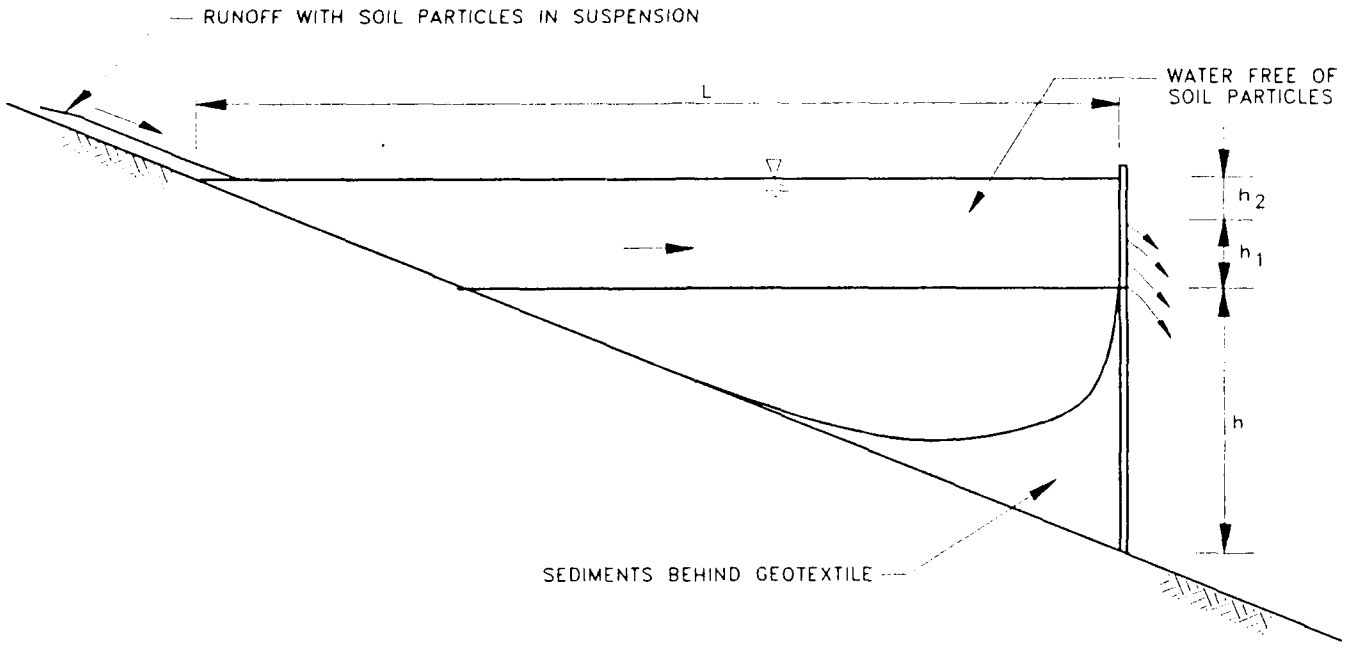


Figure 9. Filtration of surface water by a silt fence

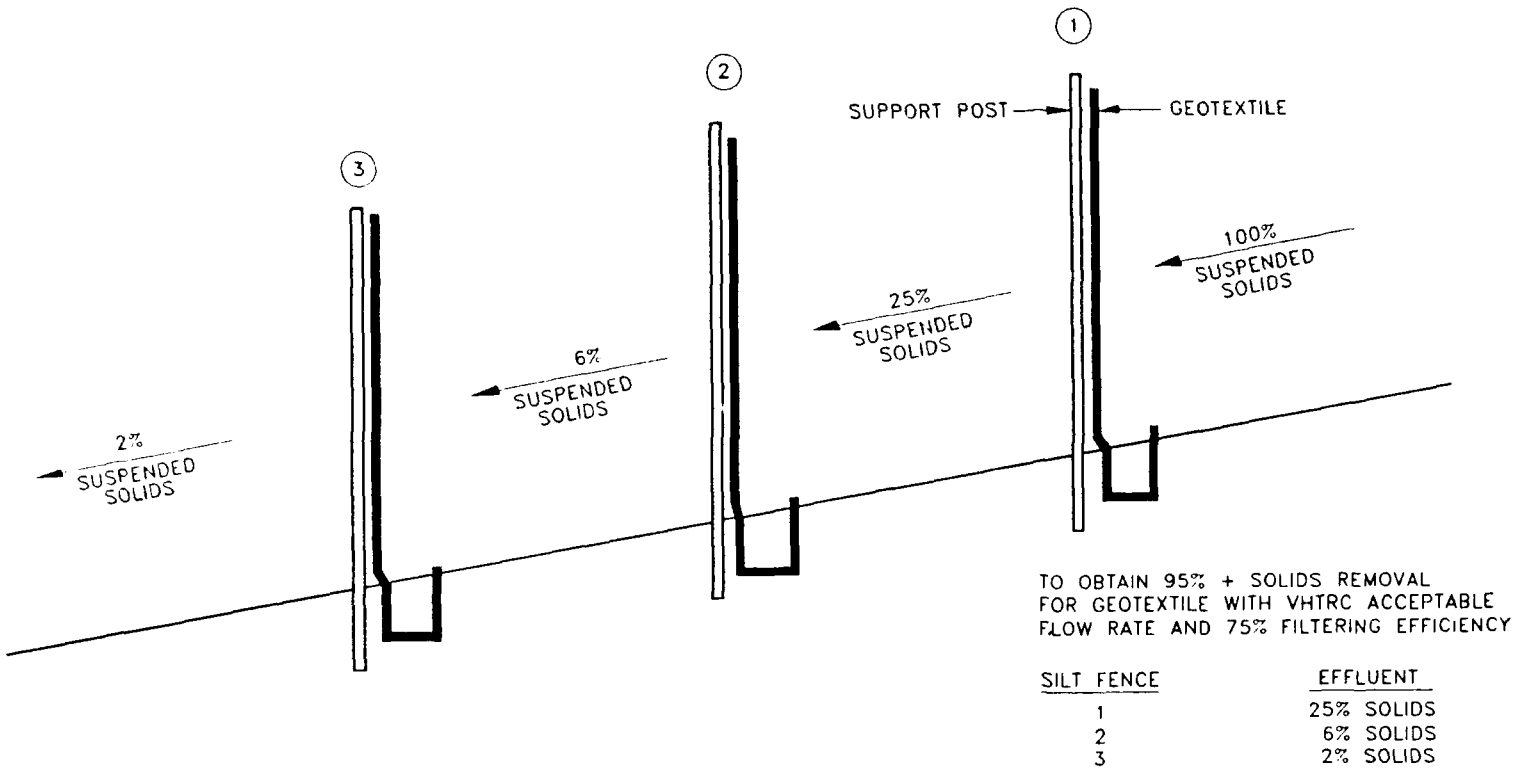


Figure 10. Example of multiple silt fences to achieve desired sediment retention

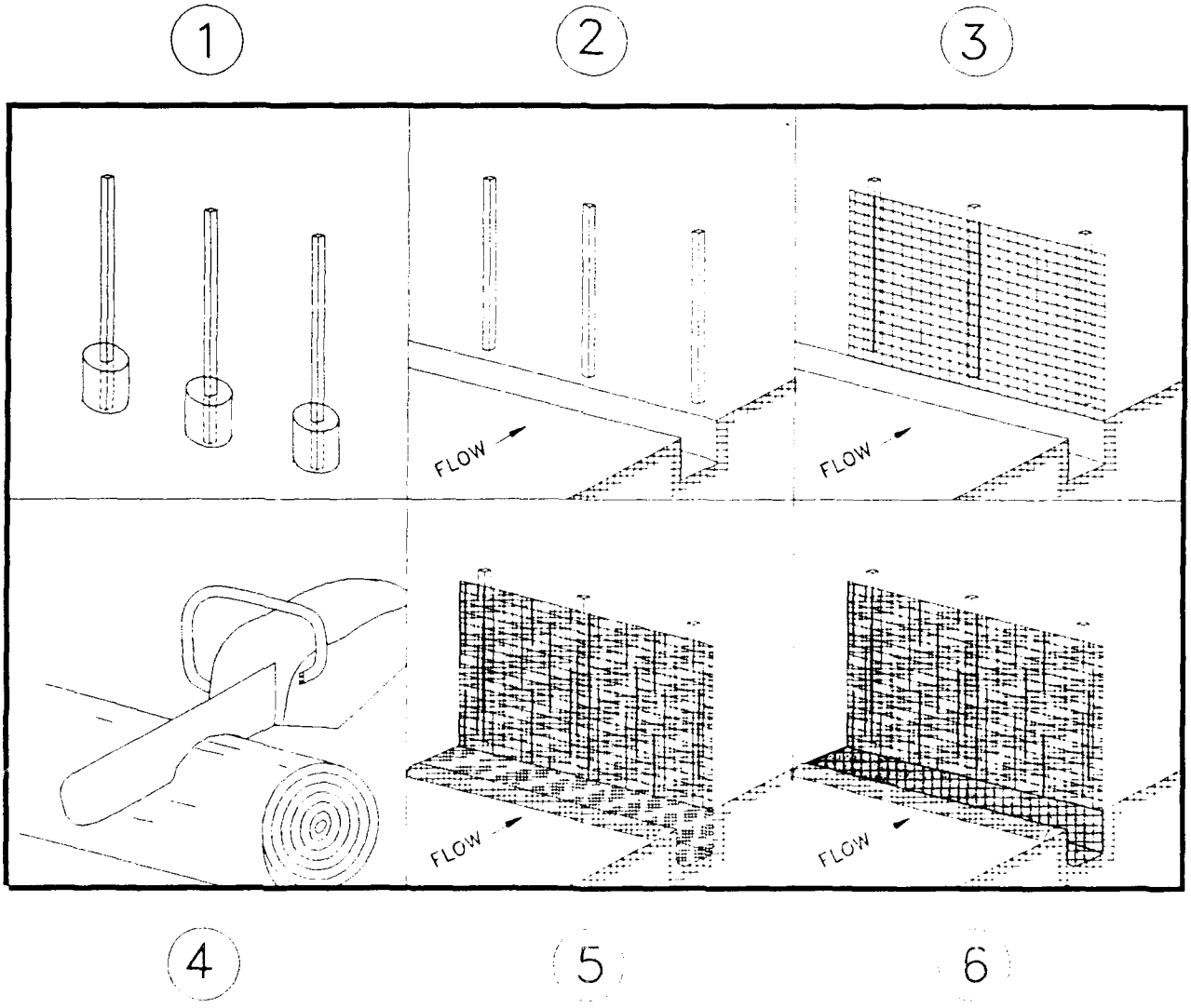


Figure 11. Steps in the construction of a silt fence

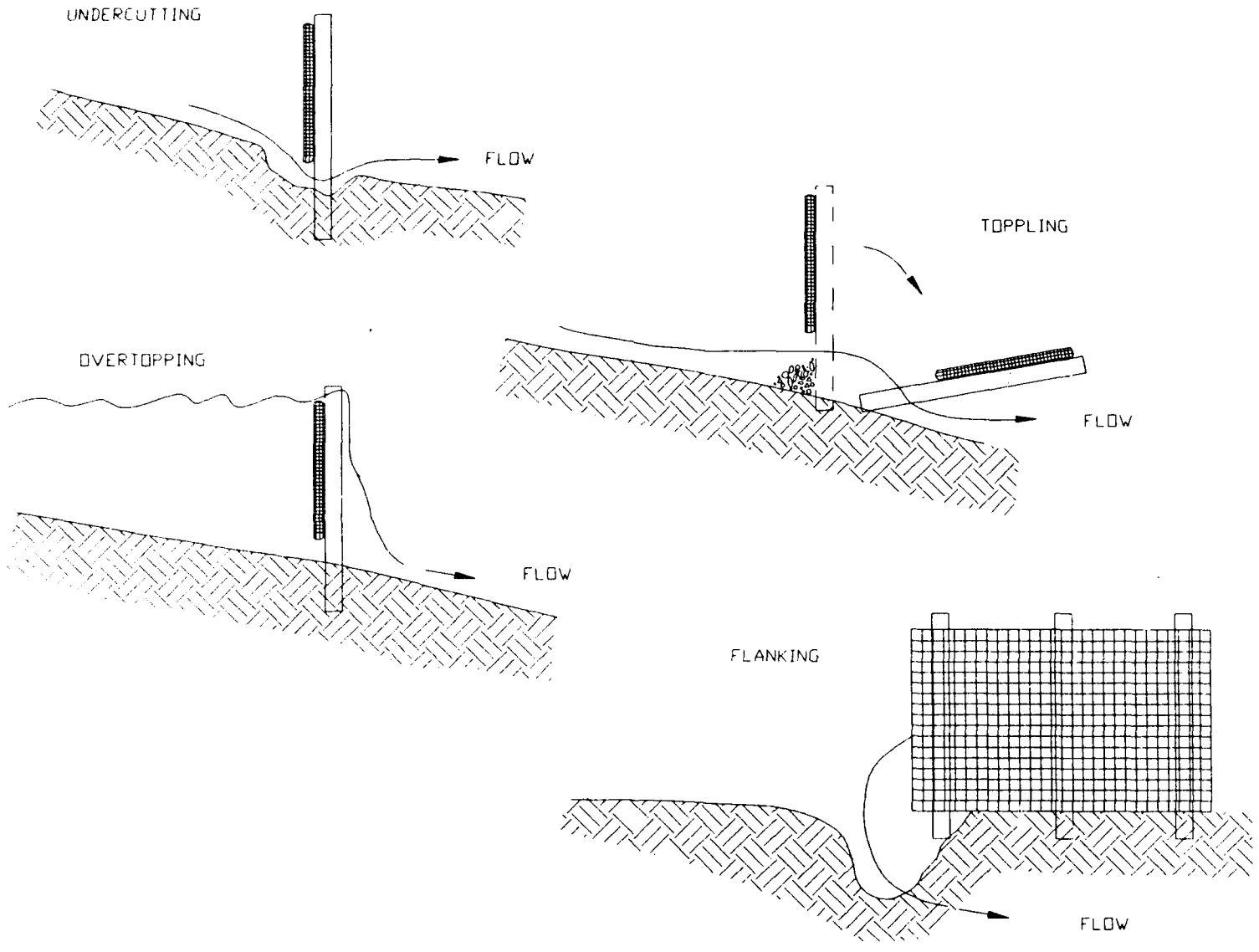


Figure 12. Typical failure modes for silt fences

APPENDIX A: RECOMMENDED GUIDE SPECIFICATION "GEOTEXTILES IN RAILROAD TRACK"

****
(January 1991)

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

****

SECTION 02274

GEOTEXTILES IN RAILROAD TRACK
1/91

****
NOTE: This guide specification covers furnishing geotextiles for and installing geotextiles beneath the ballast and/or subballast in a railroad track. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-720. Other pertinent Corps of Engineers Guide Specifications are CEGS-02100 "Clearing and Grubbing", CEGS-02210 "Grading", CEGS-02230 " Excavation, Embankment, and Preparation of Subgrade for Roadways, Railroads, and Airfields", and CEGS-02450 "Railroads." These guide specifications will be used for specifying roadbed preparation and track construction.
****

PART 1 GENERAL

****
NOTE: See Additional Notes A and B.
****

1.1 SUMMARY (Not Applicable)

****
NOTE: Paragraph "1.1. SUMMARY (Not Applicable)" is required in all CEGS in order to make CEGS compatible with guide specifications of other agencies within the SPECSINTACT system. However, this paragraph is not to be included in Corps of Engineers project specifications.
****

1.2 REFERENCES

****
NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

-C 136-	(1984a) Sieve Analysis of Fine and Coarse Aggregates
-D 1683-	(1981) Failure in Sewn Seams of Woven Fabrics
-D 3776- (Option B)	(1985) Mass per Unit Area (weight) of Woven Fabric
-D 3786-	(1987) Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics--Diaphragm Bursting Strength Tester Method
-D 4354-	(1984) Sampling of Geotextiles for Testing
-D 4355-	(1984) Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
-D 4491-	(1985) Water Permeability of Geotextiles by Permittivity
-D 4533-	(1985) Trapezoid Tearing Strength of Geotextiles
-D 4595-	(1986) Tensile Properties of Geotextiles by the Wide-Width Strip Method
- D 4632-	(1986) Breaking Load and Elongation of Geotextiles (Grab Method)
-D 4716-	(1987) Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products
-D 4751-	(1987) Determining Apparent Opening Size of a Geotextile
-D 4759-	(1988) Determining the Specification Performance of Geosynthetics

-D 4833- (1988) Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

1.3 SUBMITTALS

****
NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.
****

The following shall be submitted in accordance with Section 01300 SUBMITTALS:

[SD-50, Samples

The Contractor shall provide the Government with Geotextile samples for testing to determine compliance with this specification. Samples shall be submitted a minimum of [30] [60] [90] [_____] days prior to the beginning of installation of the geotextiles. One sample shall be provided for each 20 units (rolls, panels, etc.) of geotextile to be used in the contract. All samples shall be from the same production lot as will be supplied for the contract. Samples shall be obtained in accordance with ASTM D 4354 and ASTM D 4759 and shall be identified by the manufacturer's name, brand name, lot designation, and project name. The minimum size of sample submitted for testing shall be the full width of the geotextile by [5 feet] [30 feet] [_____] in length.]

[SD-70, Test Reports

An independent testing laboratory's certified test reports, including analysis and interpretation where necessary. These reports shall provide results of the laboratory testing performed on samples of the geotextile material delivered to the job site. Test reports shall be submitted at least [5] [_____] working days prior to the installation of the geotextile.]

SD-76, Certificate of Compliance

A manufacturer's Certificate of Compliance attesting that the geotextile meets the specified chemical, physical, and manufacturing requirements. The certification of physical properties shall be based on minimum average roll values

1.4 PRODUCT DELIVERY, STORAGE, AND HANDLING

All geotextiles shall be shipped and stored in their original ultraviolet resistant cover until the day of installation. Geotextiles shall be stored in such a manner as to be protected from vandalism, temperatures greater than 140 degrees F, dirt, dust, mud, debris, moisture, sunlight, and ultraviolet rays. All geotextiles delivered to the project site shall be

clearly labeled on the material cover to show the manufacturer's name, brand name, fabric type, location and date manufactured, lot identification, width, and length.

1.5 MEASUREMENT AND PAYMENT

****
NOTE: If the contract is a fixed price construction contract then revise or delete this paragraph as appropriate.
****

For purposes of payment, the installed geotextile shall be measured in place to the nearest [square foot] [square yard] [_____] of placement area. Materials must be actually used or installed in the completed work. No measurement will be made for wasted materials or materials used for the convenience of the Contractor. The quantities thus determined will be paid for at the unit price as shown on the Unit Price Schedule. This payment will constitute full compensation to the Contractor for providing all plant, labor, material, and equipment and for performing all operations necessary for the complete and satisfactory installation of the geotextile. Payment for material used in laps, seams, or extra lengths such as anchorage and for associated equipment such as securing pins along with the associated materials, equipment, and operations is included in the contract unit price for "geotextile" and shall not be paid for separately.

PART 2 PRODUCTS

2.1 GEOTEXTILE

2.1.1 Physical Property Requirements

****
NOTE: See Additional Note C.
****

The geotextile shall be a nonwoven, needle-punched material. The geotextile's fiber shall consist of at least [85] [95] percent by weight [polyester,] [polyamide,] [polypropylene,] [or] [polyethylene]. The geotextile shall contain stabilizers and/or inhibitors as necessary to make the filaments resistant to deterioration from ultraviolet light and heat exposure, particularly prior to placement and coverage. The fibers shall be formed into a network which will be dimensionally stable. The edges of the geotextile shall be finished in a way to prevent the outer fibers from being pulled away from the geotextile. The geotextile shall exceed the property requirements stated in Table I.

2.1.2 Dimensional Requirements

****
NOTE: See Additional Note D.
****

TABLE I. PROPERTY REQUIREMENTS

Property	Minimum Requirements*	Test Method
Weight**	15 ounce per square yard	ASTM D 3776 Option B
Color	Grey or tinted	--
Grab tensile strength	350 pounds	ASTM D 4632
Elongation at failure	20 percent	ASTM D 4632
Burst strength	620 pounds per square inch	ASTM D 3786
Puncture strength	185 pounds	ASTM D 4833
Trapezoidal tear strength	150 pounds	ASTM D 4533
Apparent opening size (AOS) (maximum required value)	Less than 0.22 millimeter (No. 70 sieve)	ASTM D 4751
Normal permeability (k)	0.1 centimeters per second	ASTM D 4491
Permittivity	0.2 centimeters per second	ASTM D 4491
Planar water flow/transmissivity at i = 1 and normal stress = 3.5 psi	0.006 square feet per minute	ASTM D 4716
Ultraviolet degradation at 150 hours	70 percent strength retained	ASTM D 4355
[Seam strength	350 pounds	ASTM D 1683]

*These property requirements are Minimum Average Roll Values in the weaker principal direction.

**Geotextile selection should not be limited by the minimum weight shown. Selection shall be based on the other property requirements listed. Heavier geotextiles have shown greater resistance to abrasion.

Each [roll] [panel] [_____] of geotextile shall be at least [_____] feet wide and [_____] feet long.

[2.2 PROTECTIVE SAND LAYER

****
NOTE: See Additional Note E.
****

Sand used in the protective sand layer below the geotextile shall meet the gradation requirements of Table II with the gradation determined using the procedures prescribed in ASTM C 136.]

[TABLE II. GRADATION OF PROTECTIVE SAND LAYER

Sieve Size	Percent Passing by Weight
1/2 inch	100
No. 4	90 - 100
No. 10	75 - 100
No. 40	40 - 70
No. 200	0 - 5]

PART 3 EXECUTION

3.1 EXAMINATION

****
NOTE: The amount of geotextile being installed and the criticalness of the installation determines the size and scope of the geotextile testing and quality control/quality assurance program. Small jobs with minor importance may not warrant extensive pre-construction testing of the geotextile and the manufacturer's Certificate of Compliance may be adequate for assuring that the physical properties are met. However for large projects and critical installations, regardless of size, a complete regimen of preconstruction and quality control testing should be specified.
****

[The Contractor shall sample the geotextile upon delivery to the project site. Sampling procedures used shall be those detailed in ASTM D 4759 and ASTM D 4354 with the number of sample units selected obtained from Table 1 of ASTM D 4354. An independent testing laboratory shall perform the index property tests specified in Table I on each of the sample units and

determine conformance with the minimum requirements of Table I. Conformance shall be determined in accordance with ASTM D 4759.] The Contracting Officer may examine any geotextiles for defects, damage, or non-conformance prior to installation. Any geotextile not meeting the minimum property requirements of Part 2 or that is determined to be damaged and/or defective shall be removed from the site and shall be replaced, at no additional cost to the Government, by additional geotextile meeting the requirements of this specification.

****

3.2 PREPARATION

Surfaces on which geotextiles will be placed shall be prepared in accordance with the applicable portions of this specification and shall be free of irregularities such as sags, cavings, erosion, or vegetation. Any irregularities shall be corrected so as to insure continuous, intimate contact of the geotextile with all the surface. Any loose material or debris will be removed prior to geotextile placement.

[3.2.1 Undercutting/Ploughing Operations. When geotextile is to be installed in an existing track following removal of the ballast by undercutting or ploughing, special care shall be taken to remove as many of the large ballast particles that remain on the roadbed surface as possible.]

****
NOTE: See Additional Note E.
****

[3.2.2 Protective Sand Layer. A protective sand layer shall be installed over the prepared roadbed [upon completion of the [undercutting] [ploughing] operations]. The protective sand layer shall be 2 inches thick and placed as shown. The protective sand layer shall be free from irregularities such as sags, cavings, erosion, etc. and shall be approved by the Contracting Officer prior to the installation of the geotextile.]

3.3 INSTALLATION

3.3.1 Placement and Cover

****
NOTE: See Additional Note F.
****

The geotextile shall be carefully placed on the prepared surface with the long dimension parallel to the prepared surface. The geotextile shall be placed free of wrinkles, folds, creases, and tension. The geotextile shall be held in place by [pins], [small aggregate piles], [ballast bags] until it is completely covered. The geotextile shall be covered immediately after placement in track. The maximum exposure time for the geotextile, from removal of the protective shipping cover to placement of the ballast/subballast cover materials sufficient to prevent exposure to sunlight, shall be [7] [_____] consecutive days.

3.3.2 Joints

****
NOTE: See Additional Note G.
****

The minimum overlap of geotextile [rolls], [panels], [_____] shall be 36 inches. If several geotextile units are placed with the required overlap prior to the placement of the [ballast] [subballast], the overlap distance of each overlap shall be checked as placement of [ballast] [subballast] approaches the overlap. Appropriate measures will be taken to insure that the required overlap exists when the geotextile is covered.

3.3.3 Protection of the Exposed Geotextile

The geotextile shall remain free of any contamination such as mud, dust, sediment, debris, etc. that will impair the function of the geotextile. Contamination shall be removed without damage to the geotextile or to the prepared surface at the Contractor's expense. If the geotextile is damaged, its function impaired by the cleaning efforts, or if it cannot be properly cleaned, the Contractor shall repair the prepared surface if necessary and replace the damaged or impaired geotextile with geotextile meeting requirements of this specification. Equipment shall not operate in direct contact with the geotextile. Surface drainage, as much as possible, will be directed away from the geotextile installation area to prevent accumulation of mud, debris, and sediment.

3.3.4 Placement of Cover Material

Placement of [ballast] [subballast] cover material in contact with the geotextile shall be performed in a manner to insure intimate contact of the geotextile with the prepared surface and with the cover material. The placement shall be performed in a manner that shall not damage the geotextile including tears, punctures, or abrasion.

3.3.5 Equipment Operations on the Cover Material

A minimum depth of [6] [8] [_____] inches of cover material will be placed over the geotextile before equipment is allowed to operate on the covered geotextile. Once the minimum cover for equipment operations exists over the geotextile, equipment may operate on the cover material. Equipment operations on the covered geotextile shall be limited to that necessary for track construction and in no case will equipment turning be allowed on the covered geotextile.

3.3.6 Minimum Ballast Depth

****
NOTE: See Additional Note H.
****

The minimum depth of ballast between the bottom of the tie and the top of the geotextile shall be [12] [_____] inches as [indicated] [specified] [in Section _____].

3.3.7 Tamping Operations

Tamping of ballast materials shall be performed by setting the tamping force and insertion depth to the minimum necessary to adequately tamp the track. The tamper operator shall monitor the depth of tamping and consciously limit the depth to prevent detrimental effects of the tamper feet on the geotextile.

3.3.8 Shoulder Removal and Reconstruction

Where track [construction] [rehabilitation] operations result in deposition of materials along the track shoulders that would impede the free drainage of the geotextile and track structure, the Contractor shall remove the material. [Where [undercutting] [ploughing] operations leave fouled shoulder materials that impedes free drainage of the geotextile and the track structure shoulder, the material shall be removed and the ballast shoulders shall be reconstructed using the materials and dimensions as indicated. Areas where shoulder removal and reconstruction are required are indicated on the drawings.]

3.3.9 Spoil Materials

Spoil materials removed from the track shall be disposed of [as indicated] [off site at the Contractors expense]. In no case will the spoil materials be placed on the shoulders, in ditches in drains, or in other areas where they would impede the flow of water away from the trace.

3.3.10 Double Layers

Double layers of geotextile shall not be allowed, except for [splicing overlaps] [at seams].

3.4 INSPECTION

At the direction of the Contracting Officer, the Contractor shall remove the cover material from the geotextile at [5] [_____] locations per [mile] [_____] so that the geotextile may be inspected for damage. At each location the cover material will be removed to expose a [4] [_____] foot by [4] [_____] foot section of the geotextile. If punctures, tears, improper installation, other impairment or damage is found within this section, additional sections shall be excavated at no cost to the government to determine the extent of the damage. All damaged geotextile shall be repaired or replaced and recovered with ballast/subballast at the Contractors expense.

****

ADDITIONAL NOTES

NOTE A: For additional information on the use of all CEGS, see CEGS-01000 CEGS GENERAL NOTES.

NOTE B: The following information should be shown on the drawings:

a. Locations for geotextile installation.

b. Locations for drainage work, including french drains to provide drainage for the geotextile.

c. Typical cross-section through track showing rail, tie, ballast, subballast, geotextile and subgrade with dimensions.

d. Locations where shoulder reconstruction is required.

e. Locations for disposal of spoil materials.

NOTE C: Table I:

a. All numerical values listed in Table I, except AOS, represent Minimum Average Roll Values and are the value in the weaker principal direction. The Minimum Average Roll Value (MARV) is the lowest of the average roll values determined from testing a small number of rolls. The average roll value is the mean test results obtained from testing specimens taken from one roll of geotextile. For Example: Ten rolls of geotextile are delivered to the project site. The quality control inspector decides to sample several rolls and determine the MARV to see if the geotextile meets the specification. The property of interest is grab tensile strength. A full-width piece that is 3 feet long is taken from each of 3 randomly selected rolls and tested by an independent laboratory. Laboratory testing consisted of taking 5 specimens from each roll and testing them in accordance with the designated test procedure. The test results are:

Grab Strength, pounds force

Test No.	Roll Number 1	2	3
1	367	348	353
2	359	354	360
3	370	358	340
4	353	346	359
5	358	355	365
Mean	361	352	355

The Minimum Average Roll Value for grab tensile strength is 352 pounds and must equal or exceed the grab tensile strength required by the project specification.

b. The minimum weight listed herein is based on the experience that geotextiles with weights less than 15 ounces per yard tend to show greater abrasion and wear than do heavier weight materials.

c. Color should be grey or tinted as not to cause "snow blindness" of personnel during installation.

d. The permeability of the geotextile should be at least five times greater than the permeability of the subgrade soil but not less than the specified value. The pressure used to measure the nominal thickness (necessary to calculate the permeability) in ASTM D 1777 should be based on the pressure expected to be placed on the geotextile in the installation.

e. Most railroad applications use overlap as a method of joining separate pieces of geotextile. But in some applications seaming may be specified. ASTM D 1683 is used to specify seam strengths, but

ASTM D 4632 should be used for strength testing instead of ASTM D 1682 as given in ASTM D 1683. If seams are specified, see Federal the Standard 751a. If the geotextile is expected to perform a reinforcement function, the seam may require testing by ASTM D 4595.

NOTE D: Paragraph 2.1.2: It is desirable that the width of the geotextile be sufficient to cover the entire width of

the roadbed with no longitudinal seams or overlaps. Where mechanized geotextile laying equipment will be used to place the geotextile, the maximum diameter of the geotextile rolls should not exceed the capability of the equipment to be used on the project.

NOTE E: Paragraph 2.2, Table II, and Paragraph 3.1.2: The use of a protective sand layer above/below the geotextile is optional. Indications are that the sand layer serves a dual function of protecting the geotextile and providing an additional filtration layer. The sand used in the protective layer(s) should be a clean, free-draining, nonpumping sand. Gradations other than those given in Table II may be used to meet the necessary filtration requirements. See TM 5-820-2 for additional information on subsurface drainage and filtration criteria. Delete Paragraph 2.2, Table II, and Paragraph 3.1.2 if protective sand layer is not specified.

NOTE F: Paragraph 3.3.1: Prior to the placement of the cover material (ballast or subballast), the geotextile may be anchored in several ways--pins, small ballast piles, ballast bags, etc. If fixing of the geotextile is critical and adverse conditions exist, e.g. steep slopes or high winds, the specification can detail anchoring requirements, e.g. pin length and spacing. Care should be taken to prevent or quickly release any tension caused by anchoring and placement of the geotextile cover materials. Excessive tension can cause bridging of irregularities beneath the geotextile and increase the potential for puncture.

NOTE G: Paragraph 3.3.2: If there is reason to suspect movement which will reduce overlap, provision should be made in the specification to remove cover materials at selected areas in order to determine if required overlap is being maintained after cover placement.

NOTE H: Paragraph 3.3.6: The minimum depth of ballast for the track section being constructed/reconstructed is to be specified in Section 02450 "Railroads." However, where geotextiles are used in the track structure, the minimum depth of ballast/subballast between the tie and the geotextile is 12 inches. Severe damage to the geotextile is likely to occur if the ballast depth is less than 12 inches.

****

-- End of Section --

APPENDIX B: *RECOMMENDED GUIDE SPECIFICATION*
"GEOTEXTILES FOR FILTRATION AND DRAINAGE"

****
(January 1991)

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

****

SECTION 02277

GEOTEXTILES FOR FILTRATION AND DRAINAGE
1/91

****
NOTE: This guide specification covers the requirements for furnishing and installing geotextiles as filters and drains. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-720.
****

PART 1 GENERAL

****
NOTE: See Additional Note A.
****

1.1 SUMMARY (Not Applicable)

****
NOTE: Paragraph "1.1 SUMMARY (Not Applicable)" is required in all CEGS in order to make CEGS compatible with guide specifications of other agencies within the SPECSINTACT system. However, this paragraph is not to be included in Corps of Engineers project specifications.
****

1.2 REFERENCES

****
NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

****
NOTE: See Additional Note B.
****

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

-D 1682-	(1964) Breaking Load and Elongation of Textile Fabrics
-D 1683-	(1981) Failure in Sewn Seams of Woven Fabrics
-D 1777-	(1964) Measuring Thickness of Textile Materials
-D 4354-	(1984) Sampling of Geotextiles for Testing
-D 4491-	(1985) Water Permeability of Geotextiles by Permittivity
-D 4533-	(1985) Trapezoid Tearing Strength of Geotextiles
-D 4595-	(1986) Tensile Properties of Geotextiles by the Wide-Width Strip Method
-D 4632-	(1986) Breaking Load and Elongation of Geotextiles (Grab Method)
-D 4716-	(1987) Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products
-D 4751-	(1987) Determining Apparent Opening Size of a Geotextile
-D 4759-	(1988) Determining the Specification Performance of Geosynthetics
-D 4833-	(1988) Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

FEDERAL STANDARDS (FED. STD)

CW 02215	(1986) Geotextiles as Filters

1.3 SUBMITTALS

****

NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary

factors in determining if a submittal for the item should be required.
****

The following shall be submitted in accordance with Section 01300 SUBMITTALS:

[SD-50, Smaples

The Contractor shall provide the Government with Geotextile samples for testing to determine compliance with this specification. Samples shall be submitted a minimum of [30] [60] [90] [_____] days prior to the beginning of installation of the geotextiles. One sample shall be provided for each 20 units (rolls, panels, etc.) of geotextile to be used in the contract. All samples shall be from the same production lot as will be supplied for the contract. Samples shall be obtained in accordance with ASTM D 4354 and ASTM D 4759 and shall be identified by the manufacturer's name, brand name, lot designation, and project name. The minimum size of sample submitted for testing shall be the full width of the geotextile by [5 feet] [30 feet] [_____] in length.]

[SD-70, Test Reports

An independent testing laboratory's certified test reports, including analysis and interpretation where necessary. These reports shall provide results of the laboratory testing performed on samples of the geotextile material delivered to the job site. Test reports shall be submitted at least [5] [_____] working days prior to the installation of the geotextile.]

SD-76, Certificate of Compliance

A manufacturer's Certificate of Compliance attesting that the geotextile meets the specified chemical, physical, and manufacturing requirements. The certification of physical properties shall be based on minimum average roll values.

1.4 PRODUCT DELIVERY, STORAGE, AND HANDLING

All geotextiles shall be shipped and stored in their original ultraviolet resistant cover until the day of installation. Geotextiles shall be stored in such a manner as to be protected from vandalism, temperatures greater than 140 degrees F, dirt, dust, mud, debris, moisture, sunlight, and ultraviolet rays. All geotextiles delivered to the project site shall be clearly labeled on the material cover to show the manufacturer's name, brand name, fabric type, location and date manufactured, lot identification, width, and length.

1.5 MEASUREMENT FOR PAYMENT

****
NOTE: If the contract is a fixed price construction contract then revise or delete this paragraph as appropriate.
****

For purposes of payment, the installed geotextile shall be measured in place to the nearest [square foot] [square yard] [_____] of placement area. Materials must be actually used or installed in the completed work. No measurement will be made for wasted materials or materials used for the convenience of the Contractor. The quantities thus determined will be paid for at the unit price as shown on the Unit Price Schedule. This payment will constitute full compensation to the Contractor for providing all plant, labor, material, and equipment and for performing all operations necessary for the complete and satisfactory installation of the geotextile. Payment for material used in laps, seams, or extra lengths such as anchorage and for associated equipment such as securing pins along with the associated materials, equipment, and operations is included in the contract unit price for "geotextile" and shall not be paid for separately.

1.6 SAMPLING AND TESTING

****
NOTE: See Additional Note C.
****

1.6.1 Samples

The Contractor will sample the geotextile immediately upon delivery to the project site. [Each] [one of every ..... rolls] [panels] [.....] of geotextile will be sampled. The sampling procedure will follow that given in the appropriate test method. Samples submitted for testing shall be identified by brand name, type of fabric, location and date manufactured, lot identification, length, and width. The size of the sample shall be as directed in the appropriate test method. The samples shall be tested at an approved testing laboratory at the Contractor's expense.

1.6.2 TEST PERFORMANCE

The tests performed shall determine if the specification requirements are met. The Contractor shall submit a report [.....] week[s] before construction begins, stating the test results and certifying that all tests were performed in accordance with the procedures indicated in PART 2. If the certified test results indicate values less than those specified, the [roll] [panel] [.....] from which the sample was obtained will be rejected. In case of any failing tests, the Contracting Officer may require testing on samples taken from other [rolls] [panels] [.....]. The [Contractor] [.....] shall collect all samples as directed and perform the tests at his expense. If these additional tests show nonconformance with the specification requirements, the Contracting Officer may reject the entire stock of geotextile stored at the project site.

PART 2 PRODUCTS

****
NOTE: See Additional Note D.
****

2.1 GEOTEXTILE

The geotextile shall be a [woven], [nonwoven], [woven or nonwoven] pervious sheet of plastic yarn. Tape or slit film-type products will not be accepted. The geotextile's fiber shall consist of at least [85] [95] percent by weight of [polyester], [polyamide], [polypropylene], or [polyethylene] and shall contain stabilizers and/or inhibitors as necessary to make the filaments resistant to deterioration from ultraviolet light and heat exposure, particularly prior to placement and coverage of the geotextile. The fibers shall be formed into a network which will be dimensionally stable. The edges of the geotextile shall be finished in a way to prevent outer fibers from being pulled away from the geotextile. The geotextile shall meet or exceed the property requirements stated in Table I.

TABLE I. PROPERTY REQUIREMENTS

Property	Minimum Required Value	Test Method
Apparent Opening Size (AOS)	..... mm	ASTM D 4751
Permeability	..... cm/sec	ASTM D 4491 ASTM D 1777 ASTM D 4716
Grab tensile strength	..... pounds	ASTM D 4632
Elongation	..... percent	ASTM D 4632
Puncture strength	..... pounds	ASTM D 4833
Burst strength	..... psi	ASTM D 3786
Trapezoid tear	..... pounds	ASTM D 4533
Ultraviolet degradation at 150 hr	70% strength retained	ASTM D 4355
[Seam strength	..... pounds	ASTM D 1683]

PART 3 EXECUTION

3.1 PREPARATION

Surfaces on which geotextiles will be placed shall be prepared in accordance with the applicable portions of this specification and shall be free of irregularities such as cavings, erosion features, or vegetation. Any irregularities will be removed so as to insure continuous, intimate contact of the geotextile with all the surface. Any loose material or debris will be removed prior to geotextile placement.

3.2 INSTALLATION

****
NOTE: See Additional Note E.
****

3.2.1 Placement and Cover

The geotextile shall be carefully placed on the prepared surface, free of wrinkles, folds, creases, and tension. The geotextile shall be [temporally] held in place by [pins] [small aggregate piles] [stones]. The geotextile will be covered as soon as possible after placement, but exposure time for the geotextile, from removal of the protective cover on the [rolls] [panels] [.....] to placement of cover materials sufficient to prevent exposure to sunlight, will not exceed 7 consecutive days. Partial [rolls] [panels] [.....] of geotextile shall be protected in the same manner as unused [rolls] [panels] [.....].

****
NOTE: See Additional Note F.
****

3.2.2 Joints

The overlap of geotextile [rolls] [panels] [.....] shall be [12] [24] [36] [.....] inches. Appropriate measures will be taken to insure required overlap exists after cover placement.

3.2.3 Protection of the Exposed Geotextile

The geotextile shall remain free of any contamination such as mud, dust, sediment, debris, etc. Any contamination shall be removed without damage to the geotextile or the prepared surface at the Contractor's expense. If the geotextile is damaged, its function impaired by the cleaning efforts, or if it cannot be properly cleaned, the Contractor shall repair the prepared surface if necessary and replace the damaged or impaired geotextile with geotextile meeting this specification at the Contractor's expense. Equipment will not be allowed on the geotextile. Surface drainage, as much as possible, will be directed away from the geotextile installation area to prevent accumulation of mud, debris, and sediment.

3.2.4 Placement of Cover Material

Placement of cover material in contact with the geotextile shall be performed in a manner to insure intimate contact of the geotextile with the prepared surface and with the cover material. The placement shall also be performed in a manner that shall not damage the geotextile including tear, puncture, or abrasion. [The Contractor, at the direction of the Contracting Officer, shall remove cover material form the geotextiles for [.....] sections with dimensions of [..... feet by ..... feet] to allow inspection of the geotextile.] [Any geotextile damaged beneath the cover material shall be replaced as necessary and recovered at the Contractor's expense.]

3.2.5 Equipment Operations on the Cover Material

A minimum depth of [8] [12] [.....] inches of cover material will be placed over the geotextile before equipment is allowed to operate over the covered geotextile. Once the minimum cover for equipment operations exists over the geotextile, equipment may operate on the cover material, but equipment turning will not be allowed on the cover.

****

ADDITIONAL NOTES

NOTE A: For additional information on the use of all CEGS, see CEGS-01000 CEGS GENERAL NOTES.

NOTE B: Paragraph 1.2: The listed designations for publications are those that were in effect when this guide specification was being prepared. These designations are updated when necessary by Notice, and references in project specifications need be no later than in the current Notice for this guide specification. To minimize the possibility of error, the letter suffixes, amendments, and dates indicating specific issues should be retained in paragraph 1.2, and omitted elsewhere in the project specifications.

NOTE C: The specifier should be specific in defining the frequency of sampling per given unit of geotextile. ASTM standard practices D 4354 and D 4759 provide limited, very general guidance for geotextile sampling procedures and specification performance. The specifier should exercise his judgement (with or without use of the ASTM practices) for determining sampling methods and frequency based on specific project characteristics such as consequences of failure cost, etc.

NOTE D: Paragraph 2.1 and Table I:

a. The specified value of AOS is based on the grain size of the soil/material in contact with the geotextile. Normally, the specified value of AOS will be within the range of 0.06 to 0.3 mm. The pressure used to measure nominal thickness (necessary to calculate permeability) in D 1777 should be based on the pressure expected to be placed on the geotextile in the installation. Geotextile permeability should exceed the permeability of the soil/material

from which it will receive water. If flow in the plane of the geotextile must be specified, use ASTM D 4716. Apparent opening size and permeability should be specified based on the following table.

Geotextile Filtration Properties for Drainage Applications

Protected Material[1] (Percent Passing No. 200 Sieve)	Piping[2]	Permeability	
		Woven[3]	Nonwoven[4]
Less than 5%	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 10%	$k_G \geq 5k_s$
5 to 50%	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 4%	$k_G \geq 5k_s$
50 to 85%	AOS (mm) $\leq D_{85}$ (mm) Upper limit on AOS is AOS (mm) $\leq$ 0.212 mm (No. 70 US Standard Sieve)	POA $\geq$ 4%	$k_G \geq 5k_s$
Greater than 85%	AOS (mm) $\geq$ 0.125 mm (No. 120 US Standard Sieve)		$k_G \geq 5k_s$

[1]Protected Material is the material that is to be prevented from moving in the direction of the drainage flow. e.g. at the subgrade soil/drainage trench interface with water moving into the trench, the soil would be the protected material.

[2]When the protected material contains appreciable quantities of material retained on the No. 4 sieve use only the soil passing the No. 4 sieve in selecting the AOS of the geotextile.

[3]POA, percent open area, is the net area of a geotextile that is not occupied by filaments. POA is normally determined only for woven and nonwoven geotextiles having distinct visible and measurable openings that continue directly through the geotextile.

[4]k_g is the permeability of the nonwoven geotextile and k_s is the permeability of the protected soil.

b. Specify property requirements based on the requirements given in the following table for the expected installation condition.

Geotextile Survivability Properties for Drainage Applications

Property	Minimum Requirements[1] For Condition Class A[2]	Class B[3]	Test Method
Grab Strength lb	180	80	ASTM D 4632
Elongation (%)	15	15	ASTM D 4632
Sewn Seam Strength[4] lb	180	80	ASTM D 4884
Puncture Strength lb	80	25	ASTM D 4833
Burst Strength psi	290	130	ASTM D 3786
Trapezoid Tear lb	50	25	ASTM D 4533
Ultraviolet Degradation at 150 hours	70% strength retained	70% strength retained	ASTM D 4355

[1]Minimum Average Roll Value. Use value in weaker principle direction. All numerical values represent minimum average roll value (i.e., test results from any sampled roll in a lot shall meet or exceed the minimum values in the table). Stated values are for noncritical, nonsevere applications. Lots sampled according to ASTM D 4354.
[2]Class A installation conditions for geotextile are where installation stresses are more severe than Class B conditions; i.e., very coarse, sharp angular aggregate is used a heavy degree of compaction (ASTM D 698) is specified, depth of trench is greater than 10 feet, or where geotextile is in contact.
[3]Class B with ballast material installation are those where geotextile conditions is used with smooth graded surfaces having no sharp angular projections, no sharp angular aggregate is used; compaction requirements are light (< ASTM D 698), and trenches are less than 10 ft in depth.
[4]Values apply to both field and manufactured seams.

c. Most filtration and drainage applications use overlap as a method of joining the separate pieces of geotextile, but in some applications, seaming may be

specified. ASTM D 1683 may be used to specify seam strengths, but D 4632 should be used for strength testing instead of D 1682 as given in D 1683. If seams are specified, see Federal Standard 751a. If the geotextile is expected to perform a reinforcement function, the seam may require testing by D 4595, and the guide specification for geotextile reinforcement should be consulted.

NOTE E: Paragraph 3.2.1: Prior to cover material placement, the geotextile may be fixed in several ways--pins, aggregate, stone, etc. If fixing the geotextile is critical and adverse conditions may exist, e.g. steep slopes and high winds, the specification can detail fixing methods, e.g. pin length and spacing. Care should be taken to prevent or quickly release any tension caused by fixing and placement of geotextile cover materials. Excessive tension in the geotextile can cause bridging of irregularities beneath the geotextile and increase the potential for puncture.

NOTE F: Paragraph 3.2.2: Overlap distance should be based on the amount of movement conservatively expected based on installation conditions such as slope, effect of compaction, placement of cover, etc. If there is reason to suspect movement which will reduce overlap, provision should be made in the specification to remove cover materials at selected areas in order to determine if required overlap is being maintained after cover placement. The overlap distance should exceed the expected movement at the joints by a factor of 2. If any strength is required perpendicular to the overlap alinement, seams should be considered.

****

-- End of Section --

APPENDIX C: RECOMMENDED GUIDE SPECIFICATION "GEOTEXTILES USED IN EROSION CONTROL"

****
(January 1991)

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

****

SECTION .....

GEOTEXTILES USED IN EROSION CONTROL
1/91

****
NOTE: This guide specification covers furnishing geotextiles for and installing geotextiles in erosion control applications along railroad track. In this application the geotextile is used as a filter beneath the cover material, such as riprap, cement blocks, sand bags, etc., to protect the underlying soil against erosion and piping around and under the cover material. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-720. Other pertinent Corps of Engineers Guide Specifications are CEGS-02100 "Clearing and Grubbing", CEGS-02210 "Grading", CEGS-02230 "Excavation, Embankment, and Preparation of Subgrade for Roadways, Railroads, and Airfields", and CEGS-02450 "Railroads." These guide specifications will be used for specifying embankment and roadbed preparation and track construction.
****

PART 1 GENERAL

****
NOTE: See Additional Note A.
****

1.1 SUMMARY (Not Applicable)

****
NOTE: Paragraph "1.1. SUMMARY (Not Applicable)" is required in all CEGS in order to make CEGS compatible with guide specifications of other agencies within the SPECSINTACT system. However, this paragraph is not to be included in Corps of Engineers project specifications.
****

1.2 REFERENCES

****

NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

-D 1683-	(1981) Failure in Sewn Seams of Woven Fabrics
-D 3786-	(1987) Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics--Diaphragm Bursting Strength Tester Method
-D 4354-	(1984) Sampling of Geotextiles for Testing
-D 4355-	(1984) Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
-D 4491-	(1985) Water Permeability of Geotextiles by Permittivity
-D 4533-	(1985) Trapezoid Tearing Strength of Geotextiles
-D 4632-	(1986) Breaking Load and Elongation of Geotextiles (Grab Method)
-D 4716-	(1987) Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products
-D 4751-	(1987) Determining Apparent Opening Size of a Geotextile
-D 4759-	(1988) Determining the Specification Performance of Geosynthetics

-D 4833-

(1988) Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products

1.3 SUBMITTALS

****

NOTE: Submittals must be limit to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

****

The following shall be submitted in accordance with Section 01300 SUBMITTALS:

[SD-50, Samples

The Contractor shall provide the Government with Geotextile samples for testing to determine compliance with this specification. Samples shall be submitted a minimum of [30] [60] [90] [_____] days prior to the beginning of installation of the geotextiles. One sample shall be provided for each 20 units (rolls, panels, etc.) of geotextile to be used in the contract. All samples shall be from the same production lot as will be supplied for the contract. Samples shall be obtained in accordance with ASTM D 4354 and ASTM D 4759 and shall be identified by the manufacturer's name, brand name, lot designation, and project name. The minimum size of sample submitted for testing shall be the full width of the geotextile by [5 feet] [30 feet] [_____] in length.]

[SD-70, Test Reports

An independent testing laboratory's certified test reports, including analysis and interpretation where necessary. These reports shall provide results of the laboratory testing performed on samples of the geotextile material delivered to the job site. Test reports shall be submitted at least [5] [_____] working days prior to the installation of the geotextile.]

SD-76, Certificate of Compliance

A manufacturer's Certificate of Compliance attesting that the geotextile meets the specified chemical, physical, and manufacturing requirements. The certification of physical properties shall be based on minimum average roll values.

1.4 PRODUCT DELIVERY, STORAGE, AND HANDLING

All geotextiles shall be shipped and stored in their original ultraviolet resistant cover until the day of installation. Geotextiles shall be stored in such a manner as to be protected from vandalism, temperatures greater than 140 degrees F, dirt, dust, mud, debris, moisture, sunlight, and ultraviolet rays. All geotextiles delivered to the project site shall be

clearly labeled on the material cover to show the manufacturer's name, brand name, fabric type, location and date manufactured, lot identification, width, and length.

1.5 MEASUREMENT AND PAYMENT

****
NOTE: If the contract is a fixed price construction contract then revise or delete this paragraph as appropriate.
****

For purposes of payment, the installed geotextile shall be measured in place to the nearest [square foot] [square yard] [_____] of placement area. Materials must be actually used or installed in the completed work. No measurement will be made for wasted materials or materials used for the convenience of the Contractor. The quantities thus determined will be paid for at the unit price as shown on the Unit Price Schedule. This payment will constitute full compensation to the Contractor for providing all plant, labor, material, and equipment and for performing all operations necessary for the complete and satisfactory installation of the geotextile. No separate payment shall be made for:

a. Shipping, handling, storage, and protection of geotextile.

b. Replaced geotextile damaged by any cause nor for its removal and replacement.

c. Additional geotextile required for anchoring the terminal ends of the geotextile or for seams, overlap joints and repairs.

d. Material used to provide cushioning layer to permit increase in allowable drop height of stone.

e. Securing pins or other accessories used for fastening the geotextile and threads used in joining geotextiles by sewing.

1.6 SAMPLING AND TESTING

****
NOTE: See Additional Note B.
****

1.6.1 Samples

The Contractor will sample the geotextile immediately upon delivery to the project site. [Each] [one of every ..... rolls] [panels] [.. ..] of geotextile will be sampled. The sampling procedure will follow that given in the appropriate test method. Samples submitted for testing shall be identified by brand name, type of fabric, location and date manufactured, lot identification, length, and width. The size of the sample shall be as directed in the appropriate test method. The samples shall be tested at an approved testing laboratory at the Contractor's expense.

1.6.2 TEST PERFORMANCE

The tests performed shall determine if the specification requirements are met. The Contractor shall submit a report [.....] week[s] before construction begins, stating the test results and certifying that all tests were performed in accordance with the procedures indicated in PART 2. If the certified test results indicate values less than those specified, the [roll] [panel] [.....] from which the sample was obtained will be rejected. In case of any failing tests, the Contracting Officer may require testing on samples taken from other [rolls] [panels] [.....]. The [Contractor] [....] shall collect all samples as directed and perform the tests at his expense. If these additional tests show nonconformance with the specification requirements, the Contracting Officer may reject the entire stock of geotextile stored at the project site.

PART 2 PRODUCTS

2.1 GEOTEXTILE

2.1.1 Physical Property Requirements

****
NOTE: See Additional Note C.
****

The geotextile shall be a [woven] [or] [nonwoven] pervious sheet of plastic monofilament yarns as defined by ASTM D-123. Fibers used in the manufacture of the geotextile and the threads used in joining geotextiles by sewing shall consist of long-chain synthetic polymers only, composed of at least 85 percent by weight of polyethylene, polypropylene, polyesters, or polyamides, and shall contain stabilizers and/or inhibitors added to the base material if necessary to make the filaments resistant to deterioration due to UV and heat exposure. Geotextile sheets shall be formed of monofilament yarns into such a network in which yarns retain dimensional stability relative to each other during handling, placement, and long-term service. The geotextile shall have flexibility so it can adjust to differential settlements of the protected soil surface, yet have sufficient strength so that it will not be punctured, torn, or otherwise damaged during placement. It shall be free of defects, rips, holes, or flaws and durable enough to last the expected project life. The geotextile shall conform to the minimum strength and property requirements listed in Table I for each specified use.

2.2 FASTENERS

****
See Additional Note D.
****

Pins for securing the geotextile shall be of steel, a minimum of 3/16 inch in diameter, 18 inches long, pointed at one end, and fabricated with a head on the other end to retain a steel washer having outside diameter of not less than 1.5 inches.

TABLE I. PROPERTY REQUIREMENTS

Property	Minimum Required Value	Test Method
Apparent Opening Size (AOS)	..... mm	ASTM D 4751
Permeability	.... cm/sec	ASTM D 4491 ASTM D 4716
Grab Tensile Strength	..... pounds	ASTM D 4632
Elongation	..... percent	ASTM D 4632
Puncture Strength	..... pounds	ASTM D 4833
Burst Strength	..... psi	ASTM D 3786
Trapezoid Tear Strength	..... pounds	ASTM D 4533
Ultraviolet Degradation at 150 hours	70% Strength Retained	ASTM D 4355
[Seam Strength	..... pounds	ASTM D 1683]

2.3 BEDDING MATERIAL

Material for the bedding layer shall consist of [sand] [gravel] [crushed stone] and shall contain no organic materials or soft friable particles.

2.4 COVER MATERIAL

****
NOTE: See Additional Note E.
****

Stone for the armament shall be hard, dense, durable, free from cracks, angular in shape, resistant to weathering and to water action, free from shale, slate, and organic material, and shall meet the specified size requirements anticipated by design criteria. The maximum dimension of the stone shall not exceed four times the minimum dimension, and its specific gravity shall be greater than 2.5.

PART 3 EXECUTION

INSTALLATION

3.1 SITE PREPARATION

Prior to the placement of the geotextile, the slope surface shall be cleared of vegetation, large rocks, limbs, stumps, trees, brush, roots, and other debris; graded and compacted to a relatively smooth plane, free of

obstructions, depressions, and soft pockets of material. Pockets of soft soil shall be excavated and replaced with compacted fill material to provide a uniform stable surface. Depressions, holes, or large cavities shall be filled and compacted. All fill material shall be free of refuse, vegetable matter, frozen soil, and other objectionable material, and shall be at a moisture content which will permit compaction to the density specified in Section ..... The finished surface shall conform to the proposed grade and be smooth to provide intimate geotextile to soil contact to prevent piping. The geotextile shall not be placed until the slope surface has been inspected and approved by the Contracting Officer.

****
NOTE: See Additional Note F.
****

3.2 PLACEMENT OF GEOTEXTILE

The geotextile shall be rolled smooth on the soil surface and held firmly at the locations as indicated on the drawings. At the time of installation, the geotextile shall be replaced by the Contractor at no cost to the Government if it has defects, rips, holes, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. The geotextile strips shall be placed with the longer dimension (machine direction) [parallel] [as shown] [perpendicular] to the [center line of the channel] [center line of the ditch] [streambank] [cut and fill slope] [shoreline]. The strips shall be laid so that placement of the cover material will not stretch or tear the geotextile. Folds, wrinkles, and creases in the geotextile shall be avoided. Geotextile sections may be folded and overlapped to allow placement, but no cuts shall be allowed in the geotextile except as shown or as authorized by the Contracting Office. The length of the geotextile shall be approximately 15 percent greater than the slope length. At the toe of a streambank, the geotextile and the cover material shall extend 3 feet below mean low water level or to the bottom of the streambed for streams shallower than 3 feet to minimize erosion at the toe. At the top of the bank the geotextile and cover material shall be placed [along the top of the bank] [to an elevation adopted for other streambank protection systems] [2 feet above expected maximum water stage]. Driving directly on the geotextile with construction equipment or heavy vehicles is not permitted so as not to plug, tear, or puncture the geotextile. The geotextile shall be protected from contamination by surface runoff and any geotextile so contaminated shall be removed and replaced with uncontaminated geotextile.

****
NOTE: See Additional Note G.
****

3.3 JOINING ADJACENT GEOTEXTILE SECTIONS

Parallel geotextile sections shall be properly joined together by [overlapping] [sewing] [stapling] [heatbonding] [gluing] [in the factory] [on site] to form sections not less than ..... feet wide. Adjacent rolls of geotextile shall be overlapped a minimum width of ..... inches at ends of rolls and sides of adjoining strips to create a continuous cover on the soil

surface. During the installation, overlapping shall be inspected to insure complete geotextile to geotextile contact. The upslope strip of geotextile shall overlap the downslope strip and the upstream strip shall overlap the downstream strip. The overlaps at the ends of the strips shall be staggered so that they are at least 5 feet apart. During installation, unsewn geotextile sections shall not be unrolled more than 25 feet ahead of the placement of cover material to avoid overlap separation. Overlapped sections shall not become separated during construction. Where feasible, sew adjoining sections to minimize the number of overlaps. [Prior to construction, several dummy seams shall be sewn by the Contractor and submitted for testing. Seams shall be tested in accordance with ASTM D 1683, and the seam strength for both factory and field seams shall not be less than the required seam tensile strength specified in Table I in any principal direction. All seams shall be sewn with a thread of a material meeting the durability and chemical requirements for the geotextile yarns. Thread shall be a contrasting color. The seam shall be located 2 inches from the outside edge of the geotextile and shall be sewn twice with parallel stitching spaced 1/4 to 1/2 inch apart. All seams shall be exposed with the seam up so they can be observed and easily repaired. The thickness of the needle and the size of the stitch shall be matched to the texture of the geotextile. All seams shall be subject to the approval of the Contracting Officer.]

3.4 FASTENING THE GEOTEXTILE

The geotextile shall be held firmly in place on the slope [by placing stones or earth on it] or [by pinning]. Security pins shall be inserted along a line through the midpoint of the overlap or in the vicinity of the seams at ..... foot intervals. Additional pins, regardless of location, shall be installed if necessary. The use of security pins shall be held to the minimum necessary to prevent any slippage of the geotextile. The temporary pins shall be removed as the cover material is placed on the geotextile. Each security pin shall be pushed through the overlapped joint or through the geotextile until the washer bears against it and secures it firmly to the protected soil.

3.5 GEOTEXTILE EXPOSURE FOLLOWING PLACEMENT

After placement, the geotextile shall not be left uncovered for more than 7 days to minimize damage potential.

3.6 CORRECTIVE MEASURES

Any geotextile damaged or displaced before, during, or after placement of [granular filter material] [bedding material] [cover material] shall be completely replaced or repaired and overlaps and seams corrected by the Contractor at his expense in a manner acceptable to the Contracting Officer. [Torn or otherwise damaged geotextiles may be repaired in place by placing a piece of the same type of geotextile over the damaged area. The patch shall overlap the existing geotextile a minimum of 3 feet beyond the perimeter of the tear or other damage. The overlap shall be pinned or otherwise secured to the ground to prevent shifting of the patch.

****
NOTE: See Additional Note H.
****

3.7 PLACEMENT OF COVER MATERIAL

Placement of cover material on the geotextile shall be conducted with care in order not to tear, puncture, or shift the geotextile. The riprap armor and bedding layer shall be placed over the geotextile to its full specified thickness and to extent shown in the drawings, so as to provide a uniform coverage. Placement shall be in one operation; placing in layers is not permitted. The cover material shall be placed within a sufficient time frame, as recommended by the manufacturer or as determined by the Contracting Officer, to prevent UV damage to the geotextile. Failure to comply shall require replacement of geotextile. The cover material shall be placed on the geotextile in such a manner that there will be no vehicles or equipment driven directly on the unprotected, uncovered geotextile. Design grading may be performed during placement of riprap. Regrading of rocks after placement will not be allowed. Placement of the riprap shall begin at the toe and proceed up the slope in such a manner that the rocks seat themselves without rolling or sliding sideway or downward over the geotextile which may damage it. The drop height of rocks shall be less than 3 feet and rock weight shall not exceed 250 pounds when being placed directly on the geotextile. In no event shall rocks be allowed to roll down the slope. An 8 inch thick [sand] [gravel] [crushed stone] bedding layer is required between the cover material and geotextile if the rock placement height exceeds 3 feet or if rock weight exceeds 250 pounds. The rocks shall be so placed and distributed that there will be no large accumulation of either the larger or smaller sizes of rock. The rocks shall be placed as close together as possible and the voids between the rocks filled with smaller rocks so that the geotextile is completely covered with a uniformly thick, reasonably well gradedAcoverage, free from humps and depressions.

****
NOTE: See Additional Note I.
****

3.8 ANCHORING THE TERMINAL ENDS OF GEOTEXTILE

The terminal ends of the geotextile shall be secured as shown] [or] [the riprap revetment shall be extended beyond the geotextile 5 feet at the crest and toe of the slope.] The top edge of the geotextile shall be buried into the key trench after the placement of the riprap.

****
ADDITIONAL NOTES

NOTE A: For additional information on the use of all CEGS, See CEGS-01000 CEGS GENERAL NOTES.

NOTE B: The specifier should be specific in defining the frequency of sampling per given unit of geotextile. ASTM standard

practices D 4354 and D 4759 provide limited, very general guidance for geotextile sampling procedures and specification performance. The specificer should exercise his judgement (with or without use of the ASTM practices) for determining sampling methods and frequency based on specific project characteristics such as consequences of failure cost, etc.

NOTE C: Paragraph 2.1 and Table I:

a. Multifilament yarns absorb water, causing the individual yarns to swell; therefore, the size of the openings is reduced and the permeability of the geotextile decreased. Placed under rock riprap, gabions, or other armament, the geotextile must satisfy the following requirements: (a) It must have sufficient permeability to allow free passage of ground water and to prevent a buildup of excess hydrostatic pressure which may damage the erosion control system, (b) It must have opening sizes that will prevent large amounts of soil particles from passing through the geotextile, while preventing clogging, to avoid loss of soil through the erosion control system causing it to settle and/or become unstable, and (c) It must be strong enough to be able to distribute the weight of armor rocks over the frequently soft underlying soil, to prevent rocks from sinking into the soil. The geotextile must resist deterioration from climatic conditions, chemicals found in soil and water, soil microorganisms, insects, and rodents.

b. The specified value of AOS is based on the grain size of the soil/material in contact with the geotextile. Normally, the specified value of AOS will be within the range of 0.06 to 0.3 mm. The pressure used to measure nominal thickness (necessary to calculate permeability) in D 1777 should be based on the pressure expected to be placed on the

geotextile in the installation. Geotextile permeability should exceed the permeability of the soil/material from which it will receive water. If flow in the plane of the geotextile must be specified, use ASTM D 4716. Apparent opening size and permeability should be specified based on the following table.

Geotextile Filtration Properties for Erosion Control Applications

Protected Material[1] (Percent Passing No. 200 Sieve)	Piping[2]	Permeability	
		Woven[3]	Nonwoven[4]
Less than 5%	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 10%	$k_G \geq 5k_s$
5 to 50%	AOS (mm) $\leq D_{85}$ (mm)	POA $\geq$ 4%	$k_G \geq 5k_s$
50 to 85%	AOS (mm) $\leq D_{85}$ (mm) Upper limit on AOS is AOS (mm) $\leq$ 0.212 mm (No. 70 US Standard Sieve)	POA $\geq$ 4%	$k_G \geq 5k_s$
Greater than 85%	AOS (mm) $\geq$ 0.125 mm (No. 120 US Standard Sieve)		$k_G \geq 5k_s$

[1]Protected Material is the material that is to be prevented from moving in the direction of the drainage flow. e.g. at the subgrade soil/drainage trench interface with water moving into the trench, the soil would be the protected material.
[2]When the protected material contains appreciable quantities of material retained on the No. 4 sieve use only the soil passing the No. 4 sieve in selecting the AOS of the geotextile.
[3]POA, percent open area, is the net area of a geotextile that is not occupied by filaments. POA is normally determined only for woven and nonwoven geotextiles having distinct visible and measurable openings that continue directly through the geotextile.
[4]k_G is the permeability of the nonwoven geotextile and k_s is the permeability of the protected soil.

c. Specify property requirements based on the requirements given in the following table for the expected installation condition.

Geotextile Survivability Properties for Erosion Control Applications

Property	Minimum Requirements[1] Application Class A[2]	Class B[3]	Test Method
Grab Strength lb	200	90	ASTM D 4632
Elongation (%)	15	15	ASTM D 4632
Sewn Seam Strength[4] lb	200	90	ASTM D 4884
Puncture Strength lb	80	40	ASTM D 4833
Burst Strength psi	320	140	ASTM D 3786
Trapezoid Tear lb	50	30	ASTM D 4533
Ultraviolet Degradation at 150 hour	70% strength retained	70% strength retained	ASTM D 4355

Notes:

[1]Minimum Average Roll Value. Use value in weaker principle direction. All numerical values represent minimum average roll value (i.e., test results from any sampled roll in a lot shall meet or exceed the minimum values in the table). Stated values are for non-critical, non-severe applications. Lots sampled according to ASTM D 4354.

[2]Class A applications are those where geotextiles are under conditions where installation stresses are more severe than Class B conditions; i.e., stone placement height should be less than 3 feet and stone weights should not exceed 250 pound, no sand cushion.

[3]Class B applications are those where geotextile is used in structures or under conditions where the geotextile is protected by a sand cushion or by "zero drop height" placement of stone.

[4]Values apply to both field and manufactured seams.

d. Many erosion control applications use overlap as a method of joining the separate pieces of geotextile, but in some applications, seaming may be specified. ASTM D 1683 may be used to specify seam strengths, but D 4632 should be used for strength testing instead of D 1682 as given in D 1683. If seams are specified, see Federal Standard 751a. If the geotextile is expected to perform a

reinforcement function, the seam may require testing by D 4595, and the guide specification for geotextile reinforcement should be consulted.

NOTE D: Paragraph 2.2: Longer pins are advisable for use in loose soils, or other equivalent securing devices may be substituted if approved.

NOTE E: Paragraph 2.4: Cover materials are acting as structural anchors for the erosion control system. Their function is to keep the geotextile in intimate contact with the protected soil, to absorb and dissipate energy from surface water runoff, stream channel flow, and wave action, and to protect the geotextile from extended exposure to UV radiation. It can consist of gravel, rock fragments, riprap, precast concrete blocks, gabions, concrete rubble, articulated concrete mattresses or other armament. The most common cover material is riprap. In this publication the discussion is restricted to riprap-geotextile erosion control system.

NOTE F: Paragraph 3.2: When used for channel, ditch, or streambank protection, where currents acting parallel to the bank are the principal erosion forces, the geotextile strips should be placed with the longer dimension (machine direction) in the direction of anticipated water flow. In case of cut and fill slopes, or shorelines subject to wave attack, the geotextile strips should be placed vertically down the slope. Surface drainage should be directed away from the top of slope to prevent erosion under the geotextile. If the soil to be protected has an excessive high silt content and if severe erosion conditions are expected, a 6 inch thick layer of sand or gravel should be placed between the protected soil surface and the geotextile to prevent fine soil particles either from passing through the geotextile or from clogging its pores and building up hydrostatic pressure. In instances where steep slopes (steeper than 1 vertical on 3 horizontal) are to be covered, field trails may be required to determine whether the cover

material will be stable on the geotextile and/or if the geotextile will be able to remain on the slope without sliding.

NOTE G: Paragraph 3.3: Minimum overlaps should be specified at 12 to 18 inches depending on the weight of the rocks, compressibility of the protected soil, specified orientation of the overlap to the direction of wave attack, on flow velocity, and seepage possibility. For underwater placement, minimum overlap should be 3 feet. Specific applications may require larger overlaps to assure satisfactory performance.

NOTE H: Paragraph 3.7:

a. Stones of subsequent layers may be dropped form slightly greater heights, depending on the weights of rock, but never more than 10 feet. When rocks are being dropped through 5 feet or more of water, rocks weighing 2 tons or less will not damage the geotextile.

b. Bedding layer is required to: (a) Dissipate pore water pressure if the cover material is not permeable enough, (b) Reduce the strength requirements of the geotextile, (c) Protect the geotextile from impact damage during placement of the cover material, (d) Protect the geotextile from abrasion damage due to wave action agitating the rock riprap, and (e) Achieve a proper distribution of loading on the protected soil in case of using large and heavy rocks in the armor to prevent them from sinking into the soil and stretching the geotextile until it tears.

c. Better protection of the geotextile, better dissipation of wave forces, and greater strength of the erosion protection system is achieved by filling the voids between the rocks.

NOTE I: Paragraph 3.8: The final construction step is the anchoring of the geotextile at its terminal ends to prevent uplift or undermining of the protected slope by overbank runoff or scour at the toe by stream currents. The key trench of the toe of a streambank shall be excavated below mean water level to prevent erosion adjacent to the trench and shall be evaluated with respect to slope stability. Where water prohibits the construction of a toe trench, a folded toe sausage roll shall be used.

b. If the trench is backfilled before the riprap is placed, the weight of the riprap will cause excessive tension in the geotextile which makes it more susceptible to puncturing and tearing.

****

--End of Section--

APPENDIX D: RECOMMENDED GUIDE SPECIFICATION "GEOTEXTILES FOR SEDIMENT CONTROL (TEMPORARY SILT FENCE)"

****
(January 1991)

GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

****

SECTION 02278

GEOTEXTILES FOR SEDIMENT CONTROL (TEMPORARY SILT FENCE)
1/91

****
NOTE: This guide specification covers furnishing geotextiles for and installing geotextiles in temporary silt fences for sediment control. A silt fence is a temporary vertical barrier designed to intercept and detain sediment from unprotected areas before it leaves the construction site. A silt fence can be constructed using a sheet of geotextile support on a wire fence or it may be furnished from the manufacturer in the form of a prefabricated fence. The geotextile at the bottom of the fence is buried in a trench so that runoff will not flow beneath the fence. The permeable geotextile allows water to flow through the fence while the sediment in the water is retained against the geotextile. In addition, the fence reduces water velocity allowing the sediment to settle out of suspension. The use of silt fences is limited to situations in which only sheet or overland flows are expected. They are generally not designed for use in stream channels.
****

PART 1 GENERAL

****
NOTE: See Additional Note A.
****

1.1 SUMMARY (Not Applicable)

****
NOTE: Paragraph "1.1 SUMMARY (Not Applicable)" is required in all CEGS in order to make CEGS compatible with guide specifications of other agencies within the SPECSINTACT system. However, this paragraph is not to be included in Corps of Engineers project specifications.
****

1.2 REFERENCES

****
NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

-D 4354-	(1984) Sampling of Geotextiles for Testing
-D 4355-	(1984) Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
-D 4632-	(1986) Breaking Load and Elongation of Geotextiles (Grab Method)
-D 4751-	(1987) Determining Apparent Opening Size of a Geotextile
-D 4759-	(1988) Determining the Specification Performance of Geosynthetics

1.3 SUBMITTALS

****
NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.
****

The following shall be submitted in accordance with Section 01300 SUBMITTALS:

[SD-17, Manufacturer's Catalog Data; SD-44, Manufacturer's Instructions; and SD-82, Preventive Maintenance and Inspection

When a prefabricated fence system is proposed the Contractor shall submit, as a package, ... copies of the Manufacturer's Catalog Data, Manufacturer's Installation Instructions and Preventative Maintenance and Inspection requirements for approval.

[SD-50, Samples

The Contractor shall provide the Government with Geotextile samples for testing to determine compliance with this specification. Samples shall be submitted a minimum of [30] [60] [90] [_____] days prior to the beginning of installation of the geotextiles. One sample shall be provided for each 20 units (rolls, panels, etc.) of geotextile to be used in the contract. All samples shall be from the same production lot as will be supplied for the contract. Samples shall be obtained in accordance with ASTM D 4354 and ASTM D 4759 and shall be identified by the manufacturer's name, brand name, lot designation, and project name. The minimum size of sample submitted for testing shall be the full width of the geotextile by [5 feet] [30 feet] [_____] in length.]

[SD-70, Test Reports

An independent testing laboratory's certified test reports, including analysis and interpretation where necessary. These reports shall provide results of the laboratory testing performed on samples of the geotextile material delivered to the job site. Test reports shall be submitted at least [5] [_____] working days prior to the installation of the geotextile.]

SD-76, Certificate of Compliance

A manufacturer's Certificate of Compliance attesting that the geotextile meets the specified chemical, physical, and manufacturing requirements. The certification of physical properties shall be based on minimum average roll values.

1.4 PRODUCT DELIVERY, STORAGE, AND HANDLING

Only approved materials shall be delivered to the project site. All geotextiles shall be shipped and stored in their original ultraviolet resistant cover until the day of installation. Geotextiles shall be stored in such a manner as to be protected from vandalism, temperatures greater than 140 degrees F, dirt, dust, mud, debris, moisture, sunlight, and ultraviolet rays. All geotextiles delivered to the project site shall be clearly labeled on the material cover to show the manufacturer's name, brand name, fabric type, location and date manufactured, lot identification, width, and length.

1.5 MEASUREMENT FOR PAYMENT

****
NOTE: If the contract is a fixed price construction contract then revise or delete this paragraph as appropriate.
****

1.5.1 Silt Fence

The temporary silt fence will be measured in linear feet, complete in place. Silt fence will be paid for at the unit contract price for the

number of linear feet placed. Such payment shall be full compensation for furnishing all materials, erecting, maintaining, and removing the fence.

1.5.2 Removed Sediment

Removed sediment will be measured by the cubic yard. The removal and disposal of accumulated sediments will be paid for at the contract unit price for the number of cubic yards of sediment removed and disposed of.

PART 2 PRODUCTS

2.1 GEOTEXTILE

2.1.1 Physical Property Requirements

****
NOTE: See Additional Note C.
****

Fibers used in the manufacture of the geotextile shall consist of long-chain synthetic polymers composed of at least 95 percent by weight polyolefins, polyesters, or polyamides. They shall be formed into a network such that the filaments or yarns retain dimensional stability relative to each other, including selvedges. The geotextile shall be free of any treatment or coating which might adversely alter its physical properties after installation. Only geotextiles commercially marked for use in silt fence applications shall be used. The geotextile shall conform to the following physical requirements.

2.1.2 Tensile Strength

The tensile strength of the geotextile shall be 90 pounds minimum, as determined in accordance with ASTM D 4632. Use the test value in the weaker principal direction. The test value shall represent the minimum average roll value (i.e., test results from any sampled roll in a lot shall meet or exceed the minimum values required). Lot sampled according to ASTM D 4354. This requirement applies for both woven and nonwoven geotextiles used with either wire or prefabricated fences.

2.1.3 Elongation

The elongation measured at a tensile strength of 45 pounds shall be a maximum of 50 percent when tested, according to ASTM D 4632. This requirement applies only to geotextiles used in prefabricated fences. There is no elongation requirement for geotextiles supported by wire fence

2.1.4 Apparent Opening Size (AOS)

The maximum AOS value (mm) of the geotextile as determined by ASTM D 4751 must satisfy the following equation:

$$\frac{D_{85S}\ (mm)}{AOS_G\ (mm)} \geq 1$$

D_{85S} = particle size of the soil in mm of which 85 percent of the particles, by weight, are smaller

AOS_G = AOS sieve size of the geotextile in mm

In addition, the maximum AOS value shall not exceed 0.84 mm (No. 20 Sieve Size). The AOS limiting value shall be 0.125 mm (No. 120 Sieve Size).

2.1.5 Percent Open Area (POA)

The POA for woven geotextiles shall be greater than or equal to 4 percent. This applies for both wire or prefabricated fence. There is no POA requirement for nonwoven geotextiles.

2.1.6 Ultraviolet Degradation

ASTM D 4355, minimum 70 percent strength must be retained after 500 hours. This requirement applies for both woven and nonwoven geotextiles used with either wire or prefabricated fence.

2.1.7 Nonwoven Geotextiles

Nonwoven geotextiles shall not be approved for silt fence applications unless performance tested and approved using the Virginia Highway and Transportation Research Council Laboratory Filtering Test VTM-51.

****
NOTE: See Additional Note D.
****

2.2 FENCEPOSTS

Fenceposts shall have a minimum length of the geotextile height above original ground surface plus burial depth as required by paragraph CONSTRUCTION REQUIREMENTS and be of sufficient strength to resist damage during installation and to support applied loads. Either wood, steel, or synthetic posts may be used.

2.3 WIRE SUPPORT FENCE

Wire support fence shall be minimum 12-gage wire and the horizontal and vertical wires shall be spaced a maximum of 6 inches apart. The fence shall be strong enough to support the applied loads and with a total height required by paragraph CONSTRUCTION REQUIREMENTS.

2.4 PREFABRICATED SILT FENCE

Prefabricated fence may be used provided that it is a standard item manufactured for use as a silt fence. The geotextile and fence posts used in the prefabricated fence must meet the requirements of paragraphs 2.1 and 2.2. The prefabricated fence must also have an attached support fence that is strong enough to support the applied loads for the full height of the fence.

PART 3 EXECUTION

3.1 CONSTRUCTION REQUIREMENTS

Silt fences shall be constructed after the cutting of trees but before any soil disturbing construction activity in the drainage area.

3.1.1 Anchor Trench

A small trench, minimum 6 inches deep by 6 inches wide shall be excavated on the upstream side of the planned fence for burying and anchoring the lower edge of the geotextile.

****
NOTE: See Additional Note E.
****

3.1.2 Support Posts

Support posts shall be installed in a row along the downstream edge of the anchor trench with a normal spacing of [6] [8] feet apart. The burial depth shall be [12] [18] [24] inches.

****
NOTE: See Additional Note F.
****

3.1.3 Wire Support Fence

The wire mesh shall be securely fastened to the upstream side of the support posts. The wire fence shall extend a minimum of 2 inches into the trench and a minimum of [8] [28] [34] inches above the original ground surface.

3.1.4 Geotextile Attachment

The geotextile shall be attached to the upstream side of the wire support fence with hog rings or tie wire. The top of the geotextile shall be secured to the fence at 12-inch center-to-center spacings. The bottom of the geotextile shall extend a minimum of 6 inches into the trench and a minimum of [8] [28] [34] inches above the original ground surface. In no case shall the geotextile exceed 36 inches above the original ground surface. The geotextile shall be installed loosely. Splices between sections of geotextile shall be made only at a support post and with a minimum 6-inch overlap. Tie wires must be used to attach the geotextile

to steel posts although tie wires or staples may be used for wood posts. The lower edge of the geotextile shall be buried a minimum of 6 inches in the upstream trench and the backfill soil compacted to provide good anchorage.

3.1.5 Prefabricated Fence

When a commercially available prefabricated fence system is proposed, the Contracting Officer must approve the fence system and installation procedure before the silt fence is installed.

****

NOTE: See Additional Note G.

****

3.2 INSPECTION AND MAINTENANCE

The Contractor shall inspect all temporary silt fences immediately after each rainfall and at least daily during prolonged rainfall. Any damage to the silt fence shall be repaired immediately. Accumulated sediment shall be removed and disposed of when it reaches approximately one-half the height of the fence. Care must be taken not to tear the geotextile or dig up the bottom of the textile during sediment removal. If sediment and/or waterloading threaten overturning of the fence, tieback wires between the fencepost and an upstream anchor stake are required as necessary to hold the fence upright in a stable condition. The installation of a second silt fence may be directed by the Contracting Officer when conditions warrant. The silt fence shall not be removed until adequate vegetative growth insures no further erosion from the site.

****

ADDITIONAL NOTES

NOTE A: For additional information on the use of all CEGS, see CEGS-01000 "CEGS GENERAL NOTES."

NOTE B: This specification covers furnishing, installing, maintaining, and removing a geotextile barrier/fence silt fence designed to remove suspended particles from the water passing through it.

a. The purpose of the silt fence is to intercept and detain sediment from unprotected areas before it leaves the construction site. The use of silt fences is limited to situations in which only sheet or overland flows are expected.

b. Typical locations include the toe of the fill slopes, the downhill side of large cut areas, along streams, and at natural drainage areas. Silt fences

should be continuous and transverse to the flow and limited to handle an area equivalent to 1,000 square feet per 10 feet of fence. Caution should be used where the site slope is steeper than 1:1, and water flow rates exceed 1 cubic foot per second per 10 feet of fence.

NOTE C: Paragraph 2.1.4.

a. The limiting AOS value of 0.125 mm (No. 120 Sieve Size) is required to prevent clogging of the geotextile.

b. Paragraph 2.1.5: The minimum POA should be 4 percent to prevent clogging of the geotextile and allow adequate flow. The POA test does not apply to nonwoven geotextiles.

c. Paragraph 2.1.7: The Filter Efficiency Test (VTM-51) is required for a nonwoven geotextile to insure it is capable of filtering out most of the soil particles carried in the runoff without unduly impending the flow.

NOTE D: Paragraph 2.2: It has been found that oak posts having dimensions of at least 1-1/4 inches by 1-1/4 inches or steel posts of U, T, L, or C shape weighing 1.3 pounds per linear foot have performed satisfactorily. In soft ground, swamps, etc., a wider post is advantageous as additional passive resistance needs to be developed.

NOTE E: Paragraph 3.1.2: The post spacing and burial depth should be based on the soil strength conditions.

NOTE F: Paragraph 3.1.3: The value used for the minimum height that the wire fence shall extend above the original ground surface must be the same as the value used in paragraph 3.1.6 for the minimum height that the geotextile shall extend above the original ground surface.

NOTE G: Paragraph 3.2: A second silt fence may be warranted downstream from the first silt fence when continued wet conditions prevent removal of accumulated sediment and/or heavy runoff or high water is anticipated that could cause sediment to bypass the first fence.

****

--End of Section--

APPENDIX E: LABORATORY AND FIELD TEST METHODS FOR GEOTEXTILE SILT FENCE FILTERING EFFICIENCY

VIRGINIA HIGHWAY AND TRANSPORTATION RESEARCH COUNCIL
LABORATORY AND FIELD TEST METHODS FOR GEOTEXTILE
SILT FENCE FILTERING EFFICIENCY
VTM-51

LABORATORY METHOD

1. Scope

This method is used to determine the filtering efficiency and flow rate of a geotextile in the laboratory.

2. Apparatus

a. A flume 48-in. long by 32-in. wide by 12-in. high with a gutter attached to one side. (See Figure E-1).

b. Two 20-gal containers.

c. A stirrer on a 1/4-in. portable drill.

d. Stopwatch.

e. A DH-48 integrated water sampler with ten 500-ml bottles.

3. Procedure

a. Stretch a sample of the geotextile 39-in. long by 12-in. wide across the flume opening 32-in. wide and fasten securely in place to assure that all the sediment-laden water passes through the sample. Note: The flume opening is the standard length of a straw bale.

b. Elevate the flume to an 8 percent (1:12.5) slope.

c. Take a depth integrated, suspended solids sample from an untreated, fairly sediment-free water supply. Continuously agitate the supply for uniformity during the sampling process.

d. Prewet the geotextile by passing 50 liters of untreated, fairly sediment-free water through it.

e. Mix 150 g of minus U. S. No. 10 sieve material of the soil of design interest or, if unavailable, of a typical silty soil (see gradation curve, Figure E-2) in 50 liters of the untreated water placed in one of the 20-gal containers. Thoroughly agitate the solution with the stirrer on the 1/4-in. portable drill to obtain a uniform mix.

f. After uniformly mixing the solution, quickly dump the solution behind the geotextile sample in the flume. Start the timer at dumping.

g. Rinse the mixing container with 1 to 2 liters of the filtrate and dump into the flume.

h. Time the flow of water through the geotextile until the water level drops to a point 10.5-in. behind the geotextile. At this point, the flow has essentially ceased.

i. Collect all filtrate in a second mixing container.

j. At the completion of the test, agitate the collected filtrate until the mixture is uniformly mixed. Obtain a depth integrated suspended solids sample from the mixture during agitation.

k. Process the two suspended solids samples by the "nonfilterable residue" procedure described in the Standard Methods for the Examination on Water and Wastewater, 17th ed. (APHA, 1989).

l. Calculate the filtering efficiency (FE) of the geotextile as follows:

$$FE\ (\%) = \frac{(SS_{bg} + 3{,}000) - SS_{after}}{(SS_{bg} + 3{,}000)} \times 100$$

where SS_{after} and SS_{bg} are the suspended solids value after filtration and the background level value, respectively.

m. Calculate the flow rate of the geotextile as follows:

$$\text{Flow rate } (gal/ft^2/min) = 14.85 \text{ times } (min)$$

n. Repeat Steps e. through l. for the same geotextile sample two more times. Average test results to obtain "design" values.

FIELD METHOD

1. Scope

This method is used in determining the filtering efficiency of a geotextile in the field.

2. Apparatus

a. Stopwatch.

b. A sprayer to provide a uniform rain event over a prescribed area.

c. A smaller sampler with ten 500-ml bottles.

d. Wood stakes, each 30 in. long.

e. Pick and shovel.

f. Heavy duty stapler.

g. Ruler.

3. Procedure

a. In a silty soil, locate a site with uniform soil conditions and an approximate 8 percent slope.

b. Construct a small silt fence and mark off a 10-ft^2 area behind it.

c. Spray the prescribed area with 20 gal of water at a rate of 1.5 in./hr.

d. Collect a representative 500-ml sample of the sediment-laden water above and below the silt fence at the following times: 5 min and 15 min after commencing the spray, and at the termination of spraying.

e. Process the samples for suspended solids by the "non-filterable residue" procedure described in Standard Methods for the Examination of Water and Wastewater, 17th ed. (APHA, 1989).

f. Calculate the filtering efficiency (FE) of the geotextile as follows:

$$FE\ (\%) = \frac{SS_{above} - SS_{after}}{SS_{above}} \times 100$$

where SS_{above} and SS_{below} are the suspended solids values above and below the silt fence, respectively.

g. Repeat Steps a. through f. for clayey and sandy soils.

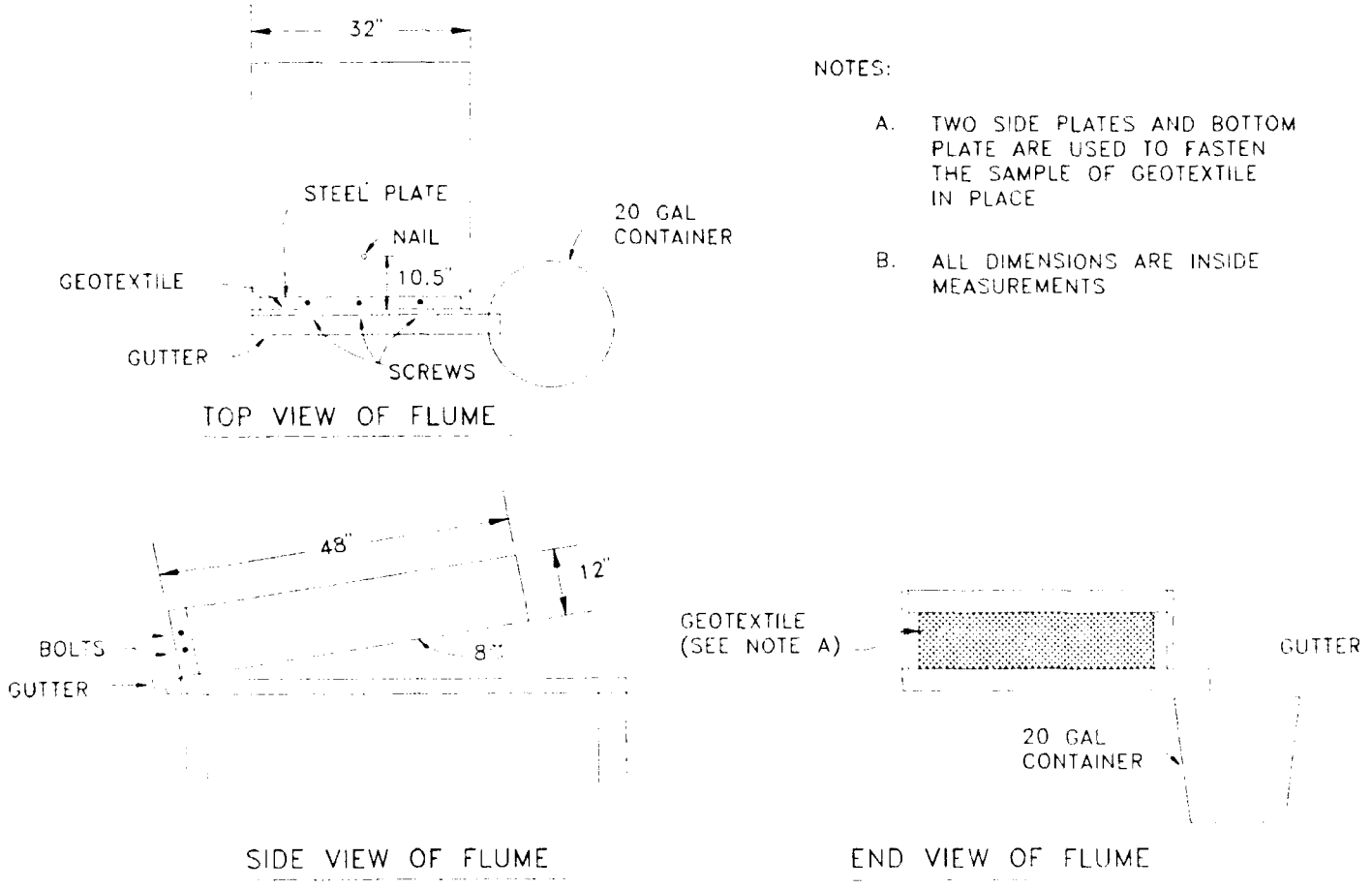


Figure E-1. Flume for VHTRC engineering geotextile filtering efficiency laboratory test

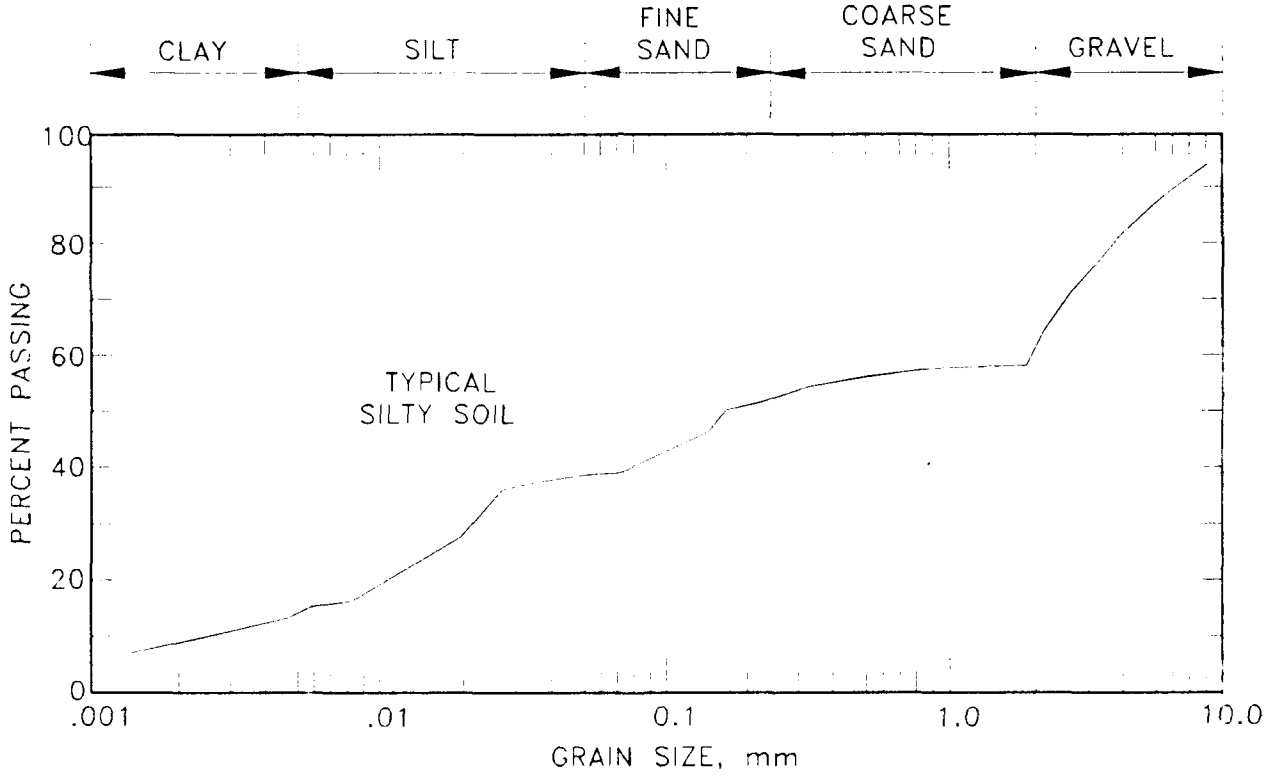


Figure E-2. Grain-size distribution for typical silty soil used in evaluating filtering efficiency of geotextiles

APPENDIX F: SILT FENCE DESIGN EXAMPLE

Silt Fence Design Example

a. Problem statement. A 180-day railroad realignment project is proposed the will require large amounts of grading/shaping plus construction of several fill sections. The terrain is moderately hilly upland, and several streams and ponds with existing high water quality are located adjacent to the proposed realignment. You are asked to determine if silt fence sediment erosion control will be required, and if so, what geotextile or geotextiles can be used.

b. Solution.

(1) A composite sample of surface and near-surface soils along the alignment was found to have a liquid limit of 18 and a plasticity index of 6. Several in situ measurements gave an average dry density of 106.5 pounds per cubic foot. The grain-size distribution for the composite surface sample is shown in Figure F-1. A composite sample from the borrow area to be used as a source for the embankment fill was found to have a liquid limit of 15 and a plasticity index of 5, with grain-size distribution as shown in Figure F-1. When compacted to 95 percent of standard ASTM D 698, the composite borrow area sample dry density was 112.7 pounds per cubic foot.

(2) The existing soil test data show that both the site surface and proposed embankment fill soils have low erosion resistance. Therefore, silt fence erosion control will be required. It is assumed that all silt fences will be built 3 feet high without wire mesh or other reinforcement, and that geotextiles will be selected according to the Virginia Highway and Transportation Research Council (VHTRC) criteria given in Table F-1 (Reproduced from Table 8 of this report).

(3) It is necessary to find a geotextile or geotextiles that will meet the VHTRC criteria for both surface and fill soils so that the same silt fence will provide sediment control for both. Geotextiles proposed for use on the project by several geotextile manufacturers/distributors include:

Geotextile	Type	EOS Sieve No.	POA Percent
A	Heat-bonded nonwoven	100	--
B	Needle-punched nonwoven	70	--
C	Slit-film woven	50	1
D	Monofilament woven	70	5
E	Monofilament woven	70	20
F	Monofilament woven	40	30
G	Felted nonwoven	80	--

All geotextiles were subjected to wide-width tensile testing and the VHTRC *silt fence simulation test. Results of the tests were as follows:*

Geotextile	Filtering Efficiency Percent		Flow Rate gal/sq ft/min		Ultimate Tensile Strength lb/in.
	Surface Soil	Fill Soil	Surface Soil	Fill Soil	
A	99	99	0.2	0.1	65
B	97	95	0.6	1.4	40
C	98	94	0.2	0.5	120
D	88	92	0.8	4.9	250
E	84	87	1.6	12.2	210
F	62	78	26.5	40.7	170
G	98	97	0.3	4.0	35

(4) Review of the test data in light of Table F-1 requirements indicates that geotextile F does not provide the necessary filtering efficiency, and geotextiles A and C do not allow a high enough flow rate. Of remaining geotextiles B, D, E, and G, only geotextiles D and E have the necessary tensile strength.

(5) Either geotextile D or E is acceptable for project silt fences, at contractor option, subject to geotextile manufacturer's certification that their material has been treated for UV radiation stability against degradation over the 180-day life of the project.

Table F-1

Geotextile Use for Silt Fences (after Wyant 1980)

Proposed Structure	Filtering Efficiency[1] Percent	Flow Rate[1] gal/ft^2/min	Wide Width Tensile Strength[2] lb/lin in.
3-ft silt fence with reinforced backing	75	0.3	Reinforcing governs
3-ft silt fence without reinforced backing	75	0.3	50
18-in. silt barrier without reinforced backing and posts 10 ft apart	75	0.3	24
18-in. silt barrier without reinforced backing and posts 3 ft apart	75	0.3	7

[1]Tests results from VHTRC Laboratory Filtering Efficiency Test (See Appendix E).
[2]From ASTM 4595 (ASTM 1990g).

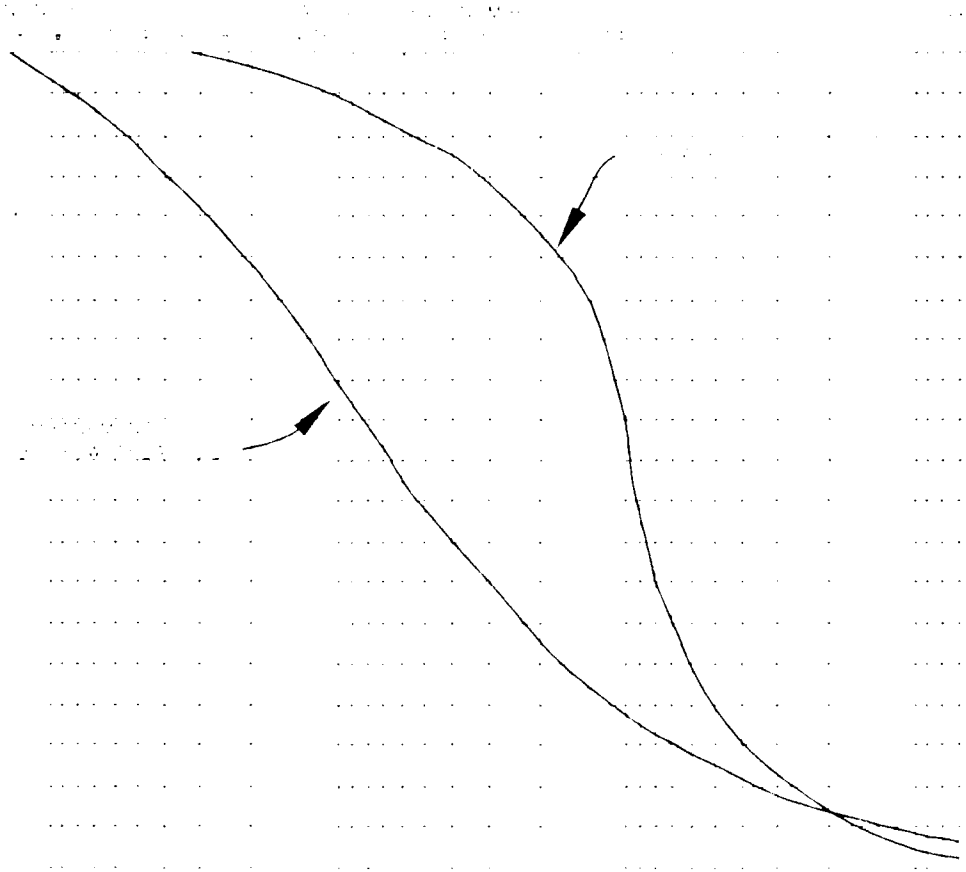


Figure F-1. Grain-size distributions for soils in example problem