USE OF GEOSYNTHETICS FOR FILTRATION AND DRAINAGE

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Functions of a Filter

Retain particles of the base soil to be filtered

Avoid piping

• Allow free flow of water
  - upstream of the filter
    Avoid external clogging
    (With unstable soils)
  - through the filter
    Avoid internal clogging

• Survive construction and environmental stresses
• Function can be provided by either natural aggregates or by Geotextiles
### SIMILARITIES
- Risks of internal clogging by
  1. finer particles of the soils to be filtered
  2. aerobic bacterial activity (ochre clogging)
  3. deicing salt precipitation
  4. ice lens formation within the frost penetration zone

### DIFFERENCES

<table>
<thead>
<tr>
<th></th>
<th>AGGREGATES</th>
<th>GEOSYNTHETICS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thickness</strong></td>
<td>High (&gt;150 mm)</td>
<td>Low (&lt; 30 mm)</td>
</tr>
<tr>
<td><strong>Porosity</strong></td>
<td>25 - 40 %</td>
<td>75 - 95 %</td>
</tr>
<tr>
<td><strong>Capillary rise $h_c$</strong></td>
<td>Important ($h_c &lt; 500$ mm)</td>
<td>Low to none ($h_c &lt; 50$ mm)</td>
</tr>
<tr>
<td><strong>Tensile strength</strong></td>
<td>None</td>
<td>Low to high</td>
</tr>
<tr>
<td><strong>Compressibility</strong></td>
<td>Negligible</td>
<td>Medium to high</td>
</tr>
<tr>
<td><strong>Transmissivity under confining stress</strong></td>
<td>Invariable</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>Uniformity</strong></td>
<td>Variable gradation as per borrow pit</td>
<td>Factory-controlled mass per unit area and thickness</td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>Completely inert</td>
<td>Altered by ultraviolet rays</td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td>Must not be contaminated by the surrounding soil. Compaction needed</td>
<td>Must be installed in intimate contact with the soil to be filtered. Installation eased by seaming of the joints</td>
</tr>
<tr>
<td><strong>Risk of damage</strong></td>
<td>None</td>
<td>Subject to puncture and tearing</td>
</tr>
</tbody>
</table>
Filtration Behaviour

- **Clogging**: the voids of a medium are progressively filled by solid matter to the point that the passage of water is compromised
  - Decrease in hydraulic conductivity

- **Internal clogging**
  - By mineral particles
  - By precipitation and chemical deposition in the voids by water containing iron, de-icing salts
  - By biological growth encrustation in aerobic conditions
Base - Filter Interaction

- **Internal Interface**
  - Piped particles
  - Continuous paths

- **External Clogging**
  - Filaments / Fibres

- **Time** $t_{GT}$

- **Interface**
  - Internal
  - External
APPLICATIONS : DRAINAGE

- Around trench drains and edge drains
- Beneath pavement bases and base courses
- Retaining walls and bridge abutments
- Drain and well pipes
- Slope stabilization
- Earth dams and Levees
APPLICATIONS: EROSION CONTROL

- Protection of runoff collection
- Slope protection
- Along stream banks
- Scour protection around structures
- Construction facilities across/adjacent to water bodies
- Culverts, drop inlets, artificial stream channels
Filter Applications

- Wrapping of trench drains (Koerner, 1998)
Filter Applications

• Wall drains
Filter Applications

- Erosion protection
Filter Applications

• Earth and rockfill dams
Filter Applications

• Vertical consolidation drains
Filter Applications

Water surface

Sediment-carrying sheet runoff

"Clear" water

Turbid water

Sediments

Geotextile

Clogged fabric

Main support posts

Flow

$X$

$H$

$h_1$

$h_2$
Filtration Flow Conditions

- **Dynamic vs static**

<table>
<thead>
<tr>
<th>Dynamic, Pulsating, Cyclic</th>
<th>Static, Unidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion Protection (Waves, Current)</td>
<td>Wall Drains</td>
</tr>
<tr>
<td>Road Drainage (Traffic Stresses)</td>
<td>Silts Fences</td>
</tr>
<tr>
<td>Conditions More Severe</td>
<td>Vertical Consolidation Drains</td>
</tr>
<tr>
<td>Reduce Filter Opening Size</td>
<td>Earth &amp; Rockfill Dams</td>
</tr>
<tr>
<td>Item</td>
<td>Critical</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>1. Risk of loss of life and/or structural damage due to drain failure:</td>
<td>High</td>
</tr>
<tr>
<td>2. Repair costs versus installation costs of drain:</td>
<td>&gt;&gt;&gt;&gt;</td>
</tr>
<tr>
<td>3. Evidence of drain clogging before potential catastrophic failure:</td>
<td>None</td>
</tr>
</tbody>
</table>
### Guidelines (Continued)

#### B. Severity of the Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Severe</th>
<th>Less Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Soil to be drained:</td>
<td>Gap-graded, pipable, Or dispersible</td>
<td>Well-graded or uniform</td>
</tr>
<tr>
<td>2. Hydraulic gradient:</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>3. Flow conditions:</td>
<td>Dynamic, cyclic, or pulsating</td>
<td>Steady state</td>
</tr>
</tbody>
</table>
Granular filter design criteria

a) Retention Criteria:
\[
\frac{d_{15}(\text{filter})}{d_{85}(\text{soil})} < 4 \text{ to } 5
\]

b) Permeability Criteria:
\[
\frac{d_{15}(\text{filter})}{d_{15}(\text{soil})} > 4 \text{ to } 5
\]
Geotextile filter requirements:

- Retention criteria
- Permeability criteria
- Anti-clogging criteria
- Serviceability criteria
- Durability criteria
Soil retention

A process in which the particle movement is resisted by granular forces

Useful design parameters

1. Coefficient of Uniformity, $C_u$

2. Linear Coefficient of Uniformity, $C_u'$

3. Coefficient of Curvature, $C_c$
Design Charts

Determination of soil retention requirements such as particle size distribution, Atterberg limits, dispersion potential, soil density conditions indicating the effect of confining stress, are all considered and design charts are prepared by Giroud (1988).
Typical hydraulic gradients (Giroud, 1988).

<table>
<thead>
<tr>
<th>Drainage Application</th>
<th>Typical Hydraulic Gradient</th>
</tr>
</thead>
<tbody>
<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>Dams</td>
<td>10</td>
</tr>
<tr>
<td>Inland Channel Protection</td>
<td>1.0</td>
</tr>
<tr>
<td>Shoreline Protection</td>
<td>10</td>
</tr>
<tr>
<td>Liquid Impoundment</td>
<td>10</td>
</tr>
</tbody>
</table>
## Typical relative densities ($I_D$) for granular soils

<table>
<thead>
<tr>
<th>Soil Conditions</th>
<th>Low Confining Pressures (TYP $\leq$ 50 kPa)</th>
<th>High Confining Pressures (TYP $&gt;$ 50 kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconsolidated Sedimentary Deposits or Uncompacted Hydraulic Fill</td>
<td>$I_D \leq 35%$</td>
<td>$35% &lt; I_D &lt; 5%$</td>
</tr>
<tr>
<td>Consolidated Residual Deposits or Compacted Fill</td>
<td>$35% &lt; I_D &lt; 65%$</td>
<td>$I_D &gt; 65%$</td>
</tr>
</tbody>
</table>
Retention Criteria:

\[ O_{e(geotextile)} \leq B \cdot D_{(soil)} \]

where:
- \( O_e \) = effective opening size in the geotextile for which \( e \) is the present openings that are smaller than the opening size \( O \) (mm), usually the \( O_{90} \) or \( O_{95} \);
- \( B \) = a coefficient (dimensionless); and
- \( D_{(soil)} \) = representative soil particle size (mm), usually the medium to larger fractions or \( D_{85} \).
Laboratory Filter Characterization

- Opening size \(O_{90}\) by wet sieving
CHART 1
SOIL RETENTION CRITERIA
FOR STEADY-STATE FLOW CONDITIONS

MORE THAN 20% CLAY
(d<sub>20</sub> < 0.002 mm)

LESS THAN 20% CLAY AND MORE THAN 10% FINES
(d<sub>50</sub> = 0.002 mm AND d<sub>10</sub> > 0.075 mm)

LEAST THAN 90% GRAVEL
(d<sub>50</sub> > 4.8 mm)

NOTES:

- d<sub>y</sub> is the particle size of which x percent is smaller
- C'<sub>us</sub> = \( \frac{d_{100}}{d_0} \) drawn through the particle-size distribution as directed above
- C<sub>c</sub> = \( \frac{(d_{50})^2}{d_{90} \times d_{10}} \)
- \( \rho_o \) is the reactive density of the soil
- PI is the plasticity index of the soil
- DHR is the double-hydrometer ratio of the soil
CHART 2
SOIL RETENTION CRITERIA
FOR DYNAMIC FLOW CONDITIONS

MORE THAN 30 % CLAY
(d<sub>30</sub> < 0.002 mm)

MORE THAN 90 % GRAVEL
(d<sub>10</sub> > 4.8 mm)

LESS THAN 30 % CLAY AND MORE THAN 50 % FINES
(d<sub>30</sub> > 0.002 mm AND d<sub>50</sub> < 0.075 mm)

PLASTIC SOIL
(PI > 5)

DISPERSED SOIL
(DHR > 0.5)

USE 3 TO 6 INCHES OF FINE SAND, THEN DESIGN THE GEOTEXTILE AS A FILTER FOR THE SAND

MORE THAN 10 d<sub>50</sub>, d<sub>95</sub> < d<sub>30</sub> AND d<sub>95</sub> < 0.1 mm

FROM SOIL PROPERTIES TESTS

LESS THAN 50 % FINES AND LESS THAN 90 % GRAVEL
(d<sub>50</sub> > 0.075 mm AND d<sub>10</sub> < 4.8 mm)

SEVERE WAVE ATTACK
O<sub>95</sub> < d<sub>50</sub>

WIDELY GRADED
O<sub>95</sub> < 2.5 d<sub>50</sub> AND O<sub>95</sub> < d<sub>90</sub>
(Cu > 5)

MILD WATER CURRENTS

UNIFORMLY GRADED
d<sub>50</sub> < O<sub>95</sub> < d<sub>90</sub>
(Cu ≤ 5)

NOTES:

\[ \frac{d_{x}}{d_{10}} \]

is the soil particle size of which \( x \) percent is smaller

PI is the plasticity index of the soil

DHR is the double-hyrometer ratio of the soil

O<sub>95</sub> is the geotextile opening size
Permeability criteria

Giroud Criteria \( K_g > i_s K_s \) Where \( i_s > 1.0 \)

FWHA Criteria

\[
K_{\text{geotextile}} \geq \text{FS} \cdot k_{\text{soil}}
\]

\[
\psi_{\text{allow}} \geq \text{FS} \cdot \psi_{\text{required}}
\]

For less critical conditions \( K_{\text{geotextile}} \geq k_{\text{soil}} \)

For Severe conditions \( K_{\text{geotextile}} \geq 10 k_{\text{soil}} \)

Min. permittivity conditions \( \psi \geq 0.1 \text{ to } 1 \text{ sec}^{-1} \)
FIGURE 1

TYPICAL HYDRAULIC CONDUCTIVITY VALUES

<table>
<thead>
<tr>
<th>BOULDERS</th>
<th>COBBLES</th>
<th>GRAVEL</th>
<th>SAND</th>
<th>FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>COARSE</td>
<td>FINE</td>
<td>COARSE</td>
</tr>
</tbody>
</table>

U.S. STANDARD SIEVE SIZES

SOIL HYDRAULIC CONDUCTIVITY, ks (cm/s)

CHARACTERISTIC PARTICLE SIZE, $d_{15}$, OF THE SOIL (mm)
Anti - Clogging Criteria

Use the largest available opening size satisfying the retention criteria

For nonwovens, porosity > 30%
For woven geotextiles percent open area ≥ 4%

The porosity of a nonwoven geotextile is given by

\[ n = (1 - \mu/(t_g \rho)) \times 100 \]

\( \mu \) is the mass per unit area of geotextile
\( t_g \) is the geotextile thickness and \( \rho \) is the density of filament
Survivability Criteria

Figure 2: Survivability Strength Requirements

<table>
<thead>
<tr>
<th>Geotextile Property</th>
<th>Grab Strength (lbs)</th>
<th>Elongation (%</th>
<th>Seam Seam Strength (lbs)</th>
<th>Fissure Strength (lbs)</th>
<th>Worst Strength (lbs)</th>
<th>Tear Strength (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate Installation Conditions</td>
<td>180</td>
<td>N/A</td>
<td>160</td>
<td>80</td>
<td>290</td>
<td>50</td>
</tr>
<tr>
<td>(Angular Drainage Media)</td>
<td>(Heavy Compaction)</td>
<td>(Heavy Confining Stress)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Contact Stresses (Rounded Drainage Media)</td>
<td>80</td>
<td>N/A</td>
<td>70</td>
<td>25</td>
<td>130</td>
<td>25</td>
</tr>
<tr>
<td>(Light Compaction)</td>
<td>(Light Confining Stress)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Installation Conditions</td>
<td>200</td>
<td>15</td>
<td>180</td>
<td>80</td>
<td>320</td>
<td>50</td>
</tr>
<tr>
<td>(Direct Stone Placement)</td>
<td>(Drop Height &gt; 3 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Contact Stresses (Sand or Geotextile Cushion)</td>
<td>90</td>
<td>15</td>
<td>80</td>
<td>40</td>
<td>140</td>
<td>30</td>
</tr>
<tr>
<td>(Drop Height &lt; 3 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: (a) After FHWA, 1985.
(b) Test methods for determining geotextile properties given in Table 4-6 in "Geotextile Filter Design Manual"
Durability Criteria

• Aspects such as geotextiles resistance to ultraviolet and adverse chemical environments need be studied in specific application.

• Exposure to sunlight extensively during must be protected by anti-oxidants such a carbon black or titanium oxide.

• Geotextiles should also be resistant to chemicals.