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FILTER FABRICS FOR AIRPORT DRAINAGE.(U)

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FILTER FABRICS FOR AIRPORT DRAINAGE.

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16. Abstract This report provides a general review of fabric experience that applies to airport construction of surface and subsurface drainage installations and develops interim guidance for design, specifications, and installation of filter fabrics. Two fabric applications of surface drainage are considered: (1) between a channel or reservoir slope and the slope protection for scour, erosion, and pipe performance, and (2) silt fences for prevention of stream pollution by sediments in runoff. Three types of subsurface drainage applications are considered: (1) trench drains, (2) separation, and (3) drainage for consolidation of soft soils. A need for long-term correlation of field performance with fabric type, soil type, soil grain size, and hydraulic characteristics is pointed out. Two levels of guidance for the use of fabrics in airport drainage are suggested for use--(1) critical applications where if the design life is long (greater than 15 years), failure of the drainage installation would endanger life or structures, or require expensive maintenance, and (2) noncritical applications for short-life projects or applications that may be easily and inexpensively replaced. Appendix A describes current FAA use of filter fabrics in drainage, and Appendix B provides specific guidance for critical and noncritical use of fabrics under the above-mentioned applications.					
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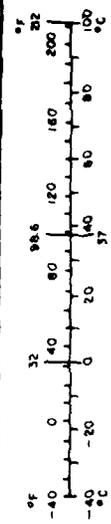
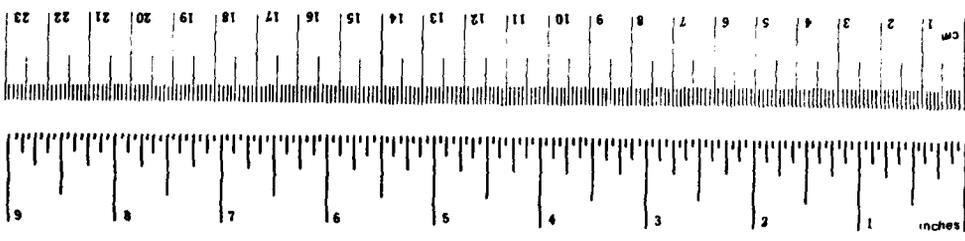
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
sq in	square inches	6.5	square centimeters	cm ²
sq ft	square feet	0.09	square meters	m ²
sq yd	square yards	0.8	square meters	m ²
sq mi	square miles	2.5	square kilometers	km ²
acres	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
ts	teaspoons	5	milliliters	ml
fl oz	fluid ounces	15	milliliters	ml
c	cups	30	milliliters	ml
pt	pints	0.24	liters	l
qt	quarts	0.47	liters	l
gal	gallons	0.96	liters	l
ft ³	cubic feet	3.8	liters	l
yd ³	cubic yards	0.03	cubic meters	m ³
		0.76	cubic meters	m ³
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
km	kilometers	1.1	yards	yd
		0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	ac
MASS (weight)				
g	grams	0.036	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	st
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
		1.06	quarts	qt
		0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
		1.3	cubic yards	yd ³
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



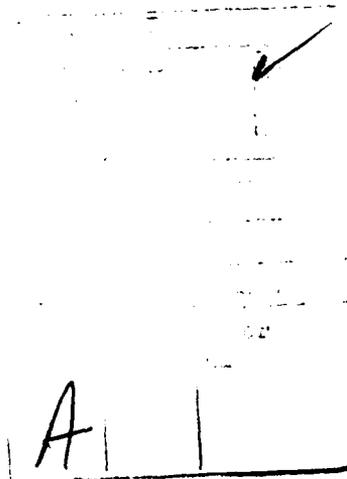
* 1 in = 2.54 exactly. For other exact conversions and more detailed tables, see NBS Mon. Pub. 1-86, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10-286

PREFACE

This study was conducted at the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the Federal Aviation Administration (FAA) Inter-Agency Agreement No. DOT FA78WAI-837. This report completes Phase I: Fabrics in Drainage Systems, Literature Search, of FAA Engineering Requirement FAA-ER-430-015.

The study was conducted from May 1978 to January 1979 by Mr. S. P. Miller of the Engineering Group (EG) under the direct supervision of Messrs. G. B. Mitchell, Chief, EG, and H. H. Ulery, Jr., Chief, Pavement Design Division, Geotechnical Laboratory (GL), and the general supervision of Messrs. C. L. McAnear, Chief Soils Mechanics Division, and J. P. Sale, Chief, GL. The advice and assistance of Mr. Fred Horn, FAA Project Monitor, and research assistance of Ms. Marie Spivey, Technical Information Center, WES, is gratefully acknowledged.

COL John L. Cannon, CE, and COL Nelson P. Conover, CE, were Commanders and Directors of WES during the period of research and preparation of the report. Mr. Fred R. Brown was Technical Director.



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INTRODUCTION

This report provides a general review of fabric experience that applies to airport construction of surface and subsurface drainage installations and, from this review, develops interim guidance for design, specifications, and installation of filter fabrics.

The review was developed from library and computer searches, personal communications, and experience with fabrics. Existing design criteria, specifications, and installation procedures were reviewed and evaluated to provide interim guidance for airport fabric use.

FABRIC USE APPLICABLE TO AIRPORT
DRAINAGE CONSTRUCTION

LITERATURE REVIEW SOURCES

Several literature searches were made through the U. S. Army Engineer Waterways Experiment Station (WES) Technical Information Center. These included:

- a. COMPENDEX (Engineering Index).
- b. Defense Documentation Center.
- c. Smithsonian Scientific Information Exchange, Current Research.
- d. SCISEARCH (Science Citation Index).

Other references were obtained from a literature search of the WES Technical Library and from written and verbal communications with researchers, designers, and users.

Five basic airfield and highway drainage references were reviewed to establish current surface and subsurface drainage practice for airfields and highways:

- a. "Airport Drainage - Advisory Circular 150/5320-5B," Department of Transportation Federal Aviation Administration.
- b. "Recommended Modifications to FAA Advisory Circular, Airport Drainage Improved Airport, Airside Drainage Criteria, Phase I," Jack Fowler, WES.²
- c. "Methodology and Effectiveness of Drainage Systems for Airfield Pavements," Harry R. Cedergren.³
- d. "Development of Guidelines for the Design of Subsurface Drainage Systems for Highway Pavement Structural Sections," H. R. Cedergren, J. A. Arman, and K. H. O'Brien.⁴
- e. Drainage of Highway and Airfield Pavements, Harry R. Cedergren.⁵

Five primary sources of filter fabric information were used to determine the current state of knowledge and criteria for filter fabric usage in drainage:

- a. "Sample Specifications for Engineering Fabrics," U. S. Department of Transportation, Federal Highway Administration, Offices of Research and Development, Washington, D. C.⁶

- b. "Guidelines for Use of Fabrics in Construction of Low-Volume Roads," J. Steward, R. Williamson, and J. Monney, USDA, Forest Service.⁷
- c. "Test Methods and Use Criteria for Filter Fabrics (Draft)," J. R. Bell et al., Oregon State University for the Federal Highway Administration.⁸
- d. Highway Focus, Vol 9, No. 1, U. S. Department of Transportation, Federal Highway Administration.⁹
- e. Proceedings, International Conference on the Use of Fabrics in Geotechnics, Paris, France, April 1977.¹⁰

Most fabric applications have been for roads or highways, and it is assumed that for drainage purposes, highway fabric experience and principles of usage are valid for airports. This assumption was previously made by Cedergren (1974).⁵

Additionally, several references were used, particularly those describing experimental and construction projects using filter fabrics. Two current studies of fabrics for use in highway subdrains and stream-bank erosion control were discussed with their authors.* Reports from these studies should be available in the latter part of 1979. The FAA regional offices were contacted to determine current usage levels in U. S. airports, Appendix A.

USE CLASSIFICATION

Fabric applications for airport drainage may be divided into two major categories: surface and subsurface. Most subsurface uses involve filtering and drainage, while surface uses primarily provide erosion prevention and filtering in control of surface water waves and currents (e.g., reservoirs and slope or channel flows).

* Dardeau, E. Jr., and Keown, M. P., Personal Communication, Subject: Use of Fabrics for Control of Streambank Erosion, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., January 1979.

Forshey, A. D., Personal Communication, Subject: Research Project, "Use of Filter Cloths for Sub-Surface Drainage Systems for Highways," Pennsylvania Department of Transportation, Harrisburg, Pa., January 1979.

SURFACE DRAINAGE

Fabrics have been used in surface drainage applications in many ways. They serve as a pervious media between channel slopes and slope protection (riprap or man-made materials) to prevent waves and currents from washing out or eroding the fine-grained bank soil from beneath the protection materials (Figure 1). Used in this manner, fabrics may also prevent erosion (piping) of fine-grained bank materials in areas where groundwater in the channel bank is higher than the channel water level. This occurs where the groundwater level is either naturally higher than the stream or periodically above stream level due to short-term high channel stages (sudden drawdown conditions). The fabric prevents piping of the bank soils as the groundwater seeps into the stream. Layered fabrics have been filled with cement grout or other materials and used to cover channel slopes for protection of bank materials from scour due to wave or current attack. Fabrics have been used as concrete forms where standard concrete forms are difficult to erect, e.g., around scoured bridge abutments, or to repair deteriorated piling beneath docks or wharves.¹¹ Prevention of erosion by sheet flow down embankment or cut slopes is another fabric surface drainage function. Fabric placed beneath aggregate at culvert outlets can also prevent erosion. Fabrics have been used to form silt fences, which prevent movement of fine-grained soils (pollution) from construction sites to streams (Figure 2).

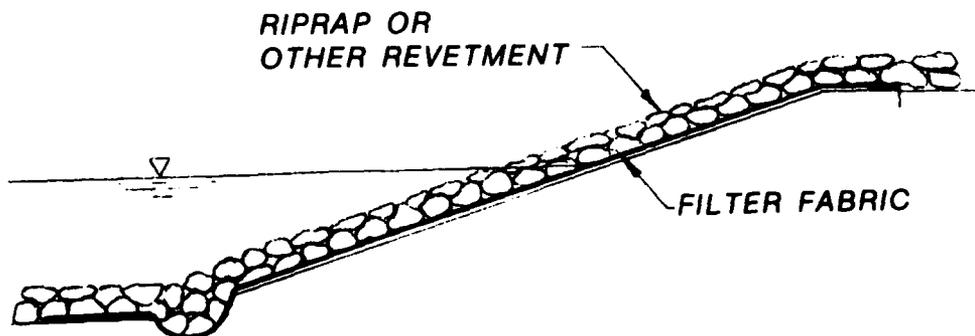


Figure 1 Fabric use in slope protection

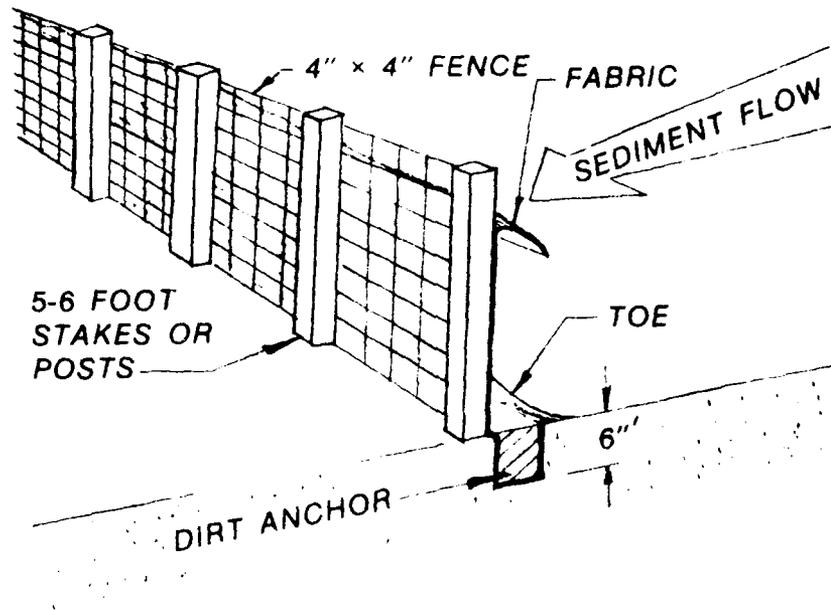


Figure 3. Silt fence (after Reference 6)

SUBSURFACE DRAINAGE

Airport subsurface drainage is used to control groundwater levels and remove infiltrated precipitation beneath pavements or increase the stability of slopes. Fabrics used in trench drains along and beneath runways and taxiways remove surface infiltration and high groundwater from beneath the pavement. Fabrics may line the trench and be filled with aggregate to form an envelope that may or may not contain a perforated pipe (depending on flow quantities and flow gradient) or fabrics may be used to wrap a perforated pipe surrounded by aggregate to prevent infiltration of the surrounding filter material or soils into the pipe (Figures 3b and 3c). A variation of the trench type of fabric drain, the fin drain, has been made by wrapping a slit pipe containing corrugated fencing with a fabric and installing it in a narrow trench with a small amount of backfill¹² (Figure 3d).

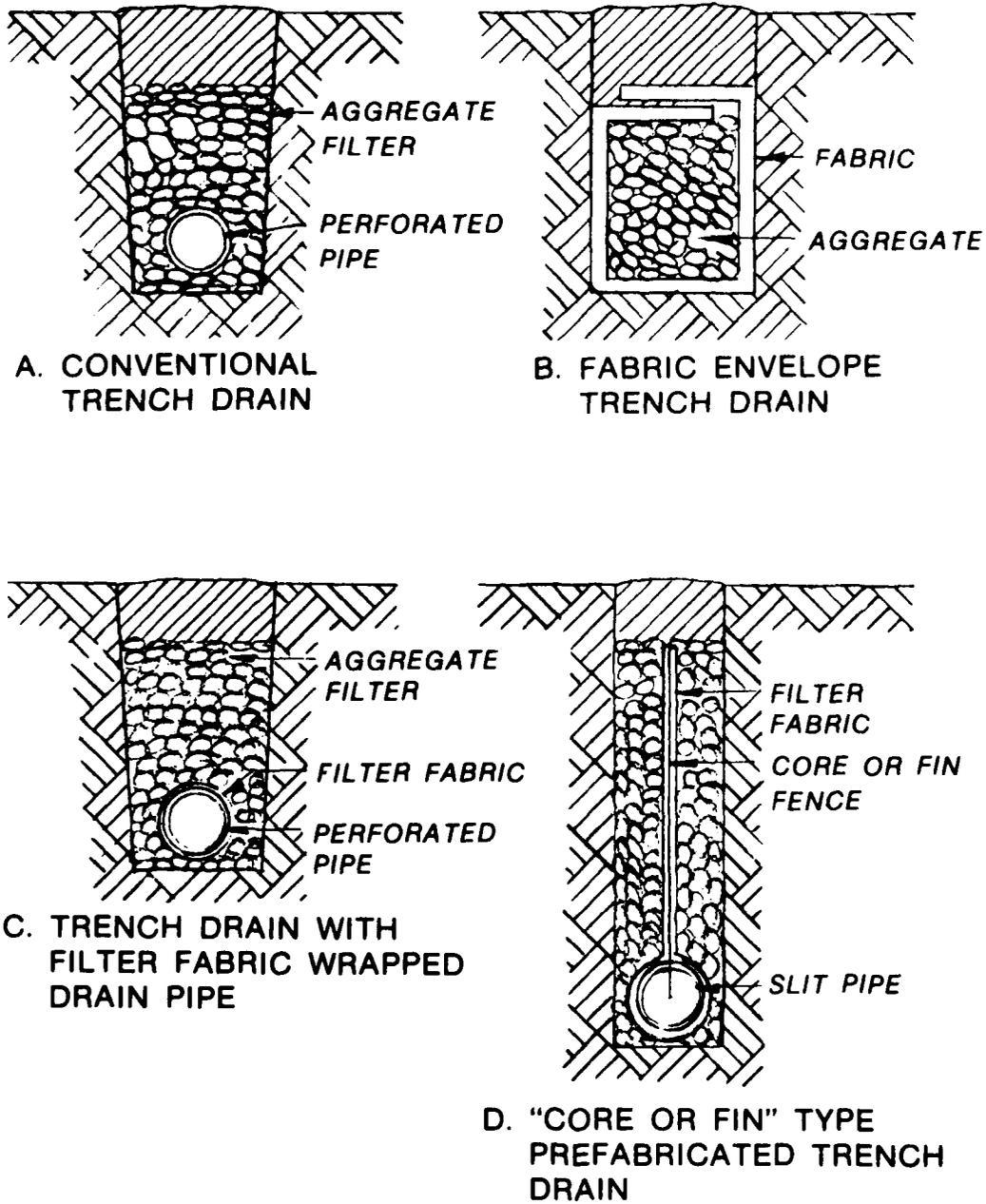


Figure 3. Trench drain types

Fabrics have been used to separate fine-grained subgrade materials from coarse subbase or base materials to prevent infiltration of fine material into the coarser base materials, which would reduce base drainage capacity (Figure 4).

Finally, fabrics are used to speed consolidation of soft, saturated soils in or beneath embankments. They may be used in conjunction with granular materials as horizontal or vertical drains to provide high permeability flow paths for the excess pore water of the soft soils.

AIRPORT CONSTRUCTION APPLICATION

Of the surface and subsurface uses mentioned above, the following specific fabric applications will be considered in this report:

a. Surface drainage.

- (1) between a channel or reservoir slope and the slope protection for scour, erosion, and pipe prevention.
- (2) Silt fences for prevention of stream pollution by sediments in runoff.

b. Subsurface drainage.

- (1) Trench drains.
- (2) Separation.
- (3) Drainage for consolidation of soft soils.

Layered fabrics that can be filled with grout have limited use and a proprietary nature.¹³ Fabrics for concrete forms are also very limited in use with site-specific criteria.¹¹ Sheet flow erosion prevention with fabrics normally involves low-strength short-term materials such as wood, paper, or burlap, and engineering criteria are not used in their application. These three fabric applications will not be considered in this report because of the above-mentioned characteristics.

REQUIREMENTS OF FILTERS AND DRAINS

Before evaluating fabric experience, fabric requirements for applications pertinent to this review will be described and, where possible, quantified.

The fabrics used in airport construction must meet either or

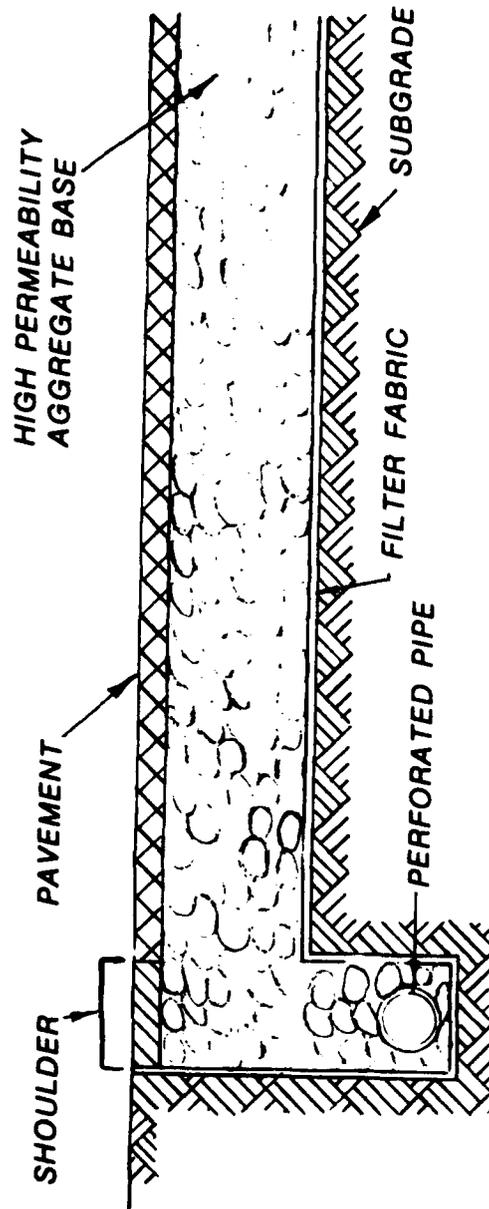


Figure 4. Fabric used for separation

both of two basic requirements: retain a soil and/or pass water. These requirements have been labeled by geotechnical engineers as the piping (soil retention) and permeability (ease of water passage) requirements. Fabric properties important to these requirements include opening size and shape, permeability, structural rigidity, thickness, compressibility, and porosity.

Extensive research and experience have defined piping and permeability criteria for granular soils used for filters and drains. These criteria are met by requiring the granular drain or filter materials to have a limited range, grain-size relationship with the retained soil that is the source of water to be passed into or through the drain or filter. Relationships have also been developed between uniform openings (circles or slots) in drainage pipe and the D_{85} grain size (the size in millimetres* of which 85 percent of the soil particles are smaller) of the soil surrounding these pipes.

To develop fabric piping criteria, the drainage pipe criteria have been used for fabrics by determining an "equivalent opening size" (EOS) of the fabric and relating it to the D_{85} soil size.¹⁴ Determination of installed fabric permeability is more difficult. Fabric permeability may be determined for the fabric in an unused condition and, for most fabrics, is equal to or greater than medium sand. However, the initial permeability of a fabric is of secondary importance since fabric permeability after installation and exposure to seepage will control its performance. Factors such as soil movement into the fabric matrix for nonwoven fabrics and blocking of openings by soil particles for woven fabrics may influence the "installed" fabric permeability.

Since "installed" piping and permeability characteristics of a fabric control performance, if these characteristics can be determined, then the other properties previously listed are of secondary concern. Eventually it may be possible to measure the fabric properties such as opening size and shape, porosity, compressibility, etc., and relate

* A table for converting U. S. customary units of measurement to metric (SI) units of measurement is given on page ii.

these to soil grain size to predict piping and permeability performance. If this could be done, it would greatly ease design because one would only need the grain size of the project soil or soils to relate to predetermined fabric properties. Unfortunately, fabrics vary greatly in their properties because of the different manufacturing methods and materials and thus frustrate this attractive solution.

Fabrics have been used principally where the flow of water is perpendicular to their greatest dimension. When used to carry water in the plane of their greatest dimension, porosity, thickness, and compressibility become very important. Projects where fabric would be used in this manner are limited, and the fabric's ability to carry water under a particular project condition could be easily measured by applying an appropriate confining pressure to the fabric while inducing water flow under an appropriate differential head.

In addition to the filter/drainage function of fabrics, they must have a durable integrity in their environment. Durable integrity is the ability to maintain the drainage/filter function for the design life of the project in the installation environment. This property depends primarily on the chemical makeup of the fabric fibers and any bonding agents used in the fabric.

Finally, the fabrics must be economically competitive with alternates such as granular filters or alternate designs. This requirement is not addressed in this report because of the variations of materials and alternatives for different projects and the variation of prices. Fabric cost generally ranges from \$0.06 to \$0.50 per sq ft.

REVIEW OF FABRIC EXPERIENCE - SURFACE DRAINAGE

Use of fabrics in surface drainage will be reported in two parts:

- a. As used between a channel or reservoir slope and overlying slope protection or armor (riprap, stones, blocks, etc.) for scour, erosion, and piping prevention.
- b. Silt fences for prevention of stream pollution by sediments in surface runoff.

Discussion of fabric usage on slopes will be subdivided into four general requirement areas: permeability/piping, drainage, durable integrity, and strength. Silt fence applications will be considered separately from slope usage because silt fence applications have different requirements and require fewer engineering design considerations.

FABRIC USE BETWEEN A SOIL SLOPE AND SLOPE PROTECTION

PERMEABILITY/PIPING

Fabric permeability obviously must exceed that of the protected soil, and this relationship must continue for the project life. Normally, fabric permeability should be several times that of the soil to allow for variations in fabric permeability, some variation in soil permeability, construction activity tending to reduce cloth permeability (such as placement of dirt or debris on fabric), and possible fabric permeability reduction with time. Though no studies have been made to determine the value that should be assigned to the fabric-soil permeability ratio, one fabric manufacturer¹⁵ has suggested a value of 5. Subsequently, a report by a Canadian materials laboratory¹⁶ has recommended that fabrics have 2 or 5 times the soil permeability depending on whether the soil is uniform or well-graded, respectively. Several methods have been used to measure fabric permeability,^{14,17} but problems with turbulent flow and fabric stacking have prevented a definite method of measurement. An American Society for Testing and Materials (ASTM) Subcommittee (D 13.61) has conducted round-robin fabric-only permeability testing using various devices and different laboratories,¹⁸ but a standard method of testing has not been developed.

This type of fabric-only testing for installations involving soils is of secondary importance since it essentially verifies that the fabric has a certain initial permeability, but does not predict long-term permeability of the fabric after interacting with the soil under seepage conditions. Effective fabric permeability measured during exposure to soil and seepage conditions similar to those expected on a project would be more meaningful for engineering design. Attempts have been made to make measurements that would, in part, meet this need.^{14,17,19} But to perform tests similar to these--permeameter tests with soil and fabric, run for long periods--would not be practical for many fabric applications. Examples of projects that would not routinely support this type of rather complicated, expensive testing are those having considerable variations in soils, small projects, and projects requiring the consideration of several fabrics for legal reasons. Though a case can be made against this type of evaluation, e.g., it does not look at all field conditions (intermittent and surge seepage and reverse flow) and is relatively complicated and expensive, no other methods for prediction of installed fabric permeability have been successfully developed. The Corps of Engineers (CE) uses a gradient ratio test,²⁰ which is a permeability test using soil and fabric as shown schematically (Figure 5). Previously, the Corps of Engineers used percent open area (POA) as a rough measure of fabric permeability. POA was determined by measuring the open areas within a set area of the fabric and computing a total percentage of area open.^{14,21} This procedure was designed for woven fabrics, which usually are thin and have regular, distinct openings, and does not apply to nonwovens, which have irregular openings, or to thicker nonwoven fabrics, which have torturous paths through the fabric.

Piping characteristics of fabrics have generally been determined by sieving sized particles through the fabrics and measuring an equivalent opening size, average pore size, or pore size distribution curve.^{14,15,22} Calhoun¹⁴ treated wovens as a plane with holes much as slotted drain pipes are considered for subdrains. After measuring the fabric equivalent opening size (EOS) with rounded sand, this size was related to the D_{85} size of the soil to be protected:

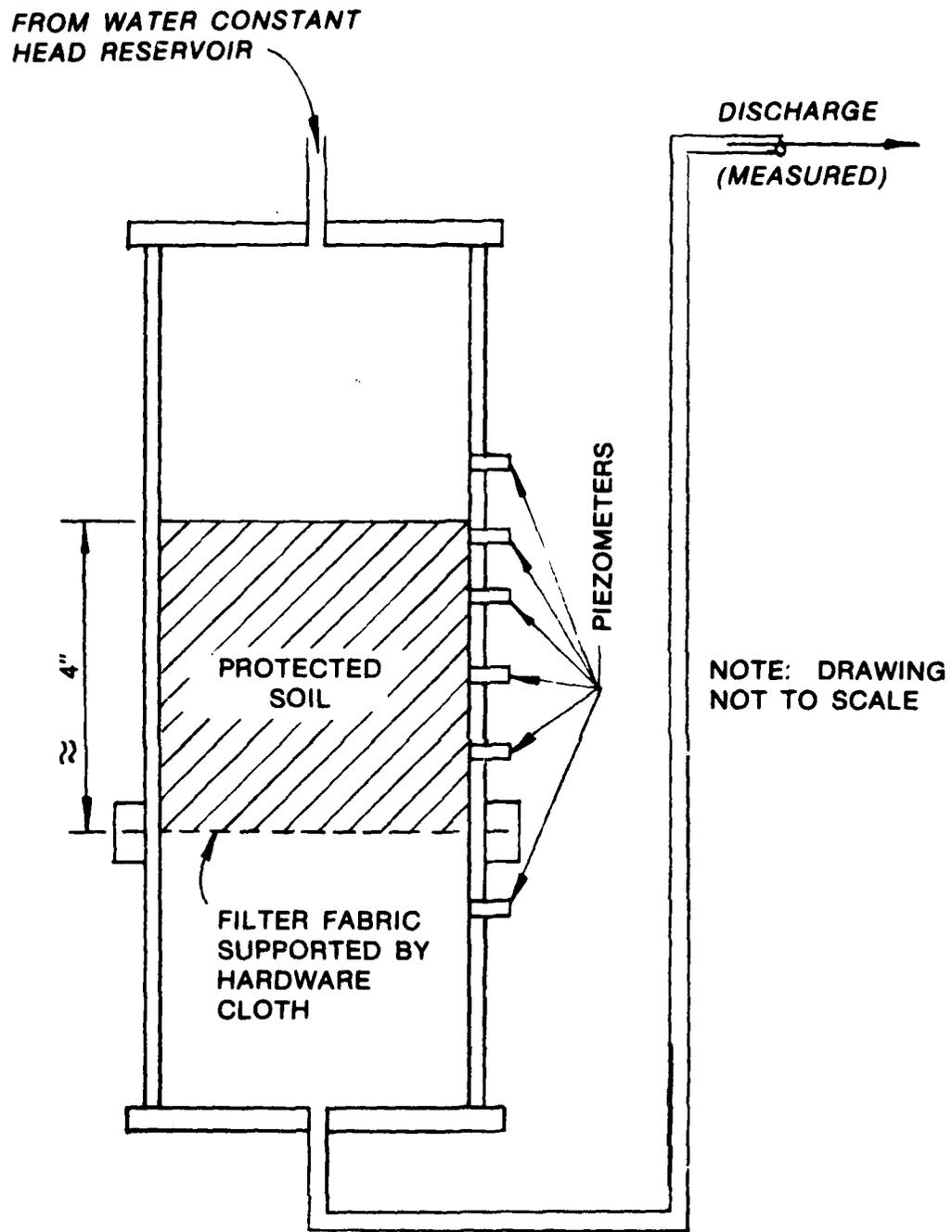


Figure 5. Schematic of the gradient ratio test apparatus

$$\frac{D_{85} \text{ Soil}}{\text{EOS}} > 1$$

The validity of this type of measurement for nonwovens has not been proved. Currently,²⁰ glass beads of standard sizes are used by the CE for EOS determination. Glass beads provide a more standard means of measurement, but their use is not without problems. Most nonwoven fabrics exhibit apparent EOS's of the No. 100 U. S. Standard sieve or less, and therefore only very small beads will pass through them. Because of this and the torturous paths through some of the thicker nonwoven fabrics, beads become attracted to and captured within the fabric. Additionally, very little is known about correlating opening measurements with glass beads and field piping performance of fabrics with soil. Measurement of fine passage during gradient ratio type tests has been attempted. Other attempts have used electronic scanning devices and computers to calculate percent of openings.²³ This method is obviously complicated and expensive.

The best approach to date has been to examine the permeability performance of fabrics with project soils in a permeameter and determine the piping characteristics by relating the apparent opening size of the fabric (from sieving of sized particles) to the grain size of the project soils. Certainly this is a conservative and expensive approach that must be modified drastically, if not abandoned, as a result of performance experience.

DRAINAGE

In cases where stone or other irregularly shaped armor is used on fabric in slope protection, there is little if any need for the fabric to have a water-carrying capacity in the plane of the fabric. However, in certain applications movement of water in the plane of the fabric may be necessary if large areas of the fabric are covered, preventing transverse flow. If flat, man-made revetment blocks are used, flow from the fabric may be limited to the cracks or joints between each block. In this case, permeability and flow testing should be accomplished in the

plane of the fabric with a compressive load on the fabric equivalent to field load. Results may then be compared with project flow values calculated from soil permeability and hydraulic gradients. Limited, experimental testing has been accomplished on some fabrics.²⁴

DURABLE INTEGRITY

Most fabrics accepted for current use are not affected by environments normally found in drainage applications. For airport usage, one researcher¹⁴ evaluated the effects of jet aircraft fuel on fabrics. Fabrics placed where drainage systems might be exposed to fuel, e.g., fuel dump areas, should be subjected to a similar test. The same rationale applies for any fabric application exposing the fabric to abnormal soil conditions, such as strong alkali or acid or other contaminants. The one common weakness of plastic fabrics is exposure to ultraviolet rays and sunlight. Exposure causes deterioration that may affect fabric strength over a long or short period (weeks to a year), depending on the chemical makeup and any inhibitors added to the plastic. Many specifications have a general statement of fabric chemical content,²⁰ but this represents only a very general control since plastics may use any of a large number of chemical combinations and additives.

STRENGTH

Fabrics beneath slope protection must exhibit several types of strengths. Primary among these are tensile, abrasive, tear, puncture, and burst. Creep under long-term load is a related characteristic of interest. Requirements for each of these strengths varies with the manner of construction and severity of service.

Tensile strength is required for handling purposes, and to withstand loads applied due to the armor elements resting on the fabric, along the slope. Abrasive strength is necessary to prevent abrading of the fabric under armor element movement during placement and service life of the project. Tear strength is necessary during placement and service to resist tearing of the fabric at the pins that hold the fabric

in place on the slope and at any sharp changes or deformations in the slope. To avoid damage to the fabric during placement of the armor elements, fabrics must be resistant to damage from punctures, particularly where angular, heavy stones are dropped from some distance above the fabric. Finally, some designers feel that fabrics must resist hydrostatic pressures from beneath and thus must exhibit a burst strength. Properly designed fabric installations should not be subject to hydrostatic pressures from beneath since the fabric should be more permeable than the soil beneath it and thus pass water faster than it is brought to the fabric by the soil. As with all construction components, there will be cases when for various reasons fabrics will be subject to burst stresses; requirements for tear and tensile strengths will also cause the fabric to have a burst strength of related magnitude.

SILT FENCES

Silt fences are generally used during construction for control of sediments in surface runoff until a more permanent means of erosion control can be installed, e.g., seeding, paving, etc. They have become more important recently because of governmental requirements to control sediment pollution of streams during construction.²⁵ Silt fences must literally filter the runoff water leaving an area, removing sediments and passing water with a minimum of flow resistance. Essentially, fabrics must have openings small enough to retain the soil particles (sediment) and have minimum effect on water flow. Design parameters have not been developed for these functions, though the requirement to retain fine soil particles means fabrics with opening sizes equivalent to the U. S. Standard No. 100 sieve or smaller would be chosen. Expected design life would have to be considered when choosing fabrics since resistance to sunlight varies considerably. Fences are constructed in many ways. Two of the most common ways are:

- a. Attaching fabric, anchored in a small trench, to a wire fence.
- b. Similarly anchored fabric laid over a small windrow of brush.

These fences are placed at the edge of the erosion area in a place where runoff passes or around the edge of a construction site. Depending on construction duration, amount of runoff, and sediment load, fences may have to be periodically replaced.

PROBLEMS INVOLVING USE OF FABRICS IN SLOPE PROTECTION

Some problems have arisen with fabric usage in slope protection that may provide guidance for future applications. The problems may, by nature, be divided into three areas: construction damage to fabric, soil movement beneath fabric, and armor slippage on fabrics.

CONSTRUCTION DAMAGE

Puncture and tear damage to fabric have occurred during placement of riprap protection along a waterway when riprap stone was placed on fabric by dragging stone upslope from the toe over in-place stone and dropping it on the fabric. The slope was 2 horizontal to 1 vertical (2H:1V), and it was felt that the steeper slope (compared to the usual 3H:1V slope) increased the tension in the pinned fabric as more stone was placed on it, making it more susceptible to puncture. Placement of a sand layer as a cushion on top of the fabric achieved limited success.*

SOIL MOVEMENT BENEATH FABRIC

Four instances of bank distress (soil movement beneath fabric and the armor elements) have been reported involving nonwoven and woven fabrics.

A nonwoven fabric was installed beneath cellular concrete blocks to prevent shoreline erosion on a lake in northeast Texas.²⁶ During construction, damage involving displacements of soil, fabric, and concrete blocks was caused during heavy wave wash. The installation was

* Fetzer, C., Personal Communication, Subject: Puncture Problems with Fabrics Beneath Riprap Slope Protection, Tennessee-Tombigbee Waterway, U. S. Army Engineer Division, Ohio River, Cincinnati, Ohio, January 1979.

subjected to cyclic wave forces (2- to 3-ft waves) and soil moved down-slope, forming a bulge at the lower end of the fabric. Soils in the damaged areas were fine sands and silts, which are susceptible to flow slides. It was concluded that the cause of the damage was flow slides initiated by waves and that the fabric did not contribute to the damage since its permeability after the damage was still greater than the soil. Algae growth that occurred on exposed fabric after the damage during periods of high temperature and moisture reduced fabric permeability approximately two orders of magnitude (from 0.4 to 0.005 cm/sec).

A second instance of soil movement beneath slope protection (including a woven fabric) occurred in weir structures along a creek channel.²⁷ Again, flow slides were considered a most probable explanation and the fabric was not suspect. Damage to some of the slope protection indicated that fabrics placed over erosive soils lack the ability to fill in any erosion channels left beneath the fabric during construction or that develop subsequent to installation, whereas a granular filter will not bridge these areas and thus tend to prevent continued erosion.

Finally, fabric placed beneath riprap in a test revetment along the Mississippi River bulged due to soil movement.²⁸ The woven fabric with a low percent open area (5 percent) was apparently clogged and did not allow bank hydrostatic pressure to reduce fast enough to prevent flowing of the fine sands beneath. A cake of fines was found beneath the fabric.

Damage to slope protection reported by another study indicated that a fabric as open (or permeable) as can be chosen that still meets piping criteria should be used in places where high velocity through flows are expected from behind the flow protection.²⁹

ARMOR SLIPPAGE

When fabrics are used on slopes steeper than 3H:1V, problems may arise in keeping armor elements on the fabrics. The St. Paul District of the Corps of Engineers recommends fabric be used on slopes greater than 3H:1V only after careful consideration since fabric-armor element

friction is probably not sufficient to hold armor elements in place if there is a loss of armor elements at the toe of the slope.* Apparently a failure of this type occurred in Wheeling, West Virginia, and will be reported as a case history in a forthcoming report on the use of filter fabrics for streambank erosion control.

GUIDELINES

These experiences support the following guidelines:

- a. Where liquefaction is the source of slope stability problems, use of fabric and slope protection will not particularly alleviate the problem.
- b. Under favorable temperature and moisture conditions, algae may grow on fabric and reduce its permeability.
- c. Steep slopes (greater than 3H:1V) and heavier riprap may cause problems, such as puncture and tear of fabric, during placement of the stone even if a sand bedding is placed on the fabric to cushion the stone.
- d. Erosion can take place beneath a fabric since it will tend to bridge any channels existing at the time of installation or developing after installation. This is particularly critical in highly erodible soils.

* Halmark, C., Personal Communication, Subject: Use of Filter Fabric on Slopes Exceeding 1V:3H, U. S. Army Engineer District, St. Paul, St. Paul, Minn., January 1979.

REVIEW OF FABRIC EXPERIENCE - SUBSURFACE DRAINAGE

Subsurface drainage use of fabrics will be considered under three headings because of variations in type and degree of requirements for each application:

- a. Trench drains.
- b. Separation.
- c. Drainage for consolidation of soft soils.

TRENCH DRAINS

PERMEABILITY/PIPING

Permeability and piping requirements have been approached in the same manner for trench drains as for use between slopes and slope protection.

DRAINAGE

The same requirements for permeability determination under load apply for trench drains as those for slope protection. Normally trench drain applications involve only flow perpendicular to the plane of the fabric.

DURABLE INTEGRITY

Again, considerations for durability given under slope protection use apply to subdrains.

STRENGTH

Strength requirements differ from slope protection usage in magnitude and kind. The primary concern is tensile strength since for most trench drain applications if moderate tensile strength exists and proper care is taken during installation, little strength is required during the project life. If the trench is subject to frequent heavy loading, e.g., large wheel loads, there may be need for high tensile, abrasive, tear, and puncture strengths, but normally most of the structural strength requirements of an installation are supplied by the soil and granular material. Through relatively loose installation

and strain, the fabric will conform to the soil and aggregate strains with minimal stress. The fabric should be placed in a manner to prevent bridging of large voids and a minimal amount of compaction used in installing the aggregate portion of the drain.

SEPARATION

Fabrics may be used to prevent contamination of a high permeability base or subbase materials (Figure 4), and thus maintain high base or subbase permeability during project life. Permeability is not normally a consideration unless there are rises in the groundwater table above the level of the fabric. In this case, consideration of the separation fabric as a filter would be necessary.

Piping is the primary concern since prevention of fine-grained subgrade intrusion is the function of separation. Equivalent opening size criteria, as discussed under slope protection usage, are the principal means of determining piping performance prediction. Enough strength is required to prevent destruction of the cloth, but load capacity is not a consideration for strictly separation functions. The fabric should be installed loosely enough to transmit any loads from the base or subbase to the subgrade. Use of fabrics for reinforcement is not included in the scope of this study.

DRAINAGE FOR CONSOLIDATION OF SOFT SOILS

Fabrics have been used to consolidate soft soils and embankments. One method consists of pneumatically filling a woven polypropylene stocking with sand and vibrating it into a prebored hole, while another method uses a polyester nonwoven fabric, 30 cm wide, which is jetted or vibrated into place with a lance.³⁰⁻³² A third method uses a 10-cm plastic core embossed with studs and wrapped with a fabric sleeve which is forced into the soil by a mandrel.* These methods have provided

* Taylor, H. M., Personal Communication, Subject: Installation of "Alidrain," Synthetic Vertical Strains in Interstate-70 Construction, St. Louis, Mo., U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., August 1979.

vertical drainage for soil masses, but little is known about any engineering criteria used in their design, though a few case histories of installations are available. Fabrics for horizontal drainage of embankments have been studied theoretically and laboratory testing has been used to define the fabric characteristics for use as a drainage layer for consolidation.²⁴

CASE HISTORY OF FABRIC USE FOR RUNWAY SEPARATION AND TRENCH DRAINS

Dresser^{33,34}* described a runway rehabilitation project using fabric for separation and trench drains at the Jacksonville, Florida, airport. Seepage from the subgrade and general pavement distress had required the removal of old pavement and underlying materials and replacement with an effective drainage system and new pavement. The selected design consisted of a 14-in. portland cement concrete (PCC) pavement, 6-in. Econocrete (from old pavement) base, and 6-in. coarse, recycled, concrete aggregate subbase that would serve as a drainage system. Beneath each edge of the replaced pavement, trench drains approximately 20 in. deep were installed with perforated pipe and side outlets. A lightweight nonwoven fabric was used for separation beneath the recycled concrete aggregate on a subgrade with a high percentage of material passing the No. 200 sieve. The fabric was extended from the subgrade down to line the drainage trenches on each side and was tied into the existing pavements on each side of the area being rehabilitated. The fabric placed in the drainage trenches allowed coarse aggregate to be used without concern for piping failure since the fabric would form a piping barrier to the fine-grained subgrade soils. The fabric was chosen after reviewing reports and references, with three products or equivalent being listed in the project specifications. Specific fabric design criteria were not mentioned in the report. The project engineer was contacted approximately two years after the fabric was installed.

* Dresser, J. G. Jr., Personal Communication, Subject: Use of Fabric at Jacksonville, Florida, Airport, Jensen Construction Co., Lake City, Fla., January 1979.

and he was very satisfied with the system performance, stating that the water table had fallen in the area and that he would specify this type of installation again, as is currently being installed at the apron area of the same airport.*

The author visited this site in June 1979³⁵ and inspected the runway and drain outlets and discussed the project's performance with Mr. Dresser and personnel of the Jacksonville Port Authority, owner. The pavement was in excellent shape and the drains were functioning. The rehabilitated pavement showed no evidence of pumping (staining from water pumped from beneath the pavement carrying subbase and subgrade fines) as did the outer sections of runway, which had not been included in the project. Piezometers indicated that the fluctuating groundwater table was being controlled by the drainage system, and all parties agreed that the project had performed well to date.

A similar project was under construction in the apron area of the airport and the accompanying figures illustrate the procedure used to install the fabric-lined trench drains and the fabric separator between the subgrade and subbase. Figure 6 shows the drainage trench made in the prepared subgrade by a backhoe. Workmen roll the fabric out over the trench and a small amount of backfill is placed on the fabric to force it into the trench but still allow some fabric movement by workmen for final positioning (Figures 7 and 8). Four inches of aggregate are placed in the fabric and the fabric is shaped to approximately conform to the trench bottom and sides (Figure 9). Corrugated, slotted, flexible, plastic pipe is placed in the trench (Figures 10 and 11) and the trench is backfilled to within a few inches of the top and compacted with a powered hand compactor (Figure 12). Between drains, fabric lapped at the edges (Figure 13) separated the subgrade from the crushed stone subbase.

Figures 14 and 15 illustrate conditions that require care to allow drains to function properly. Fine-grained material has been blown

* Dresser, J. G. Jr., Personal Communication, Subject: Use of Fabric at Jacksonville, Florida, Airport, Jensen Construction Co., Lake City, Fla., January 1979.



Figure 6. Excavation in trench
in summer of 1962.



Figure 7. Fabric rolled out over trench



Figure 10. Slotted, flexible pipe used in drains



Figure 11. Pipe being placed in drain with coupling



Figure 12. Portion of backfilled trench.



Figure 13. Fabric separating subgrade from base, showing overlap



Figure 14. Contamination of equipment and installation



Figure 15. Drain outlet pipe (located in center of photograph behind pencil), illustrating need for maintenance

and washed into an uncompleted drain installation and has contaminated the end of the drain and trench shown in Figure 14. This material should be removed and any contaminated backfill and fines removed from the interior of the fabric. Figure 15 is a view of an outlet (shown by the pencil in the center of the picture) overgrown by weeds. A shovel was used to clear muck and mud away from the end of the pipe, and weeds had to be pulled back in order to get even this picture of the drain outlet. Outlets should be kept free of dirt and vegetation and precautions taken to prevent structural damage from vehicles and entrance of rodents with accompanying nest building. Any of these problems can impede the function of a drain and eventually result in pavement damage.

PROBLEMS INVOLVING USE OF FABRICS FOR SUBSURFACE DRAINAGE

No case histories were found describing problems with subsurface drainage. This is probably due to the nature of this type of construction--beneath ground--and the lack of any short-term means of evaluating an installation. For this usage failure would most likely be over a long period of time.

One study³⁶ has recently been completed that evaluated a series of highway edge drains over a two-year period. Several fabrics were used as well as granular drains. A section of each drain was excavated and tested (strength and elongation, permeability) after one year and after two years. It was concluded that the fabric sites functioned as well as the granular sites for the two-year test period. Over the two-year period, fabric permeability and strength decreased and concern was expressed that if this trend continued, serious problems could result. Follow-up testing may be conducted after four or five years of exposure. In one test section, a fabric with an EOS larger than the design criteria EOS given previously in this report was used in one section. Fines were found within the drain and in the pipes in this section, though for the evaluation period, this section functioned as well as the others.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Fabrics have been successfully used for surface and subsurface installations applicable to airport construction. Problems with fabrics have only occasionally been reported, though this does not provide a very reliable, representative indication of performance.

Current design criteria are based on accepted and proven drainage principles used for granular filters and drains, but little is known about the actual mechanisms of soil-fabric interaction during seepage. These interactions may be different for the fabrics constructed differently. Further, long-term correlation of field performance with fabric type, soil type, soil grain size, and hydraulic characteristics is needed. Presently few installations have used specific design criteria or have related performance to fabric and soil properties.

Several fabric test procedures have been used by researchers and designers that may be used for interim guidance. Current studies are evaluating test methods and limited field performance^{8*} while an American Society for Testing and Materials (ASTM) Subcommittee, D13.61, is developing test methods for geotechnical fabrics.¹⁸ Further test development and research is not justified until more field performance can be related to previous testing. When field performance can be used as a guide for the predictive ability of the various fabric tests, follow-up research to define the most applicable test methods can be conducted.

RECOMMENDATIONS

Critical review of fabric usage prompts the use of two levels of

* Dardeau, E. Jr., and Keown, M. P., Personal Communication, Subject: Use of Fabrics for Control of Streambank Erosion, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., January 1979.
Forshey, A. D., Personal Communication, Subject: Research Project, "Use of Filter Cloths for Sub-Surface Drainage Systems for Highways," Pennsylvania Department of Transportation, Harrisburg, Pa., January 1979.

guidance for the use of fabrics in airport drainage. Until further field studies and correlations are made, it is recommended that fabric usage be divided into critical and noncritical applications for purposes of design criteria and specification. Critical applications include those where if the design life is long (greater than 15 years), failure of the drainage installation would endanger life or structures, or require expensive maintenance. Noncritical applications include short-life projects and those applications that may be easily and inexpensively replaced. Appendix B provides specific guidance for critical and noncritical use of fabrics under the application headings discussed in this report.

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APPENDIX A: CURRENT FAA USE OF FILTER FABRICS IN DRAINAGE

Each FAA regional office was contacted to determine the procedures used in the design and construction of fabric drainage applications and the extent to which the procedures were used. Each office was most cooperative and this support is gratefully acknowledged.

These fabric applications indicated that most fabric usage is recent (1-2 years) and that specification is either Corps of Engineers type, i.e., percent open area or EOS, or a by-product specification or equal. These applications will provide a base of field performance with which to evaluate fabric test and specification methods through comparison of soil and fabric characteristics with performance.

Additionally, manufacturer representatives have provided general reports of fabric usage in airport drainage that have not been included in Table A-1 but are in the project files at the WES.

Table A-1

FAA Fabric Use for Drainage

FAA Region	Contact	Location	Application/Remarks
New England	Joel B. Hill	Presque Isle, Maine	Fabric installed 1978, fabric wrapped around subdrain pipe. Specifications required Carthage Mills Filter X or equal.
		Lebanon, New Hampshire	Fabric installed 1978, used with stone fill for erosion control.
		Old Town, Maine	Fabric specified for use in 1979 to line trench for underdrains. Specifications require Monsanto Bidim C22 or equal.
Eastern Southern	Carl Steinhauer	Kennedy Airport	Fabric used to wrap drainage pipe.
	Don Morgan (also Richard B. Smith, Airport Engineer, Jacksonville Port Authority)	Jacksonville, Florida	1977 fabric used as a separator between fine subgrade material and aggregate subbase and to line sub-drains. Specifications required: Poly-Filter X Mirafi 140 Typar 3401 or equal
Great Lakes	Clifford Carstens	Jackson, Minnesota	Fabric installed as an envelope in an edge drain along apron and taxiway, 1978, approximately 1000-ft length.
		Westbend, Wisconsin	Proposed 1979 construction approximately 1000-ft length of subdrain.

(continued)

Table A-1 (Continued)

FAA Region	Contact	Location	Application/Remarks
Central	Bill Carson	Johnson County Industrial Airport, Olathe, Kansas	Used as subdrains in clay subgrade-summer 1978-envelope drains. Specified Stabilenka or Mirafi 140 or equal (used Typar?) satisfactory performance. Cost: 12,630 ft @ \$7.73/ft.
		Lambert-St. Louis International Airport, St. Louis, Missouri	To be used in 1979 construction of envelope drains. Fabric specified by weight, EOS, and chemical makeup.
		Clinton Municipal Airport, Clinton, Iowa	Subdrains using fabric to line trench (to be constructed). Fabric specified to be Typar, Mirafi 140, or equal.
		Perryville Municipal Airport, Perryville, Missouri	Typar used as a subgrade stabilizer between subgrade and aggregate base course beneath overrun - locally funded construction approximately two years ago.
Southwest	Blair Harvey		No fabric use in subsurface drainage.
Rocky Mountain	Craig Sparks		No fabric use in subsurface drainage. Possible future use at two locations in Utah as a separator and for control of a shallow water table.
Northwest	Chuck Glasgow		No subdrainage applications. Used Petromat in Idaho as a separator between soft soil and a sand.

(continued)

Table A-1 (Concluded)

FAA Region	Contact	Location	Application/Remarks
Western	Morris Sasson Gunnar Tenneson		No fabric use in drainage.
Alaskan	Ken Moore		Fabric used in runway embankment as a separator - have used fiberglass, without insulation backing, around perforated pipe to drain soft, wet soils - no set design procedure - word of mouth.
Pacific-Asian	Dan Matsumoto Franklin D. Benson	Honolulu, Hawaii	Fabric (woven) used in construction of Reef Runways and Taxiways project, 1972, to prevent fines from moving from beneath stone protection during wave attack. Generally used Corps of Engineers specifications for guidance. Performance - satisfactory.

APPENDIX B: INTERIM GUIDANCE
FOR USE OF FABRIC IN AIRPORT DRAINAGE

This guidance is based on a review of fabric research and use and, because of this limited basis, is interim. The specifications in general contain required fabric characteristics for design and thus separate criteria are not listed for design. It is assumed that normal drainage design practice will be followed in computing quantities of flow and for the use of drain pipes and aggregate. Most of the specifications have been taken from existing Government agency publications and are referenced appropriately. It is strongly recommended that engineers involved in drainage design using fabrics keep abreast of new developments in the use of fabrics. The practice is in its early stages and further experience will define much better the most reliably predictive tests for fabrics.

Guidance is provided for each application discussed in the report, except for consolidation. Because of the very limited use and proprietary nature of consolidation applications, interim guidance is not currently available. Certain portions of the specifications will not apply to some installations, e.g., susceptibility to jet fuel, and should be applied appropriately by the designer.

SURFACE DRAINAGE

BENEATH SLOPE PROTECTION

The most generally accepted guidance for use of fabric beneath slope protection is the Corps of Engineers Guide Specification, Plastic Filter Fabric, latest edition CW 02215, November 1977.²⁰ Earlier editions have included more types of testing and more stringent strength requirements, which may still be applicable to installations that use large armor elements and are subject to severe wave and/or current attack (see Table 2 of CE 1310, May 1973²¹). This earlier edition included tests such as low temperature strength tests, freeze-thaw, and brittleness, which may be applicable to certain airport installations in cold climates. The original WES report,¹⁴ which was the basis for these

guide specifications, described a fabric test with jet fuel, which may be applicable if the fabric could be exposed to jet fuel, e.g., through fuel dumping during emergencies.

It should be noted that measurement of EOS in the November 1977 edition is by standard size glass beads, which may present problems as noted in this report. For woven fabric, percent open area has also been used in the past edition in place of the gradient ratio test. The percent open area procedure is included for use with applicable fabrics.

Instructions for the guide specification and the guide specification itself begin on page B-4.

SILT FENCES

Silt fences are noncritical structures, but certain fabric requirements can be imposed to provide a more economic and effective sediment barrier. The following guidelines have been used by the USDA Forest Service⁷ and the Federal Highway Administration. The requirement for thickness is probably not necessary if the companion specifications for permeability and EOS are met.

Probably a slurry test, using a soil-water mixture passing through the fabric, would be most appropriate for this application. This type of test has been performed but no standard method exists. The New York Department of Transportation uses a test similar to this, but specifications have not been issued based on the test procedure.⁹

The guide specification for silt fences begins on page B-16.

SUBSURFACE DRAINAGE

TRENCH DRAINS

The interim guide specification that follows contains installation instructions and design criteria, but caution should be taken in placing fabric drains beneath structural pavement or buildings. Only after documentation of a particular fabric's performance should installations be made that could require high cost replacement due to failure of the drainage system. For less critical installations, the more stringent sections such as gradient ratio testing may be deleted

from the project specification.

Instructions for the guide specifications for filter fabric used in trench drains and the guide specification itself begin on page B-18.

SEPARATION

General guidance for separation is provided. Requirements may vary greatly depending on the type of surface that the fabric is placed upon, the magnitude and frequency of loading, and project life. Excerpts from Corps of Engineers CW 02215, November 1977, Guide Specification,²⁰ are provided and can be used as a basis for fabric composition requirement. EOS should be considered since the primary function of a fabric separation layer is to prevent movement of fine-grained subgrade materials into a coarser base. If groundwater levels will rise above the elevation of the separation layer, consideration must be given to fabric permeability to prevent uplift forces beneath the base materials. Permeability may be evaluated with the percent open area of gradient ratio test described in the guidance for fabrics in slope protection contained in this Appendix. It should also be noted that this specification only applies to the separation function. If any appreciable reinforcement of a pavement system is required, consideration should be given to increasing the tensile strength requirements. Paragraphs 5 and 6 are taken from the USDA Forest Service specifications for use on low-volume roads.⁷

The guide specification for filter fabric use for separation begins on page B-29.

GUIDE SPECIFICATION
FOR
FILTER FABRIC USED BENEATH SLOPE PROTECTION²⁰

Instructions

1. This guide specification is to facilitate the preparation and review of specifications for the procurement and installation of woven and nonwoven plastic filter fabric. It has been developed based on limited field performance observations and the laboratory test evaluation of a limited number of currently available fabric types with thicknesses of 0.2 inch or less. An increasing number of filter fabrics are becoming commercially available that are not only economically competitive, but also possess greatly varying engineering properties and physical characteristics. It is therefore necessary that the burden of acceptance of specific fabric types rest with the designer, and that each design application be given critical study to determine a particular fabric's engineering suitability for use. The EOS and gradient ratio filter design tests, which are described in the instructions that follow, are physical property and performance type tests, respectively, that along with the strength requirements given in Table 1, should provide a basis with which to judge the acceptability of a particular fabric for use. The designer should require prospective fabric suppliers to furnish these test results before their fabric will be considered for use, or before contract specifications are adjusted to permit the use of fabrics with properties outside the limits imposed by this guide. In addition, the designer should perform EOS and gradient ratio tests before contract advertising on at least two commercially available fabrics to serve as a basis for the estimate of cost, and to assure that there are fabrics that will satisfy the requirements of the specifications. Further, specifications should require that EOS and gradient ratio tests be run during construction, either at a specified frequency or upon demand of

the contracting officer, as part of the contractor's quality control requirements.

2. The actual life of these fabrics is not known, and their use in inaccessible areas must be considered carefully. Filter fabrics should not be used to wrap piezometer screens or as filter material within or on the upstream face of earth dams, or within any portion of the embankment.

3. Filter design criteria for plastic filter fabrics are based on the "equivalent opening size" (EOS) and "gradient ratio." The EOS is defined as the number of the U. S. Standard sieve having openings closest in size to the filter fabric openings. The gradient ratio is the ratio of the seepage gradient through the fabric and 1 inch of soil to the gradient through 2 inches of soil specimen. The gradient ratio, determined as described below, should not exceed 3.

a. Determination of Equivalent Opening Size (EOS). Five unaged fabric samples shall be tested. Obtain 50 grams of each of the following fractions of standard glass beads:

<u>U. S. Standard Sieve Number</u>					
<u>Designated</u> <u>EOS</u>	<u>Passing</u>	<u>Retained On</u>	<u>Designated</u> <u>EOS</u>	<u>Passing</u>	<u>Retained On</u>
20	18	20	70	60	70
30	25	30	100	80	100
40	35	40	120	100	120
50	45	50			

Suitable glass beads can be obtained from:

Cataphote Division
Ferro Corporation
P. O. Box 2369
Jackson, Mississippi 39205
Telephone: (601) 939-4631

Within each size range, 95 percent of the beads should be within the specified range. The fabric shall be affixed to a standard sieve 8 inches in diameter having openings larger than the largest beads to be used in the test. The fabric shall be attached to the sieve in such a

manner that no beads can pass between the fabric and the sieve wall. Shaking shall be accomplished as described in paragraph 2d(1)(g), Appendix V, EM 1110-2-1902, U. S. Army Corps of Engineers, except the times for shaking shall be 20 minutes. Determine by sieving (using successively coarser fractions) that size of beads of which five percent or less by weight passes through the fabric; the equivalent opening size, EOS, of the fabric sample is the "retained on" U. S. Standard Sieve number of this fraction.

b. Determination of Gradient Ratio. A constant head permeability test shall be performed in a permeameter cylinder on soil specimens representative in classification and density of those materials to be protected, and in accordance with EM 1110-2-1906, Appendix VII, U. S. Army Corps of Engineers, with the following modifications:

(1) A piece of hardware cloth with 1/4-inch openings shall be placed beneath the filter fabric specimen to support it. The fabric and the hardware cloth shall be clamped between flanges so that no soil nor water can pass around the edges of the cloth.

(2) The soil specimen shall have a length of 4 inches. Piezometer taps shall be placed 1 inch below the fabric and 1, 2, and 3 inches above the fabric.

(3) Tap water shall be permeated through the specimen under a constant head loss for a continuous period of 24 hours. The tailwater level shall be above the top of the soil specimen. The gradient ratio shall be determined from the readings taken at the end of the 24-hour period.

(4) The gradient ratio is the ratio of the hydraulic gradient over the fabric and the 1 inch of soil immediately next to the fabric, i_1 , to the hydraulic gradient over the 2 inches of soil between 1 and 3 inches above the fabric, i_2 .

$$G. R. = i_1/i_2$$

4. It is the responsibility of the designer to specify filter fabric that retains the soil being protected, yet will have openings large

enough to permit drainage and prevent clogging. The designer should select the "equivalent opening sizes" based on the following criteria:

a. Filter fabric adjacent to granular materials containing 50 percent or less by weight fines (minus No. 200 materials):

$$\frac{85 \text{ percent passing size of soil}}{\text{opening size of EOS sieve}} \geq 1$$

b. Filter fabrics adjacent to all other type soils:

EOS no larger than the openings in the U. S. Standard Sieve No. 70 (0.0083 inch).

To reduce the chance of clogging, no fabric should be specified with an EOS smaller than the openings of a U. S. Standard Sieve Size No. 100 (0.0059 inch). When possible, it is preferable to specify a fabric with openings as large as allowed by the criteria. Filter fabrics should not be used for soils with 85 percent or more smaller than the No. 200 sieve.

5. Paragraph 5 of the guide specification describes installation in open areas and on generally planar surfaces. For installation in drainage systems or about collector pipes, additional specification requirements may need to be added.

6. Capitalized instructional notes to the Contracting Officer will be deleted for the text of the contract specification.

7. Standards and other specifications referenced in this guide specification should be checked for obsolescence and for dates and applicability of amendments and revisions issued subsequent to the publication of this guide specification.

NOTE: THESE INSTRUCTIONS ARE FOR INFORMATION ONLY
AND WILL NOT BE INCLUDED IN CONTRACT SPECIFICATIONS.

GUIDE SPECIFICATION
FOR
FILTER FABRIC USED BENEATH SLOPE PROTECTION²⁰

SECTION ____
PLASTIC FILTER FABRIC

1. SCOPE: The work provided for herein consists of furnishing all plant, labor, material, and equipment and performing all operations required for furnishing, hauling, and placing the plastic filter fabric, complete, as specified herein and shown on the contract drawings, and maintaining the plastic filter fabric until placement of the *(filter material) (bedding material) (riprap) cover is completed and accepted.

2. APPLICABLE PUBLICATIONS: The following publications of the current issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the references thereto:

American Society for Testing and Materials (ASTM)

D 751-73	Testing Coated Fabrics
D 1175-71	Abrasion Resistance of Textile Fabrics
D 1682-64	Breaking Load and Elongation of Textile Fabrics
D 1683-68	Seam Breaking Strength of Woven Textile Fabrics

3. MATERIALS:

3.1 Fabric: Plastic filter fabric shall be a pervious sheet of plastic yarn. The plastic filter fabric shall provide an Equivalent Opening Size (EOS) no finer than the U. S. Standard Sieve No. __ and no coarser than the U. S. Standard Sieve No. __.

* A SINGLE ASTERISK THROUGHOUT THIS GUIDE INDICATES THAT INAPPLICABLE PROVISIONS ARE TO BE DELETED.

NOTE: SEE PARAGRAPHS 3 AND 4 IN THE INSTRUCTIONS FOR HOW TO DETERMINE AND SELECT THE EOS. IF THE CONTRACTOR QUALITY CONTROL IS TO BE RESPONSIBLE FOR EOS, THE TEST PROCEDURES IN PARAGRAPH 3a OF THE INSTRUCTIONS SHOULD BE IN THE CONTRACT SPECIFICATION.

The plastic yarn shall consist of a long-chain synthetic polymer composed of at least 85 percent by weight of propylene, ethylene, ester, amide, or vinylidene-chloride, and shall contain stabilizers and/or inhibitors added to the base plastic if necessary to make the filaments resistant to deterioration due to ultraviolet and heat exposure. The fabric shall conform to the physical strength requirements in Table 1. The fabric should be fixed so that the yarns will retain their relative position with respect to each other. The edges of the fabric shall be finished to prevent the outer yarn from pulling away from the fabric.

*(The fabric shall be manufactured into a width not less than ___ feet.)

NOTE: MOST FABRICS ARE MANUFACTURED IN WIDTHS OF 6 FEET, BUT TO REDUCE THE NUMBER OF OVERLAPS, WIDER SECTIONS MAY BE PRODUCED BY ATTACHING NARROW SECTIONS TOGETHER. PREASSEMBLED SECTIONS OF 36-FOOT WIDTHS OR MORE ARE PREFERRED TO KEEP THE NUMBER OF OVERLAPS TO A MINIMUM.

If requested by the Contracting Officer, the Contractor shall provide to the Government plastic filter fabric samples for testing to determine compliance with any or all of the requirements in this specification. When samples are to be provided, they shall be submitted a minimum of *(60) days prior to the beginning of installation of the same plastic filter fabric.

3.2 Seams: The seams of the fabric shall be sewn with thread of a material meeting the chemical requirements given above for plastic yarn or shall be bonded by cementing or by heat. The sheets of filter fabric shall be attached at the factory or another approved location to form sections not less than ___ feet wide. Seams shall be tested in accordance with method ASTM D 1683, using 1-inch square jaws and 12 inches per minute constant rate of traverse. The strengths shall be not less than 90 percent of the required tensile strength (Table 1) of the unaged fabric in any principal direction.

TABLE 1. PHYSICAL STRENGTH REQUIREMENTS

Physical Property	Test Procedure	**Acceptable Test Results
Tensile Strength +(unaged fabric)	ASTM D 1682 Grab Test Method using 1-inch square jaws and a travel rate of 12 inches per minute	200-pound minimum in any principal direction
Puncture Strength +(unaged fabric)	ASTM D 751 Tension Testing Machine with Ring Clamp; steel ball replaced with a 5/16-inch-diameter solid steel cylinder with a hemispherical tip centered within the ring clamp	80-pound minimum
Abrasion Resistance	ASTM D 1682, as above, after abraded as in ASTM D 1175 Rotary Platform, Double Head Method; rubber-base abrasive wheels equal to CS-17 "Calibrase" by Taber Instrument Co.; 1 kilogram load per wheel; 1000 revolutions	55-pound minimum in any principal direction

** Acceptable test results strengths may be reduced 50 percent for fabric to be used in drainage trenches, beneath concrete slabs, or to be cushioned from rock placement by a layer of sand or by zero drop height placement.

+ Unaged fabric is defined as fabric in the condition received from the manufacturer or distributor.

3.3 Acceptance Requirements: All brands of plastic filter fabric and all seams to be used shall be accepted on the following basis. The Contractor shall furnish the Contracting Officer, in duplicate, a mill certificate or affidavit signed by a legally authorized official from the company manufacturing the fabric. The mill certificate or affidavit shall attest that the fabric meets the chemical, physical, and manufacturing requirements stated in this specification.

3.4 Securing Pins: Securing pins shall be 3/16-inch in diameter, of steel, pointed at one end and fabricated with a head to retain a steel washer having an outside diameter of no less than 1.5 inches. The lengths of the pins shall be no less than ___ inches.

NOTE: THE SECURING PINS SHOULD HAVE A MINIMUM LENGTH OF 18 INCHES WHEN USED IN SOILS HAVING A MEDIUM TO HIGH DENSITY. FOR LOOSE SOILS LONGER PINS SHOULD BE USED. SECURING PINS ARE NOT REQUIRED FOR ENCAPSULATED DRAINS, NOR UNDER CONCRETE SLABS.

4. SHIPMENT AND STORAGE: During all periods of shipment and storage, the fabric shall be protected from direct sunlight, ultraviolet rays, temperatures greater than 140°F, mud, dirt, dust, and debris. To the extent possible, the fabric shall be maintained wrapped in a heavy-duty protective covering.

5. INSTALLATION OF PLASTIC FILTER FABRIC: The plastic filter fabric shall be placed in the manner and at the locations shown on the drawings. At the time of installation, fabric shall be rejected if it has defects, rips, holes, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. The surface to receive fabric shall be prepared to a relatively smooth condition free of obstructions, depression, debris, and soft or low density pockets of material. The fabric shall be placed with the long dimension *(parallel) (perpendicular) to the *(centerline of the channel) (shoreline) (trench) and shall be laid smooth and free of tension, stress, folds, wrinkles, or creases. The strips shall be placed to provide a minimum width of ___ inches of overlap for each joint.

NOTE: MINIMUM OVERLAPS SHOULD BE SPECIFIED AT 12 TO 18 INCHES DEPENDING ON THE SPECIFIED ORIENTATION OF THE OVERLAP TO THE DIRECTION OF WAVE ATTACK. FOR UNDERWATER PLACEMENT, MINIMUM OVERLAP SHOULD BE 3 FEET.

Securing pins with washers shall be inserted through both strips of overlapped fabric at not greater than *(2-) (3-) (5-) foot intervals along a line through the midpoint of the overlap.

NOTE: THE MAXIMUM PIN SPACINGS SHOULD BE 2 FEET FOR SLOPES STEEPER THAN 1V ON 3H, 3 FEET FOR SLOPES OF 1V ON 3H TO 1V ON 4H, AND 5 FEET FOR SLOPES FLATTER THAN 1V ON 4H.

Additional pins regardless of location shall be installed as necessary to prevent any slippage of the filter fabric. The fabric shall be placed so that the *(upstream) (upper) strip of fabric will overlap the *(downstream) (next lower) strip. Each securing pin shall be pushed through the fabric until the washer bears against the fabric and secures it firmly to the foundation. The fabric shall be protected at all times during construction from contamination by surface runoff and any fabric so contaminated shall be removed and replaced with uncontaminated fabric. Any damage to the fabric during its installation or during placement of *(filter materials) (bedding materials) (riprap) shall be replaced by the Contractor at no cost to the Government. The work shall be scheduled so that the covering of the fabric with a layer of the specified material is accomplished within 30 days after placement of the fabric. Failure to comply shall require replacement of fabric. The filter fabric shall be protected from damage due to the placement of riprap or other materials by limiting the height of drop of the material or by placing a cushioning layer of sand on top of the fabric before dumping the material. Before placement of riprap, the Contractor shall demonstrate that the placement technique will prevent damage to the fabric.

NOTE: ALL FABRIC CAN BE DAMAGED IF STONE IS DROPPED ON IT FROM A HEIGHT GREATER THAN 3 FEET. SOME FABRIC CAN BE DAMAGED WITH LESSER DROP HEIGHTS. WHEN STONE IS HEAVY AND ANGULAR IT MAY CAUSE PUNCTURES IN THE FABRIC EVEN IF DROPPED FROM A HEIGHT OF 1 FOOT.

6. MEASUREMENT AND PAYMENT: Plastic filter fabric will be measured for payment by the *(square foot) (square yard) ("square" (100 square feet)) in place. Measurement will be by the nearest *(square foot) (square yard) ("square"). No allowance will be made for material in laps and seams. Payment therefor will be made at the contract unit price for "Plastic filter fabric," which price and payment shall constitute full compensation for furnishing all plant, labor, material, and equipment and performing all operations in connection with placing the plastic filter fabric complete. No measurement of nor payment for will be made for securing pins, and all costs incidental thereto shall be included in the contract unit price for "Plastic filter fabric." No measurement of nor payment for will be made for seams, and all costs incidental thereto shall be included in the contract unit price for "Plastic filter fabric." No measurement of nor payment for will be made for plastic filter fabric replaced because of either contamination or damage due to either fault or negligence of the Contractor. No measurement of nor payment for will be made for the material in and placement of a sand cushion layer placed to permit increase in the allowable drop height of stone, and all costs incidental thereto shall be included in the contract unit price for "Plastic filter fabric."

OPTIONAL PARAGRAPHS²¹ (TO BE ADDED AS NECESSARY)

DETERMINATION OF OPEN AREA: Each of five samples, unaged, shall be placed separately in a 2-inch by 2-inch glass slide holder and the image projected with a slide projector on a screen. A block of 25 openings near the center of the image shall be selected and the length and width of each of the 25 openings and the widths of the fibers adjacent to the openings shall be measured to the nearest 0.001 inch. The percent open area is determined by dividing the sum of the open areas of the 25 openings by the sum of the total area of the 25 openings and their adjacent fibers. The open area shall be not less than *(4) (___) percent and not more than *(36) (___) percent.

LOW TEMPERATURE TEST: Five warp and five fill samples, 4 ± 0.2 inches by 6 ± 0.2 inches, unaged, shall be placed in a refrigerator at

0 \pm 3°F for 48 \pm 2 hours; then each sample shall be tested at the test temperature using method ASTM D 1682. The strength in either principal direction shall not be less than 85 percent of the strength of unaged samples. The elongation at failure shall be between 8 and 40 percent.

BRITTLENESS: Five warp and five fill samples, unaged, shall be tested using method Corps of Engineers CRD-C 570 or method 5311.1 in Federal Standard 601. There shall be no failures at minus 60°F.

FREEZE-THAW TEST: Five warp and five fill samples, 4 \pm 0.2 inches by 6 \pm 0.2 inches, unaged, shall be subjected to 300 freeze-thaw cycles as described in test method Corps of Engineers CRD-C 20. Each cycle shall be of 2 hours \pm 4 minutes duration. Samples then shall be tested using method ASTM D 1682. The strength in either principal direction shall not be less than 90 percent of the strength of unaged samples. The elongation at failure shall be between 10 and 35 percent.

EFFECTS OF JP-4 FUEL TEST:³⁷ Five warp and five fill samples, 4 \pm 0.2 inches by 6 \pm 0.2 inches, unaged, shall be immersed in JP-4 fuel at room temperature for a period of seven days. Each sample then shall be tested using ASTM Method D 1682. The strengths of the cloths in the principal direction shall be no less than 85 percent of the respective strengths of the unaged cloths.

TABLE 2. MINIMUM UNAGED STRENGTH REQUIREMENTS FOR PLASTIC FILTER CLOTHS²³

Type Cloth**	Prestested Cloths	Tensile Strength, lb (ASTM D 1682)		Burst psi	Functure lb
		Stronger Principal Direction	Weaker Principal Direction		
A+	Poly-Filter X	350	220	510	125
	Erosion Control Fabric				
B+	Poly-Filter GB	200	200	610	125
C+	Nicolon 66411	180	100	250	65
	Filter X				

** Types A and B cloths are suitable for use beneath riprap when stone is dropped from heights not exceeding 3 feet. Type C cloth may be used when the riprap is hand placed, or when a cushioning layer of sand is placed on top of the cloth, or beneath flat concrete slabs.

+ Where cloths will be subjected to abrasive action, the strength loss after testing should not exceed 70 percent. Abraded strengths must be no less than 100 lb in the stronger principal direction and 55 lb in the weaker principal direction.

GUIDE SPECIFICATION
FOR
FILTER FABRIC USED AS A SILT FENCE⁷

1. SCOPE: The work under this section shall also include the furnishing and installation of filter fabric to brush barriers or fences at the locations shown and in conformity with the lines and grades shown on the drawings.

2. MATERIALS: Filter fabric shall be a pervious sheet of synthetic polymer. The fabric shall meet the following minimum requirements.

2.1 Water Permeability: 500 gallons/minute/square foot.

2.2 Bursting Strength: 200 psi when tested in accordance with ASTM D-231.

2.3 Trapezoid Tear Strength: 50 pounds when tested in accordance with ASTM D-2263.

2.4 Ultraviolet Degradation: 1 year with less than 25 percent loss of bursting and tear strength. This value may be varied based on the required length of service of the particular project.

2.5 Equivalent Opening Size (EOS): 70 minimum and 100 maximum. May be determined by designer based on expected grain size of sediment.

3. CONSTRUCTION REQUIREMENTS: Where brush barriers are shown on the drawings and filter fabric shall be laid over the fill slope face of the barrier. The bottom of the fabric shall be trenched into the existing ground a minimum of six (6) inches. The top of the fabric shall be tied, stapled, nailed or otherwise securely fastened to the side or top of the brush barrier. Intermediate attachment of the fabric shall be by suitable ties, staples, or nails. A twelve- (12-) inch overlap of fabric for vertical and horizontal piecing shall be maintained. Care must be exercised in securing the fabric to the brush barrier to avoid puncturing by protruding lines.

3.1 Measurement: The filter fabric shall be measured by the linear foot along the bottom of the brush barrier.

3.2 Fences on Drawing: Where fences are shown on the drawings and filter fabric identified to be used, the filter fabric shall be attached

to the fence by tying, stapling, nailing, or otherwise securely fastening to the top and midpoint of the fence. The bottom of the fabric shall be trenched into the existing ground a minimum of six (6) inches. Fabric shall be attached to the upslope side of the fence.

3.3 Composition of Fence: The fence shall be made of substantial wood or metal posts with 40-inch 14-gage hog wire securely attached to the upslope side of the posts. Posts shall be placed no more than eight (8) feet apart and braced where required to hold the sediment load.

3.4 Failure of Fence: When a silt fence is filled or fails, a second fence will be constructed immediately downstream of the filled or failed fence. Cost of replacement fences will be borne by the Contractor.

NOTE: SOMETIMES AT THE BOTTOM OF A CHANNEL WHERE THE WATER CONCENTRATES, IT IS ALSO NECESSARY TO PROVIDE AN ENERGY DISSIPATOR SUCH AS STAKED-DOWN BALES OF STRAW.

GUIDE SPECIFICATION
FOR
FILTER FABRIC USED IN TRENCH DRAINS²⁰

Instructions

1. This guide specification is to facilitate the preparation and review of specifications for the procurement and installation of woven and nonwoven plastic filter fabric. It has been developed based on limited field performance observations and the laboratory test evaluation of a limited number of currently available fabric types. An increasing number of filter fabrics are becoming commercially available that are not only economically competitive, but also possess greatly varying engineering properties and physical characteristics. It is therefore necessary that the burden of acceptance of specific fabric types rest with the designer, and that each design application be given critical study to determine a particular fabric's engineering suitability for use. The EOS and gradient ratio filter design tests, which are described in the instructions that follow, are physical property and performance type tests, respectively, that along with the strength requirements given in Table 1, should provide a basis with which to judge the acceptability of a particular fabric for use. The designer should require prospective fabric suppliers to furnish these test results before their fabric will be considered for use, or before contract specifications are adjusted to permit the use of fabrics with properties outside the limits imposed by this guide. In addition, the designer should perform EOS and gradient ratio tests before contract advertising on at least two commercially available fabrics to serve as a basis for the estimate of cost, and to assure that there are fabrics that will satisfy the requirements of the specifications. Further, specifications should require that EOS and gradient ratio tests be run during construction, either at a specified frequency or upon demand of the Contracting Officer, as part of the Contractor's quality control requirements.

2. The actual life of these fabrics is not known, and their use in inaccessible areas must be considered carefully. Filter fabrics should not be used to wrap piezometer screens or as filter material within or on the upstream face of earth dams, or within any portion of the embankment.

3. Filter design criteria for plastic filter fabrics are based on the "equivalent opening size" (EOS) and "gradient ratio." The EOS is defined as the number of the U. S. Standard sieve having openings closest in size to the filter fabric openings. The gradient ratio is the ratio of the seepage gradient through the fabric and 1 inch of soil to the gradient through 2 inches of soil specimen. The gradient ratio, determined as described below, should not exceed 3.

a. Determination of Equivalent Opening Size (EOS). Five unaged fabric samples shall be tested. Obtain 50 grams of each of the following fractions of standard glass beads:

U. S. Standard Sieve Number

<u>Designated EOS</u>	<u>Passing</u>	<u>Retained On</u>	<u>Designated EOS</u>	<u>Passing</u>	<u>Retained On</u>
20	18	20	70	60	70
30	25	30	100	80	100
40	35	40	120	100	120
50	45	50			

Suitable glass beads can be obtained from:

Cataphote Division
 Ferro Corporation
 P. O. Box 2369
 Jackson, Mississippi 39205
 Telephone: (601) 939-4631

Within each size range, 95 percent of the beads should be within the specified range. The fabric shall be affixed to a standard sieve 8 inches in diameter having openings larger than the largest beads to be used in the test. The fabric shall be attached to the sieve in such a manner that no beads can pass between the fabric and the sieve wall. Shaking shall be accomplished as described in paragraph 2d(1)(g), Appendix V, EM 1110-2-1902, U. S. Army Corps of Engineers, except the

times for shaking shall be 20 minutes. Determine by sieving (using successively coarser fractions) that size of beads of which five percent or less by weight passes through the fabric; the equivalent opening size, EOS, of the fabric sample is the "retained on" U. S. Standard Sieve number of this fraction.

b. Determination of Gradient Ratio. A constant head permeability test shall be performed in a permeameter cylinder on soil specimens representative in classification and density of those materials to be protected, and in accordance with EM 1110-2-1906, Appendix VII, U. S. Army Corps of Engineers, with the following modifications:

(1) A piece of hardware cloth with 1/4-inch openings shall be placed beneath the filter fabric specimen to support it. The fabric and the hardware cloth shall be clamped between flanges so that no soil nor water can pass around the edges of the cloth.

(2) The soil specimen shall have a length of 4 inches. Piezometer taps shall be placed 1 inch below the fabric, and 1, 2, and 3 inches above the fabric.

(3) Tap water shall be permeated through the specimen under a constant head loss for a continuous period of 24 hours. The tailwater level shall be above the top of the soil specimen. The gradient ratio shall be determined from the readings taken at the end of the 24-hour period.

(4) The gradient ratio is the ratio of the hydraulic gradient over the fabric and the 1 inch of soil immediately next to the fabric, i_1 , to the hydraulic gradient over the 2 inches of soil between 1 and 3 inches above the fabric, i_2 .

$$G. R. = i_1/i_2$$

4. It is the responsibility of the designer to specify filter fabric that retains the soil being protected, yet will have openings large enough to permit drainage and prevent clogging. The designer should select the "equivalent opening sizes" based on the following criteria:

a. Filter fabric adjacent to granular materials containing 50 percent or less by weight fines (minus No. 200 materials):

$$\frac{85 \text{ percent passing size of soil}}{\text{opening size of EOS sieve}} \geq 1$$

b. Filter fabrics adjacent to all other type soils:

EOS no larger than the openings in the U. S. Standard Sieve No. 70 (0.0083 inch).

To reduce the chance of clogging, no fabric should be specified with an EOS smaller than the openings of a U. S. Standard Sieve Size No. 100 (0.0059 inch). When possible, it is preferable to specify a fabric with openings as large as allowed by the criteria. Filter fabrics should not be used for soils with 85 percent or more smaller than the No. 200 sieve.

5. Capitalized instructional notes to the Contracting Officer will be deleted for the text of the contract specification.

6. Standards and other specifications referenced in this guide specification should be checked for obsolescence and for dates and applicability of amendments and revisions issued subsequent to the publication of this guide specification.

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AND WILL NOT BE INCLUDED IN CONTRACT SPECIFICATIONS.

GUIDE SPECIFICATION
FOR
FILTER FABRIC USED IN TRENCH DRAINS²⁰

SECTION ____
PLASTIC FILTER FABRIC

1. SCOPE: The work provided for herein consists of furnishing all plant, labor, material, and equipment and performing all operations required for furnishing, hauling, and placing the plastic filter fabric, complete, as specified herein and shown on the contract drawings, and maintaining the plastic filter fabric until placement of the *(filter material) (bedding material) (riprap) cover is completed and accepted.

2. APPLICABLE PUBLICATIONS: The following publications of the current issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the references thereto:

American Society for Testing and Materials (ASTM)

D 751-73	Testing Coated Fabrics
D 1175-71	Abrasion Resistance of Textile Fabrics
D 1682-64	Breaking Load and Elongation of Textile Fabrics
D 1683-68	Seam Breaking Strength of Woven Textile Fabrics

3. MATERIALS:

3.1 Fabric: Plastic filter fabric shall be a pervious sheet of plastic yarn. The plastic filter fabric shall provide an Equivalent Opening Size (EOS) no finer than the U. S. Standard Sieve No. ____ and no coarser than the U. S. Standard Sieve No. ____.

* A SINGLE ASTERISK THROUGHOUT THIS GUIDE INDICATES THAT INAPPLICABLE PROVISIONS ARE TO BE DELETED.

NOTE: SEE PARAGRAPHS 3 AND 4 IN THE INSTRUCTIONS FOR HOW TO DETERMINE AND SELECT THE EOS. IF THE CONTRACTOR QUALITY CONTROL IS TO BE RESPONSIBLE FOR EOS, THE TEST PROCEDURES IN PARAGRAPH 3a OF THE INSTRUCTIONS SHOULD BE IN THE CONTRACT SPECIFICATION.

The plastic yarn shall consist of a long-chain synthetic polymer composed of at least 85 percent by weight of propylene, ethylene, ester, amide or vinylidene-chloride, and shall contain stabilizers and/or inhibitors added to the base plastic if necessary to make the filaments resistant to deterioration due to ultraviolet and heat exposure. The fabric shall conform to the physical strength requirements in Table 1. The fabric should be fixed so that the yarns will retain their relative position with respect to each other. The edges of the fabric shall be finished to prevent the outer yarn from pulling away from the fabric.

*(The fabric shall be manufactured into a width not less than ___ feet.)

NOTE: MOST FABRICS ARE MANUFACTURED IN WIDTHS OF 6 FEET, BUT TO REDUCE THE NUMBER OF OVERLAPS, WIDER SECTIONS MAY BE PRODUCED BY ATTACHING NARROW SECTIONS TOGETHER. PREASSEMBLED SECTIONS OF 36-FOOT WIDTHS OR MORE ARE PREFERRED TO KEEP THE NUMBER OF OVERLAPS TO A MINIMUM.

If requested by the Contracting Officer, the Contractor shall provide to the Government plastic filter fabric samples for testing to determine compliance with any or all of the requirements in this specification. When samples are to be provided, they shall be submitted a minimum of *(60) days prior to the beginning of installation of the same plastic filter fabric material.

3.2 Seams: The seams of the fabric shall be sewn with thread of a material meeting the chemical requirements given above for plastic yarn or shall be bonded by cementing or by heat. The sheets of filter fabric shall be attached at the factory or another approved location to form sections not less than ___ feet wide. Seams shall be tested in accordance with method ASTM D 1683, using 1-inch square jaws and 12 inches per minute constant rate of traverse. The strengths shall be not less than 90 percent of the required tensile strength (Table 1) of the unaged fabric in any principal direction.

TABLE 1. PHYSICAL STRENGTH REQUIREMENTS

Physical Property	Test Procedure	Acceptable Test Results
Tensile Strength **(unaged fabric)	ASTM D 1682 Grab Test Method using 1-inch square jaws and a travel rate of 12 inches per minute.	100-pound minimum in any principal direction.
Puncture Strength **(unaged fabric)	ASTM D 751 Tension Testing Machine with Ring Clamp; steel ball replaced with a 5/16-inch-diameter solid steel cylinder with a hemispherical tip centered within the ring clamp.	40-pound minimum.
Abrasion Resistance	ASTM D 1682, as above, after abraded as in ASTM D 1175 Rotary Platform, Double Head Method; rubber-base abrasive wheels equal to CS-17 "Calibrase" by Taber Instrument Co.; 1 kilogram load per wheel; 1000 revolutions.	**55-pound minimum in any principal direction.

** Unaged fabric is defined as fabric in the condition received from the manufacturer or distributor.
 + Note: This requirement may be deleted for installations not subject to excessive movement or aggregate on the fabric.

3.3 Acceptance Requirements: All brands of plastic filter fabric and all seams to be used shall be accepted on the following basis. The Contractor shall furnish the Contracting Officer, in duplicate, a mill certificate or affidavit signed by a legally authorized official from the company manufacturing the fabric. The mill certificate or affidavit shall attest that the fabric meets the chemical, physical, and manufacturing requirements stated in this specification.

3.4 Securing Pins: Securing pins shall be 3/16-inch in diameter, of steel, pointed at one end and fabricated with a head to retain a steel washer having an outside diameter of no less than 1.4 inches. The lengths of the pins shall be no less than inches.

NOTE: THE SECURING PINS SHOULD HAVE A MINIMUM LENGTH OF 18 INCHES WHEN USED IN SOILS HAVING A MEDIUM TO HIGH DENSITY. FOR LOOSE SOILS LONGER PINS SHOULD BE USED. SECURING PINS ARE NOT REQUIRED FOR ENCAPSULATED DRAINS, NOR UNDER CONCRETE SLABS.

4. SHIPMENT AND STORAGE: During all periods of shipment and storage, the fabric shall be protected from direct sunlight, ultra-violet rays, temperatures greater than 140°F, mud, dirt, dust, and debris. To the extent possible, the fabric shall be maintained wrapped in a heavy-duty protective covering.

5. INSTALLATION OF PLASTIC FILTER FABRIC: The plastic filter fabric shall be placed in the manner and at the locations shown on the drawings. At the time of installation, fabric shall be rejected if it has defects, rips, holes, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. The surface to receive fabric shall be prepared to a relatively smooth condition free of obstructions, depressions, debris, and soft or low density pockets of material.

5.1 Trench Lining and Overlaps: Trenches to be lined with filter fabric shall be graded to obtain relatively smooth side and bottom surfaces so that the fabric will not bridge cavities in the soil or be damaged by projecting rock. The fabric shall be laid flat, but not stretched on the soil. The fabric shall be placed with the long dimension parallel to the trench and shall be laid relatively smooth and free

of tension and excessive stress, folds, wrinkles, or creases. The filter fabric shall be installed in such a manner that all splice joints are provided with a minimum overlap of two (2) feet. The closure of the fabric at the top of the trench shall be such as to provide two thicknesses of fabric over the top of the trench firmly secured with mechanical ties. Where outlet pipe passes through the fabric, a separate piece of fabric of sufficient size to be wrapped around the pipe and flared against the side of the filled drain fabric shall be used.

5.2 Overlaps on Pipes: One layer of filter fabric shall be wrapped around perforated or slotted collector pipes in such a manner that longitudinal overlaps of fabric are in unperforated or unslotted quadrants of the pipes. The overlap shall be about 2 inches. The fabric shall be secured to the pipe in such a manner that backfill material will not infiltrate through any fabric overlaps.

5.3 Joints: One layer of filter fabric shall be wrapped around open pipe joints. The overlap should be about 2 inches. The fabric shall be secured to the pipe in such a manner that backfill material will not infiltrate through the overlap or the edges of the fabric to either side of the joint. Field splices of filter fabric shall be anchored with securing pins as directed to insure the required overlap is maintained. Care shall be taken during the aggregate filler placement operation as well as the pipe installation, when required, to prevent damage to the filter fabric. The aggregate filler shall be compacted by the use of a vibratory compactor to the satisfaction of the Engineer before making the filter fabric closure at the top of the trench. Pins shall be installed as necessary to prevent slippage of the filter fabric. Each securing pin shall be pushed through the fabric until the washer bears against the fabric and secures it firmly to the foundation. The fabric shall be protected at all times during construction from contamination by surface runoff, and any fabric so contaminated shall be removed and replaced with uncontaminated fabric. Any damage to the fabric during its installation or during placement of *(filter materials) (bedding materials) shall be replaced by the Contractor at no cost to the Government. The work shall be scheduled so that the covering

of the fabric with a layer of the specified material is accomplished within 30 days after placement of the fabric. Failure to comply shall require replacement of fabric. The completed aggregate filled underdrain line requires the capping of the underdrain trench with a layer of selected material to a depth specified by plan details. The placement and compaction of this layer shall be by a method acceptable to the Engineer. The furnishing, placing, and compaction of the capping material are considered incidental to construction of the underdrain line; hence, no additional compensation will be allowed for it.

6. MEASUREMENT AND PAYMENT: Plastic filter fabric will be measured for payment by linear feet of trench in place. Measurement will be to the nearest foot. No allowance will be made for material in laps and seams. Payment therefor will be made at the contract unit price for "Plastic filter fabric," which price and payment shall constitute full compensation for furnishing all plant, labor, material, and equipment and performing all operations in connection with placing the plastic filter fabric complete. No measurement of nor payment for will be made for securing pins, and all costs incidental thereto shall be included in the contract unit price for "Plastic filter fabric." No measurement of nor payment for will be made for plastic filter fabric replaced because of either contamination or damage due to either fault or negligence of the Contractor.

OPTIONAL PARAGRAPHS²¹ (TO BE
ADDED AS NECESSARY)

DETERMINATION OF OPEN AREA: Each of five samples, unaged, shall be placed separately in a 2-inch by 2-inch glass slide holder and the image projected with a slide projector on a screen. A block of 25 openings near the center of the image shall be selected and the length and width of each of the 25 openings and the widths of the fibers adjacent to the openings shall be measured to the nearest 0.001 inch. The percent open area is determined by dividing the sum of the open areas of the 25 openings by the sum of the total area of the 25 openings and their adjacent fibers. The open area shall be not less than *(4) () percent and not more than *(36) () percent.

LOW TEMPERATURE TEST: Five warp and five fill samples, 4 ± 0.2 inches by 6 ± 0.2 inches, unaged, shall be placed in a refrigerator at $0 \pm 3^\circ\text{F}$ for 48 ± 2 hours; then each sample shall be tested at the test temperature using method ASTM D 1682. The strength in either principal direction shall not be less than 85 percent of the strength of unaged samples. The elongation at failure shall be between 8 and 40 percent.

BRITTLENESS: Five warp and five fill samples, unaged, shall be tested using method Corps of Engineers CRD-C 570 or method 5311.1 in Federal Standard 601. There shall be no failures at minus 60°F .

FREEZE-THAW TEST: Five warp and five fill samples, 4 ± 0.2 inches by 6 ± 0.2 inches, unaged, shall be subjected to 300 freeze-thaw cycles as described in test method Corps of Engineers CRD-C 20. Each cycle shall be of 2 hours ± 4 minutes duration. Samples then shall be tested using method ASTM D 1682. The strength in either principal direction shall not be less than 90 percent of the strength of unaged samples. The elongation at failure shall be between 10 and 35 percent.

EFFECTS OF JP-4 FUEL TEST:³⁷ Five warp and five fill samples, 4 ± 0.2 inches by 6 ± 0.2 inches, unaged, shall be immersed in JP-4 fuel at room temperature for a period of seven days. Each sample then shall be tested using ASTM Method D 1682. The strengths of the cloths in the principal direction shall be no less than 85 percent of the respective strengths of the unaged cloths.

NOTE: WHEN FILTER FABRIC IS USED TO WRAP COLLECTOR PIPES, PERMANENT DEVICES TO SECURE THE FABRIC TO THE PIPE ARE NOT NEEDED SINCE THE FABRIC WILL BE HELD IN PLACE BY THE BACKFILL MATERIAL ONCE THE INSTALLATION IS COMPLETED. FILTER FABRIC HAS BEEN SATISFACTORILY SECURED TO PIPES WITH TAPE OR STRING PLACED AT ABOUT 1-FOOT INTERVALS ALONG THE OVERLAP. THE FREE ENDS OF THE FABRIC HAVE BEEN FOLDED AND STAPLED. PREFABRICATED FILTER FABRIC SHEATHS HAVE ALSO BEEN USED SUCCESSFULLY. THE SEAMS FOR SUCH SHEATHS NEED NOT BE SEWN WITH A PERMANENT TYPE OF THREAD.

GUIDE SPECIFICATION
FOR
FILTER FABRIC USED FOR SEPARATION²⁰

SECTION ___
PLASTIC FILTER FABRIC

1. SCOPE: The work provided for herein consists of furnishing all plant, labor, material, and equipment and performing all operations required for furnishing, hauling, and placing the plastic filter fabric, complete, as specified herein and shown on the contract drawings, and maintaining the plastic filter fabric until placement of the *(filter material) (bedding material) (riprap) cover is completed and accepted.

2. APPLICABLE PUBLICATIONS: The following publications of the current issues listed below, but referred to thereafter by basic designation only, form a part of this specification to the extent indicated by the references thereto:

American Society for Testing and Materials (ASTM)

D 751-73	Testing Coated Fabrics
D 1175-71	Abrasion Resistance of Textile Fabrics
D 1682-64	Breaking Load and Elongation of Textile Fabrics
D 1683-68	Seam Breaking Strength of Woven Textile Fabrics

3. MATERIALS:

3.1 Fabric: Plastic filter fabric shall be a pervious sheet of plastic yarn. The plastic filter fabric shall provide an Equivalent Opening Size (EOS) no finer than the U. S. Standard Sieve No. ___ and no coarser than the U. S. Standard Sieve No. ___.

NOTE: SEE PARAGRAPHS 3 AND 4 IN THE INSTRUCTIONS FOR SLOPE PROTECTION FOR HOW TO DETERMINE AND SELECT THE EOS. IF THE CONTRACTOR QUALITY CONTROL IS TO BE RESPONSIBLE FOR EOS, THE TEST PROCEDURES IN PARAGRAPH 3a OF THE INSTRUCTIONS SHOULD BE IN THE CONTRACT SPECIFICATION.

* A SINGLE ASTERISK THROUGHOUT THIS GUIDE INDICATES THAT INAPPLICABLE PROVISIONS ARE TO BE DELETED.

The plastic yarn shall consist of a long-chain synthetic polymer composed of at least 85 percent by weight of propylene, ethylene, ester, amide, or vinylidene-chloride, and shall contain stabilizers and/or inhibitors added to the base plastic if necessary to make the filaments resistant to deterioration due to ultraviolet and heat exposure. The fabric shall conform to the physical strength requirements in Table 1. The fabric should be fixed so that the yarns will retain their relative position with respect to each other. The edges of the fabric shall be finished to prevent the outer yarn from pulling away from the fabric.

*(The fabric shall be manufactured into a width not less than ___ feet.)

NOTE: MOST FABRICS ARE MANUFACTURED IN WIDTHS OF 6 FEET, BUT TO REDUCE THE NUMBER OF OVERLAPS, WIDER SECTIONS MAY BE PRODUCED BY ATTACHING NARROW SECTIONS TOGETHER. PREASSEMBLED SECTIONS OF 36-FOOT WIDTHS OR MORE ARE PREFERRED TO KEEP THE NUMBER OF OVERLAPS TO A MINIMUM.

If requested by the Contracting Officer, the Contractor shall provide to the Government plastic filter fabric samples for testing to determine compliance with any or all of the requirements in this specification. When samples are to be provided, they shall be submitted a minimum of *(60) days prior to the beginning of installation of the same plastic filter fabric material.

3.2 Seams: The seams of the fabric shall be sewn with thread of a material meeting the chemical requirements given above for plastic yarn or shall be bonded by cementing or by heat. The sheets of filter fabric shall be attached at the factory or another approved location to form sections not less than ___ feet wide. Seams shall be tested in accordance with method ASTM D 1683, using 1-inch square jaws and 12 inches per minute constant rate of traverse. The strengths shall be not less than 90 percent of the required tensile strength (Table 1) of the unaged fabric in any principal direction.

3.3 Acceptance Requirements: All brands of plastic filter fabric and all seams to be used shall be accepted on the following basis. The Contractor shall furnish the Contracting Officer, in duplicate, a mill certificate or affidavit signed by a legally authorized official from the company manufacturing the fabric. The mill certificate or affidavit

TABLE 1. PHYSICAL STRENGTH REQUIREMENTS

Physical Property	Test Procedure	Acceptable Test Results
Tensile Strength **(unaged fabric)	ASTM D 1682 Grab Test Method using 1-inch square jaws and a travel rate of 12 inches per minute.	100-pound minimum in any principal direction.
Puncture Strength **(unaged fabric)	ASTM D 751 Tension Testing Machine with Ring Clamp; steel ball replaced with a 5/16-inch-diameter solid steel cylinder with a hemispherical tip centered within the ring clamp.	40-pound minimum.
Abrasion Resistance	ASTM D 1682, as above, after abraded as in ASTM D 1175 Rotary Platform, Double Head Method; rubber-base abrasive wheels equal to CS-17 "Calibrase" by Taber Instrument Co.; 1 kilogram load per wheel; 1000 revolutions.	+55-pound minimum in any principal direction.

** Unaged fabric is defined as fabric in the condition received from the manufacturer or distributor.
 + Note: This requirement may be deleted for installations not subject to excessive movement of aggregate on the fabric.

shall attest that the fabric meets the chemical, physical, and manufacturing requirements stated in this specification.

3.4 Securing Pins: Securing pins shall be 3/16-inch in diameter, of steel, pointed at one end and fabricated with a head to retain a steel washer having an outside diameter of no less than 1.5 inches. The lengths of the pins shall be no less than ___ inches.

NOTE: THE SECURING PINS SHOULD HAVE A MINIMUM LENGTH OF 18 INCHES WHEN USED IN SOILS HAVING A MEDIUM TO HIGH DENSITY. FOR LOOSE SOILS LONGER PINS SHOULD BE USED.

4. SHIPMENT AND STORAGE: During all periods of shipment and storage, the fabric shall be protected from direct sunlight, ultra-violet rays, temperatures greater than 140°F, mud, dirt, dust, and debris. To the extent possible, the fabric shall be maintained wrapped in a heavy-duty protective covering.

5. CONSTRUCTION METHODS: Clearing and grubbing and necessary excavation shall be completed prior to placement of the fabric. Filter fabric shall be spread uniformly over the surface as shown on the drawings. Fabric shall be unrolled directly on the soil surface to the line and dimensions shown on the drawings. Filter fabric shall be lapped a minimum of twelve (12) inches in all directions. The Contractor shall place the fill or base material in such a way as not to tear, puncture, or shift the filter fabric. Tears or rips in the filter fabric shall be patched with fabric lapped a minimum of twelve (12) inches around the rip. Tracked or wheeled equipment shall not be permitted on the filter fabric covered subgrade. Fill or base material shall be placed on the prepared area in a manner that will produce a reasonably well compacted soil mass. Fill or base material shall be placed to its full thickness in multiple operations and in such a manner as to avoid displacing the filter fabric and the underlying material. Filter fabric shall not be placed on stumps, roots, brush, limbs, or other materials that likely will tear or puncture the fabric. Grubbed area shall be reasonably smooth and clean of debris. The finished surface shall be reasonably uniform and regular, free from humps and

depressions, with slopes not steeper than shown on the drawings, or staked on the ground.

6. METHOD OF MEASUREMENT: The filter fabric shall be measured by the area covered to the nearest square yard.

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