MIRAFI®

geotextile filter design, application, and product selection guide

Marine & Transportation Engineering

Ten Cate Nicolon

MIRAFI®

GEOTEXTILE FILTER DESIGN, APPLICATION, AND PRODUCT SELECTION GUIDE

Drainage and Erosion Control Applications

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INTRODUCTION AND EXPLANATION OF THE PROBLEM

Drainage

Aggregate trench and blanket drains are commonly used to drain water from surrounding soils or waste materials. These drains are typically installed less than three feet deep. They may be at greater depths in situations where there is a need to significantly lower the groundwater table or to drain leachate.

In loose or gap graded soils, the groundwater flow can carry soil particles toward the drain. These migrating particles can clog drainage systems.

Erosion Control

Stone and concrete revetments are often used on waterway slopes to resist soil erosion. These armored systems, when placed directly on the soil, have not sufficiently prevented erosion. Fluctuating water levels cause seepage in and out of embankment slopes resulting in the displacement of fine soil particles.

As with trench drains, these fine soil particles are carried away with receding flows. This action eventually leads to undermining of the armor system.

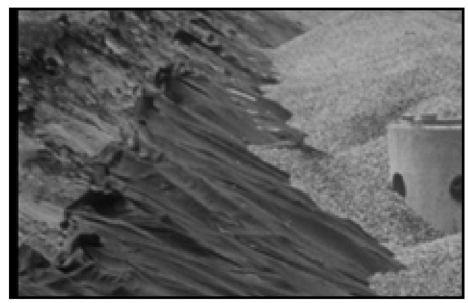
Typical Solutions

Specially graded fill material which is intended to act as a soil filter is frequently placed between the drain or revetment and the soil to be protected. This graded filter is often difficult to obtain, expensive to purchase, time consuming to install and segregates during placement, thus compromising its filtration ability.

Drainage

Geotextile filters retain soil particles while allowing seeping water to drain freely. Fine soil particles are prevented from clogging drainage systems.

Erosion Control



Geotextile filters retain soil particles while allowing water to pass freely. Buildup of hydrostatic pressures in protected slopes is prevented, thus enhancing slope stability.

THE MIRAFI® SOLUTION

Filtration geotextiles provide alternatives to graded filters.

Designing with Geotextile Filters

Geotextiles are frequently used in armored erosion control and drainage applications. Some of the most common applications include slopes, dam embankments/spilllways, shorelines armored with riprap, flexible block mats and concrete filled fabric formed systems. Drainage applications include pavement edge drains, french drains, prefabricated drainage panels and leachate collection/leak detection systems.

In all of the above applications, geotextiles are used to retain soil particles while allowing liquid to pass freely. But the fact that geotextiles are widely used where their primary function is filtration, there remains much confusion about proper filtration design procedures.

For this reason, Mirafi® commissioned Geosyntec Consultants, Inc. to develop a generic *Geotextile Filter Design Manual.* The manual offers a systematic approach to solving most common filtration design problems. It is available to practicing designers exclusively through Mirafi®. This *Geotextile Filter Design, Application, and Product Selection Guide* is excerpted from the manual.

Mechanisms of Filtration

A filter should prevent excessive migration of soil particles, while at the same time allowing liquid to flow freely through the filter layer. Filtration is therefore summarized by two seemingly conflicting requirements.

- The filter must retain soil, implying that the size of filter pore spaces or openings should be smaller than a specified maximum value; and
- The filter must be permeable enough to allow a relatively free flow through it, implying that the size of filter pore spaces and number of openings should be larger than a specified minimum value.

Geotextile Filter Requirements

Before the introduction of geotextiles, granular materials were widely used as filters for geotechnical engineering applications. Drainage criteria for geotextile filters is largely derived from those for granular filters. The criteria for both are, therefore, similar.

In addition to retention and permeability criteria, several other considerations are required for geotextile filter design. Some considerations are noted below:

- **Retention:** Ensures that the geotextile openings are small enough to prevent excessive migration of soil particles.
- **Permeability:** Ensures that the geotextile is permeable enough to allow liquids to pass through without causing significant upstream pressure buildup.
- **Anti-clogging:** Ensures that the geotextile has adequate openings, preventing trapped soil from clogging openings and affecting permeability.
- **Survivability:** Ensures that the geotextile is strong enough to resist damage during installation.
- **Durability:** Ensures that the geotextile is resilient to adverse chemical, biological and ultraviolet (UV) light exposure for the design life of the project.

The specified numerical criteria for geotextile filter requirements depends on the application of the filter, filter boundary conditions, properties of the soil being filtered, and construction methods used to install the filter. These factors are discussed in the following step-by-step geotextile design methodology

SYSTEMATIC DESIGN APPROACH

Design Methodology

The proposed design methodology represents years of research and experience in geotextile filtration design. The approach presents a logical progression through seven steps.

Step 1: Define the Application Filter Requirements

Step 2: Define Boundary Conditions

Step 3: Determine Soil Retention Requirements

Step 4: Determine Permeability Requirements

Step 5: Determine Anti-Clogging Requirements

Step 6: Determine Survivability Requirements

Step 7: Determine Durability Requirements

STEP ONE:

DEFINE APPLICATION FILTER REQUIREMENTS

Geotextile filters are used between the soil and drainage or armoring medium. Typical drainage media include natural materials such as gravel and sand, as well as geosynthetic materials such as geonets and cuspated drainage cores. Armoring material is often riprap or concrete blocks. Often, an armoring system includes a sand bedding layer beneath the surface armor. The armoring system can be considered to act as a "drain" for water seeping from the protected slope.

Identifying the Drainage Material

The drainage medium adjacent to the geotextile must be identified. The primary reasons for this include:

- Large voids or high pore volume can influence the selection of the retention criterion
- Sharp contact points such as highly angular gravel or rock will influence the geosynthetic survivability requirements.

Retention vs. Permeability Trade-Off

The drainage medium adjacent to the geotextile often affects the selection of the retention criterion. Due to the conflicting nature of filter requirements, it is necessary to decide whether retention or permeability is the favored filter characteristic.

For example, a drainage material that has relatively little void volume (i.e., a geonet or a wick drain) requires a high degree of retention from the filter. Conversely, where the drainage material void volume is large (i.e., a gravel trench or riprap layer), the permeability and anti-clogging criteria are favored.

STEP TWO:

DEFINE BOUNDARY CONDITIONS

Evaluate Confining Stress

The confining pressure is important for several reasons:

- High confining pressures tend to increase the relative density of coarse grained soil, increasing the soil's resistance to particle movement. This affects the selection of retention criteria.
- High confining pressures decrease the hydraulic conductivity of fine grained soils, increasing the potential for soil to intrude into, or through, the geotextile filter.
- For all soil conditions, high confining pressures increase the potential for the geotextile and soil mass to intrude into the flow paths. This can reduce flow capacity within the drainage media, especially when geosynthetic drainage cores are used.

Define Flow Conditions

Flow conditions can be either steady-state or dynamic. Defining these conditions is important because the retention criteria for each is different. Examples of applications with steady-state flow conditions include standard dewatering drains, wall drains and leachate collection drains. Inland waterways and shoreline protection are typical examples of applications where waves or water currents cause dynamic flow conditions.

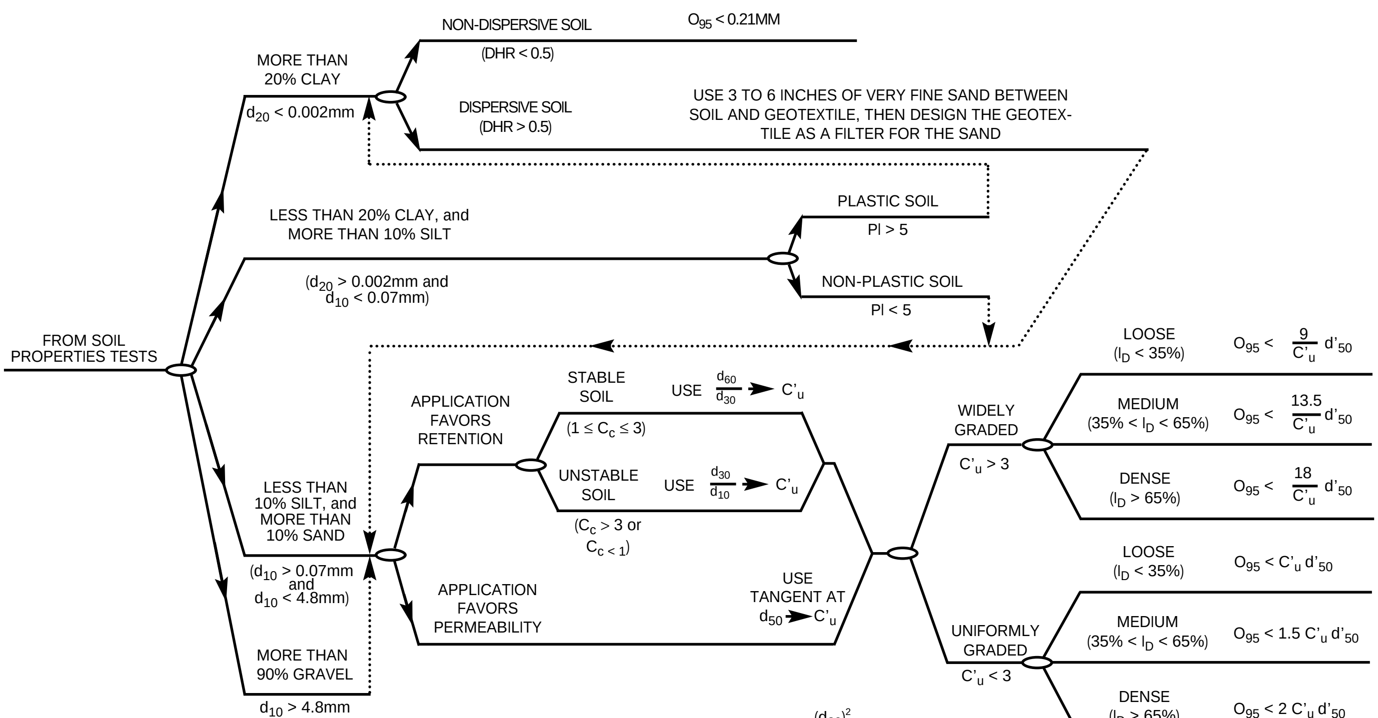
STEP THREE:

DETERMINE SOIL RETENTION REQUIREMENTS

Charts 1 and 2 indicate the use of particle-size parameters for determing retention criteria. These charts show that the amount of gravel, sand, silt and clay affects the retention criteria selection process. Chart 1 shows the numerical retention criteria for steady-state flow conditions; Chart 2 is for dynamic flow conditions.

For predominantly coarse grained soils, the grain-size distribution curve is used to calculate specific parameters such as C_u, C'_u, C_c, that govern the retention criteria.

Chart 1. Soil Retention Criteria of Steady-State Flow Conditions



NOTES:

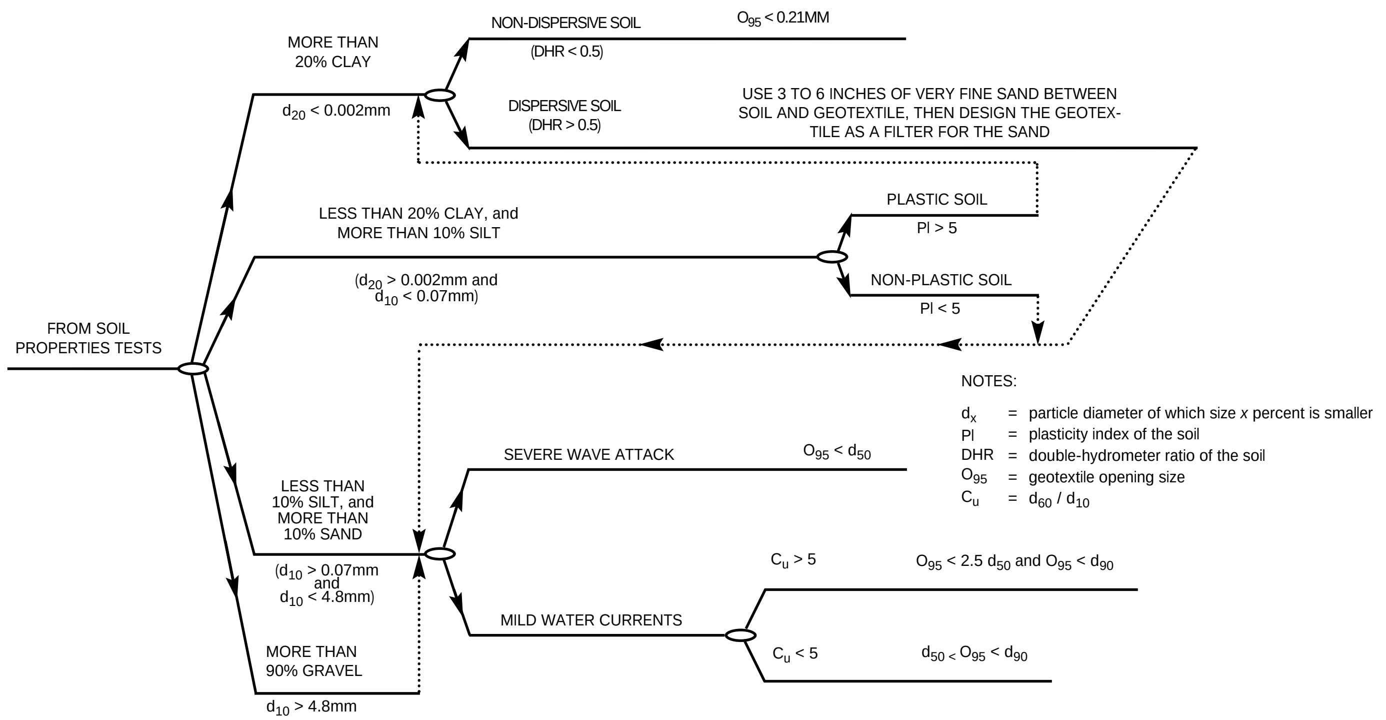
d_x = particle diameter of which size x percent is smaller

$C'_u = \sqrt{\dfrac{d'_{100}}{d'_0}}$ where: d'_{100} and d'_0 are the extremeties of a straight line drawn through the particle-size distribution, as directed above and d'_{50} is the midpoint of this line

$$C_c = \frac{(d_{30})^2}{d_{60} \times d_{10}}$$

I_D = relative density of the soil
PI = plasticity index of the soil
DHR = double-hydrometer ratio of the soil
O_{95} = geotextile opening size

Chart 2. Soil Retention Criteria of Dynamic Flow Conditions



Analysis of the soil to be protected is critical to proper filtration design.

Define Soil Particle-Size Distribution

The particle-size distribution of the soil to be protected should be determined using test method ASTM D 422. The grain size distribution curve is used to determine parameters necessary for the selection of numerical retention criteria.

Define Soil Atterberg Limits

For fine-grained soils, the plasticity index (PI) should be determined using the Atterberg Limits test procedure (ASTM D 4318). Charts 1 and 2 show how to use the PI value for selecting appropriate numerical retention criteria.

Determine the Maximum Allowable Geotextile Opening Size (O_{95})

The last step in determining soil retention requirements is evaluating the maximum allowable opening size (O_{95}) of the geotextile which will provide adequate soil retention. The O_{95} is also known as the geotextile's Apparent Opening Size (AOS) and is determined from test procedure ASTM D 4751. AOS can often be obtained from manufacturer's literature.

STEP FOUR:

DETERMINE GEOTEXTILE PERMEABILITY REQUIREMENTS

Define the Soil Hydraulic Conductivity (k_s)

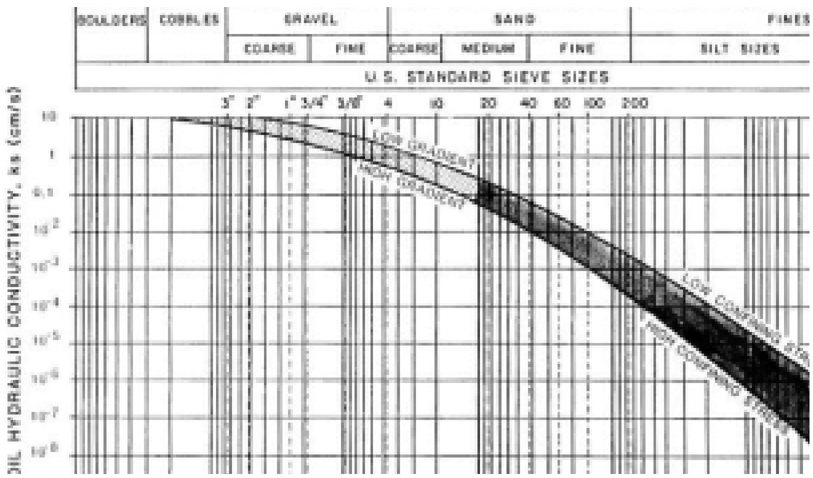
Determine the soil hydraulic conductivity, often referred to as permeability, using one of the following methods:

- For critical applications, such as earth dams, soil permeability should be lab measured using representative field conditions in accordance with test procedure ASTM D 5084.
- For non-critical applications, estimate the soil-hydraulic conductivity using the characteristic grain diameter d_{15}, of the soil (see Figure 2 on the following page).

STEP FOUR:

DETERMINE GEOTEXTILE PERMEABILITY REQUIREMENTS
(continued)

Figure 2. Typical Hydraulic Conductivity Values



Define the Hydraulic Gradient for the Application (i_s)

The hydraulic gradient will vary depending on the filtration application. Anticipated hydraulic gradients for various applications may be estimated using Table 1 below.

Table 1. Typical Hydraulic Gradients[a]

Drainage Applications	Typical Hydraulic Gradient
Channel Lining	1.0
Standard Dewatering Trench	1.0
Vertical Wall Drain	1.5
Pavement Edge Drain	1.0
Landfill LCDRS	1.5
Landfill LCRS	1.5
Landfill SWCRS	1.5
Shoreline Protection	
Current Exposure	1.0[b]
Wave Exposure	10[b]
Dams	10[b]
Liquid Impoundments	10[b]

[a] Table developed after Giroud, 1988.
[b] Critical applications may require designing with higher gradients than those given.

Determine the Minimum Allowable Geotextile Permeability (k_g)

The requirement of geotextile permeability can be affected by the filter application, flow conditions and soil type. The following equation can be used for all flow conditions to determine the minimum allowable geotextile permeability (Giroud, 1988):

$$k_g \geq i_s k_s$$

Permeability of the geotextile can be calculated from the permittivity test procedure (ASTM D 4491). This value is often available from manufacturer's literature. Geotextile permeability is defined as the product of the permittivity, Ψ, and the geotextile thickness, t_g:

$$k_g = \Psi t_g$$

STEP FIVE:

DETERMINE ANTI-CLOGGING REQUIREMENTS

To minimize the risk of clogging, follow this criteria:

- Use the largest opening size (O_{95}) that satisfies the retention criteria.
- For nonwoven geotextiles, use the largest porosity available, never less than 30%.
- For woven geotextiles, use the largest percentage of open area available, never less than 4%.

NOTE: For critical soils and applications, laboratory testing is recommended to determine geotextile clogging resistance.

STEP SIX:

DETERMINE SURVIVABILITY REQUIREMENTS

Both the type of drainage or armor material placed adjacent to the geotextile and the construction techniques used in placing these materials can result in damage to the geotextile. To ensure construction survivability, specify the minimum strength properties that fit with the severity of the installation. Use Table 2 as a guide in selecting required geotextile strength properties to ensure survivability for various degrees of installation conditions. Some engineering judgement must be used in defining this severity.

Table 2. Survivability Strength Requirements (after AASHTO, 1996)

		GRAB STRENGTH (LBS)	ELONGATION (%)	SEWN SEAM STRENGTH (LBS)	PUNCTURE STRENTH (LBS)	BURST STRENTH (LBS)	TRAPEZOID TEAR (LBS)
SUBSURFACE DRAINAGE	HIGH CONTACT STRESSES (ANGULAR DRAINAGE MEDIA) (HEAVY COMPACTION) or (HEAVY CONFINING STRESSES)	247	< 50% *	222	90	392	56
		157	≥ 50%	142	56	189	56
	LOW CONTACT STRESSES (ROUNDED DRAINAGE MEDIA) (LIGHT COMPACTION) or (LIGHT CONFINING STRESSES)	180	< 50% *	162	67	305	56
		112	≥ 50%	101	40	138	40
ARMORED EROSION CONTROL	HIGH CONTACT STRESSES (DIRECT STONE PLACEMENT) (DROP HEIGHT > 3 FT)	247	< 50% *	222	90	392	56
		202	≥ 50%	182	79	247	79
	LOW CONTACT STRESSES (SAND OR GEOTEXTILE CUSHION) and (DROP HEIGHT < 3 FT)	247	< 50% *	222	90	292	56
		157	≥ 50%	142	56	189	56

* Only woven monofilament geotextiles are acceptable as < 50% elongation filtration geotextiles. No woven slit film geotextiles are permitted.

STEP SEVEN:

DETERMINE DURABILITY REQUIREMENTS

During installation, if the geotextile filter is exposed to sunlight for extended periods, a high carbon black content and UV stabilizers are recommended for added resistance to UV degradation. Polypropylene is one of the most durable geotextiles today. It is inert to most naturally occurring chemicals in civil engineering applications.

However, if it is known that the geotextile may exposed to adverse chemicals (such as in waste containment landfill applications), use test method ASTM D5322 to determine its compatibility.

References

Giroud, J.P., “Review of Geotextile Filter Design Criteria.” Proceedings of First Indian Conference on Reinforced Soil and Geotextiles, Calcutta, India, 1988.

Heerten, G., “Dimensioning the Filtration Properties of Geotextiles Considering Long-Term Conditions.” Proceedings of Second International Conference on Geotextiles, Las Vegas, Nevada, 1982.

AASHTO, “Standard Specification for Geotextile Specification for Highway Applications”, M288-96

GEOTEXTILE FILTER FABRIC SELECTION GUIDE

		Silty Gravel w/Sand (GM)	Well-Graded Sand (SW) #1	Well-Graded Silty Sand (SW) #2	Silty Sand (SM)
SOIL PROPERTIES		k_s = .005cm/s PI = 0 C_c = 2.8 C'_u = 34 d'_{50} = 3.5mm C_u = 211 d_{50} = 5.0mm d_{90} = 22mm	k_s = .005cm/s PI = 0 C_c = 1.0 C'_u = 9.1 d'_{50} = .52mm C_u = 8.4 d_{50} = .60mm d_{90} = 2.7mm	k_s = .001cm/s PI = 0 C_c = 2.1 C'_u = 5.3 d'_{50} = .28mm C_u = 6.6 d_{50} = .28mm d_{90} = 1.6mm	k_s = .00005cm/s PI = 0 C_c = 3.0 C'_u = 16.2 d'_{50} = .21 C_u = 67 d_{50} = .22mm d_{90} = .95mm (Note: Moderate to Heavy Compaction Required)
SUBSURFACE DRAINAGE[2]	Soil Retention[1]	1.85 mm	1.03 mm	.95 mm	.18 mm
	Permeability	5×10^{-3}	5×10^{-3}	1×10^{-3}	5×10^{-5}
	Clogging Resistance	P.O.A. > 6%	P.O.A. > 6%	P.O.A. > 6%	n > 30%
	Survivability Req't	LOW	LOW	LOW	LOW
	Gradation	Widely Graded	Widely Graded	Widely Graded	Widely Graded
	Relative Soil Density	Dense	Dense	Dense	Medium
	RECOMMENDED FABRIC	**FILTERWEAVE 400**	**FILTERWEAVE 400**	**FILTERWEAVE 400**	**MIRAFI 180N**
	Soil Retention[1]	.93 mm	.51 mm	.48 mm	.18 mm
	Permeability	5×10^{-3}	5×10^{-3}	1×10^{-3}	5×10^{-5}
	Clogging Resistance	P.O.A. > 6%	P.O.A. > 6%	P.O.A. > 6%	n > 30%
	Survivability Req't	HIGH	HIGH	HIGH	HIGH
	Gradation	Widely Graded	Widely Graded	Widely Graded	Widely Graded
	Relative Soil Density	Loose	Loose	Loose	Medium
	RECOMMENDED FABRIC	**FILTERWEAVE 404**	**FILTERWEAVE 404**	**FILTERWEAVE 404**	**MIRAFI 180N**
ARMORED EROSION CONTROL[3] — Mild Current Exposure, Minimal Drawdown Potential, Non-Vegetated	Soil Retention[1]	12.5 mm	1.5 mm	0.7 mm	0.55 mm
	Permeability	5×10^{-3}	5×10^{-3}	1×10^{-3}	5×10^{-5}
	Clogging Resistance	P.O.A. > 6%	P.O.A. > 6%	P.O.A. > 6%	P.O.A. > 6%
	Flow Conditions	Mild Currents	Mild Currents	Mild Currents	Mild Currents
	RECOMMENDED FABRIC	**FILTERWEAVE 400**	**FILTERWEAVE 400**	**FILTERWEAVE 400**	**FILTERWEAVE 400**
ARMORED EROSION CONTROL[3] — Wave Exposure, High Velocity Channel Lining, Spillway Overtopping	Soil Retention[1]	5.0 mm	0.60 mm	0.28 mm	0.22 mm
	Permeability	$.5 \times 10^{-2}$	$.5 \times 10^{-2}$	1×10^{-2}	5×10^{-4}
	Clogging Resistance	P.O.A. > 6%	P.O.A. > 6%	P.O.A. > 6%	P.O.A. > 6%
	Flow Conditions	Severe Wave Attack	Severe Wave Attack	Severe Wave Attack	Severe Wave Attack
	RECOMMENDED FABRIC	**FILTERWEAVE 404**	**FILTERWEAVE 404**	**FILTERWEAVE 500**	**FILTERWEAVE 700**

1 Maximum opening size of geotextile (O_{95}) to retain soil.

2 Steady state flow condition.

3 Dynamic Flow Conditions

Clayey Sand (SC)	Sandy Silt (ML)	Lean Clay (CL)
k_s = .00001cm/s PI = 16.0 C_c = 20 C'_u = n/a d'_{50} = n/a C_u = 345 d_{50} = .55mm d_{90} = 5.8mm > 10% silt < 20% clay	k_s = .00005cm/s PI = 0 C_c = 2.9 C'_u = 1.7 d'_{50} = .07 C_u = 10.8 d_{50} = .072mm d_{90} = .13mm	k_s = .0000001cm/s PI = 16.7 C_c = 3.3 C'_u = n/a d'_{50} = n/a C_u = 36 d_{50} = .014mm d_{90} = .05mm > 16% silt < 20% clay

.21 mm	.24 mm	.21 mm
1×10^{-5}	5×10^{-5}	1×10^{-7}
n > 30%	n > 30%	n > 30%
LOW	LOW	LOW
Non-dispersive	Uniformly Graded Dense	Non-dispersive
MIRAFI 140N Series	**MIRAFI 140N Series**	**MIRAFI 140N Series**

.21 mm	.18 mm	.21 mm
1×10^{-5}	5×10^{-5}	1×10^{-7}
n > 30%	n > 30%	n > 30%
HIGH	HIGH	HIGH
Non-dispersive	Uniformly Graded Medium	Non-dispersive
MIRAFI 160N	**MIRAFI 180N**	**MIRAFI 160N**

1.4 mm	0.13 mm	0.035 mm
1×10^{-5}	5×10^{-5}	1×10^{-7}
P.O.A. > 6%	n > 30%	n > 30%
Mild Currents	Mild Currents	Mild Currents
FILTERWEAVE 400	**MIRAFI 1100N**	**MIRAFI 1160N**

0.55 mm	0.07 mm	0.014 mm
1×10^{-4}	5×10^{-4}	1×10^{-6}
P.O.A. > 6%	P.O.A. > 6%	n > 30%
Severe Wave Attack	Severe Wave Attack	Severe Wave Attack
FILTERWEAVE 404	**MIRAFI 1160N**	**MIRAFI 1160N**

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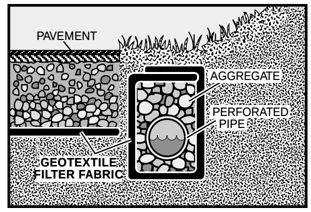
DISCLAIMER

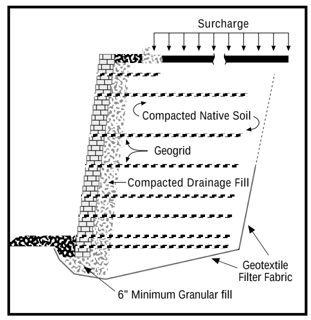
The information presented herein will not apply to every installation. Applicability of products will vary as a result of site conditions and installation procedures. Final determination of the suitability of any information or material for the use contemplated, of its manner of use, and whether the use infringes any patents, is the sole responsibility of the user.

TYPICAL SECTIONS AND APPLICATIONS:

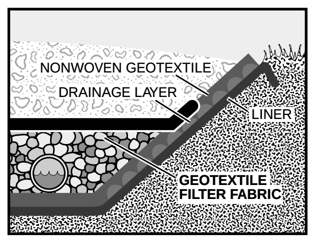
DRAINAGE



- Seepage Cut-off
- Pavement Edge Drains
- Slope Seepage Cut-off
- Surface Water Recharge
- Trench or "French" Drains

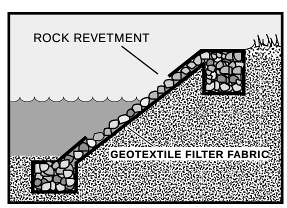


- Structure Pressure Relief
- Foundation Wall Drains
- Retaining Wall Drains
- Bridge Abutment Drains
- Planter Drains



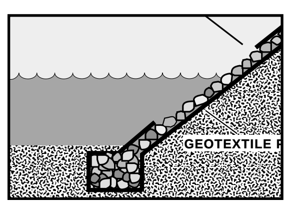
- Leachate Collection and Removal
- Blanket Drains
- Subsurface Gas Collection

ARMORED EROSION CONTROL



- River and Streambed Lining
- Culvert Inlet and Discharge Aprons
- Abutment Scour Protection
- Access Ramps

Proper installation of filtration geotextiles includes anchoring the geotextile in key trenches at the top and bottom of



- Coastal Slope Protection
- Shoreline Slope Protection
- Pier Scour Protection
- Sand Dune Protection

Underwater geotextile placement is common and must include anchorage of the toe to resist scour.

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For more information on Mirafi® Geotextiles Filters in drainge and armored erosion control applications, contact one of the following offices:

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