geotextile filter design, application, and product selection guide
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.

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/spillways, 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.
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.

**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.
Charts 1 and 2 indicate the use of particle-size parameters for determining 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**

- **Non-dispersive soil**
  - $c_45 < 0.21$ mm
  - Use 3 to 6 inches of very fine sand between soil and geotextile, then design the geotextile as a filter for the sand

- **Dispersive soil**
  - $c_45 > 0.21$ mm

- **Plastic soil**
  - $c_45 < 0.21$ mm
  - Use 3 to 6 inches of very fine sand between soil and geotextile, then design the geotextile as a filter for the sand

- **Non-plastic soil**
  - $c_45 < 0.21$ mm

**NOTES:**

- $d_x = \text{particle diameter of which size x percent is smaller}$
- $C'_u = \frac{d'_{90} - d'_{10}}{d'_{50} - d'_{10}}$
  - where: $d'_{90}$ and $d'_{10}$ 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

- $C_c = \frac{(d_{50})^2}{d_{90} \times d_{10}}$

- $I_g = \text{relative density of the soil}$
- $P_l = \text{plasticity index of the soil}$
- $DHR = \text{double-hydrometer ratio of the soil}$
- $O_{95} = \text{geotextile opening size}$

Charts 1 and 2 indicate the use of particle-size parameters for determining 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.
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 (O95)

The last step in determining soil retention requirements is evaluating the maximum allowable opening size (O95) of the geotextile which will provide adequate soil retention. The O95 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.

Define the Soil Hydraulic Conductivity (ks)

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 d15, of the soil (see Figure 2 on the following page).
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\(^{(a)}\)

<table>
<thead>
<tr>
<th>Drainage Applications</th>
<th>Typical Hydraulic Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Lining</td>
<td>1.0</td>
</tr>
<tr>
<td>Standard Dewatering Trench</td>
<td>1.0</td>
</tr>
<tr>
<td>Vertical Wall Drain</td>
<td>1.5</td>
</tr>
<tr>
<td>Pavement Edge Drain</td>
<td>1.0</td>
</tr>
<tr>
<td>Landfill LCDRS</td>
<td>1.5</td>
</tr>
<tr>
<td>Landfill LCRS</td>
<td>1.5</td>
</tr>
<tr>
<td>Landfill SWCRS</td>
<td>1.5</td>
</tr>
<tr>
<td>Shoreline Protection</td>
<td></td>
</tr>
<tr>
<td>Current Exposure</td>
<td>1.0(^{(b)})</td>
</tr>
<tr>
<td>Wave Exposure</td>
<td>10(^{(b)})</td>
</tr>
<tr>
<td>Dams</td>
<td>10(^{(b)})</td>
</tr>
<tr>
<td>Liquid Impoundments</td>
<td>10(^{(b)})</td>
</tr>
</tbody>
</table>

\(^{(a)}\) 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, \( \Psi \), and the geotextile thickness, \( t_g \):

\[
k_g = \Psi t_g
\]
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.

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.

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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Grab Strength (lbs)</th>
<th>Elongation (%)</th>
<th>Tear Strength (lbs)</th>
<th>Burst Strength (lbs)</th>
<th>Trapezoid Tear (lbs)</th>
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</thead>
<tbody>
<tr>
<td>Low Contact Stresses</td>
<td>247</td>
<td>&lt;50%*</td>
<td>222</td>
<td>90</td>
<td>392</td>
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<tr>
<td>High Contact Stresses</td>
<td>157</td>
<td>≥50%</td>
<td>142</td>
<td>56</td>
<td>189</td>
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<td>High Contact Stresses</td>
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<td>40</td>
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<tr>
<td>Direct Stone Placement (Drop Height &gt; 3 ft)</td>
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<td>&lt;50%*</td>
<td>222</td>
<td>90</td>
<td>392</td>
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<tr>
<td>Low Contact Stresses</td>
<td>202</td>
<td>≥50%</td>
<td>182</td>
<td>79</td>
<td>247</td>
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<tr>
<td>Low Contact Stresses</td>
<td>247</td>
<td>&lt;50%*</td>
<td>222</td>
<td>90</td>
<td>292</td>
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<td>157</td>
<td>≥50%</td>
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<td>56</td>
<td>189</td>
</tr>
</tbody>
</table>

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

### References


### GEOTEXTILE FILTER FABRIC SELECTION GUIDE

<table>
<thead>
<tr>
<th>SOIL PROPERTIES</th>
<th>Silty Gravel w/Sand (GM)</th>
<th>Well-Graded Sand (SW) #1</th>
<th>Well-Graded Silty Sand (SW) #2</th>
<th>Silty Sand (SM)</th>
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</thead>
<tbody>
<tr>
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<td>.005cm/s</td>
<td>.001cm/s</td>
<td>.00005cm/s</td>
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<tr>
<td>PI</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>3.0</td>
<td>3.0</td>
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<td>.28mm</td>
<td>.21</td>
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<tr>
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<td>.28mm</td>
<td>.22mm</td>
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<tr>
<td>( d_{90} )</td>
<td>22mm</td>
<td>2.7mm</td>
<td>1.6mm</td>
<td>.95mm</td>
</tr>
</tbody>
</table>

#### Soil Retention
- .93 mm
- .51 mm
- .48 mm
- .18 mm

#### Permeability
- \( 5 \times 10^{-3} \)
- \( 5 \times 10^{-3} \)
- \( 1 \times 10^{-3} \)
- \( 5 \times 10^{-5} \)

#### Clogging Resistance
- P.O.A. > 6%
- P.O.A. > 6%
- P.O.A. > 6%
- n > 30%

#### Survivability Req't
- LOW
- LOW
- HIGH
- LOW

#### Gradation
- Widely Graded
- Widely Graded
- Widely Graded
- Widely Graded

#### Relative Soil Density
- Dense
- Dense
- Wide
- Medium

#### RECOMMENDED FABRIC
- FILTERWEAVE 400
- FILTERWEAVE 400
- FILTERWEAVE 400
- MIRAFI 180N

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1. Maximum opening size of geotextile (O95) to retain soil.
2. Steady state flow condition.
3. Dynamic Flow Conditions
<table>
<thead>
<tr>
<th>Clayey Sand (SC)</th>
<th>Sandy Silt (ML)</th>
<th>Lean Clay (CL)</th>
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</thead>
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<td>(k_s = 0.0001 \text{cm/s})</td>
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<td>(k_s = 0.0000001 \text{cm/s})</td>
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<td>(PI = 0)</td>
<td>(PI = 16.7)</td>
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<tr>
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<td>(C_c = 2.9)</td>
<td>(C_c = 3.3)</td>
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<td>(d_{90} = 0.014 \text{mm})</td>
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<tr>
<td>(&gt; 10% \text{ silt})</td>
<td>(&gt; 16% \text{ silt})</td>
<td>(&lt; 20% \text{ clay})</td>
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<th>Sandy Silt (ML)</th>
<th>Lean Clay (CL)</th>
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<tr>
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<tbody>
<tr>
<td>(k_s = 0.00001 \text{cm/s})</td>
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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.

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

Proper installation of filtration geotextiles includes anchoring the geotextile in key trenches at the top and bottom of the toe to resist scour.
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