Design Guide
Fibertex Geotextiles
Fibertex Geotextiles

- are needlepunched nonwoven fabrics made from polypropylene. The drylaid needlepunch technology is based on a two step process. Firstly, polypropylene resin is extruded into fibres. Secondly, the fibres are carded and needlepunched. Finally, some types are added thermal treatment. Weights range from 100 g/m² up to 1200 g/m².

Focus on the environment

No chemical binders are used in Fibertex products or during the production process. Polypropylene is a polymer material and when incinerated it turns into carbon dioxide and water vapour, both completely harmless substances. Concern for the environment is proved by the fact that Fibertex is among the first in the nonwoven industry to introduce an environmental management system and thereby obtaining the ISO 14001 certificate. This ensures continuous focus on efficient and financially viable management of environmental issues, which in return ensures minimal harmful effects resulting from the company’s activities.

The importance of quality

Fibertex’s quality management system is certified in accordance with the most comprehensive standards set by the International Organisation for Standardisation namely DS/EN ISO 9001 which is comparable to BS 5750 Part 1 and EN 29001. This means that the quality management system has been implemented and verified at all levels within the organisation.

Fibertex Geotextiles are CE marked under the EU Construction Products Directive. CE marking certifies that Fibertex’s quality management system (DS/EN ISO 9001) complies with the EN standards (level 2+). Fibertex Geotextiles are submitted to production control and tests in accordance with the EN standards.
- in any construction...

Separation
The durability and mechanical properties of Fibertex Geotextiles make them ideal as separating layers in construction works. A strong and flexible geotextile is placed between different layers in the construction preventing migration and mingling of materials, yet allowing free movement of water....................................................... page 4

Filtration
The characteristic opening size of Fibertex Geotextiles is designed to retain particles while allowing free movement of water, making it possible to separate two layers during intense hydraulic activity. Migration of layers will reduce the load-bearing capacity of the construction and must therefore be avoided............................................... page 8

Drainage
Excess water is drained off the construction - not by passing through the Fibertex Geotextile as when used for filtration - but by flowing in the plane of the geotextile leading it away from the construction ...... page 12

Protection
When placing a Fibertex Geotextile on both sides of a waterproof membrane, the thickness and strength of the geotextile protect the membrane from puncture............................................................... page 16

Reinforcement
The mechanical properties of Fibertex Geotextiles, Fibertex Fiberforce, Fibertex HS Woven and Fibertex GeoGrid, make them ideal for reinforcing slopes and other soil structures ........................................ page 18
Fibertex Geotextiles for Separation

- To prevent mixing of construction layers
- To increase bearing capacity by avoiding material loss into the subgrade
- To improve the compaction properties of the aggregate layer
- To provide long-term stability of foundation layers

Separation is the basic use of geotextiles and is widely practised in road works and railway constructions. In the EN ISO standards the separation function is defined as “The preventing from intermixing of adjacent dissimilar soils and/or fill materials by the use of a geotextile”.

Geotextile properties

The tensile strength, puncture resistance and elongation properties of the geotextile have to be sufficient not only to fulfil the requirements to a separator but also to resist damage during installation.

The characteristic opening size of the geotextile must be sufficient to retain fines and to prevent contamination of the aggregate base while the permeability must be high enough to allow free movement of water.
Required mechanical properties

The required mechanical properties of a geotextile are based on the failure possibilities shown in Fig. 1. - 4.

Fig. 1. High elongation and dynamic perforation resistance prevent the geotextile from being damaged when rocks are dropped during installation.

Fig. 2. High elongation and tensile strength prevent damage of the geotextile when aggregate is horizontally displaced as a result of wedge effects during vertical pressure.

Fig. 3. High elongation and static puncture resistance allow the geotextile to stretch around the irregular construction surface.

Fig. 4. High elongation and static puncture resistance prevent puncture when pressure from the fill material causes migration of fine soil into cavities in the aggregate layer.
Fibertext Geotextiles for Separation

Important mechanical properties of a separation geotextile:

- $T_f$: Tensile strength at break of the geotextile [kN/m] (Minimum value)
  According to EN ISO 10319

- $\epsilon$: Elongation at break [%] (Minimum value)
  According to EN ISO 10319

- $F_p$: Static puncture resistance (CBR-test) [N] (Minimum value)
  According to EN ISO 12236

- $D_c$: Dynamic perforation (cone drop test) [mm] (Maximum value)
  According to EN 918

The requirements for these properties are influenced by the following properties of the supporting soil:

- CBR: Californian Bearing Ratio [%],
  Relative value for the plastic deformation properties of a soil.
  According to EN 13286-47

- $M_{el}$: Deformation modulus [MNm$^{-2}$]

When knowing one of these two parameters and the load that the construction is to endure, the minimum cover layer and strength properties of the geotextile can be read from table 1.

Table 1. Choice of a geotextile, when soil properties and loads are known. [1]

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Soil strength</th>
<th>Minimum cover layer</th>
<th>Geotextile properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBR [%]</td>
<td>$M_{el}$ [MNm$^{-2}$]</td>
<td>Road and Earthworks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fill A</td>
</tr>
<tr>
<td>Load ≤ 500 MN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load ≥ 500 MN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tf [kN/m]</td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>ε [%]</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Fp [N]</td>
<td></td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Dc [mm]</td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>&lt; 3</td>
<td>&lt; 6</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>3-6</td>
<td>6-15</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>&gt; 6</td>
<td>&gt; 15</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* Fill A: Round Gravel Ø≤150mm  ** Fill B: Coarse Gravel Ø≥150mm  *** Fill C: Other cover materials, Round or Coarse (broken natural stone etc.)
[1] SVG, The Swiss Confederation of geotextile experts - The geotextile manual, 2001 (in German)

The read values for $T_f$, $\epsilon$ and $F_p$ are minimum values while the read value for $D_c$ is a maximum value. All these requirements have to be fulfilled to ensure that the geotextile will function as intended.
Required hydraulic properties

To function correctly, the characteristic opening size of the geotextile has to match the soil conditions. If the characteristic opening size is too large, the soil particles will pass through the geotextile, whereas if it is too small, the water flow will be insufficient. The important hydraulic parameters of the geotextile are:

- \( O_{90\%} \) Characteristic opening size \([\mu m]\)
  - According to EN ISO 12956

- \( k_n \) Coefficient of permeability normal to the plane \([m/sec]\) (Minimum value)
  - According to EN ISO 11058

The requirements for these hydraulic properties vary according to construction type, depending on the type of water flow it must endure.

**Characteristic opening size, \( O_{90\%} \)**

**Static water flow**

(one-way water flow e.g. road and earthworks, temporary roads, parking lots, fills on poor subsoil)

Design value of the characteristic opening size, \( O_{90\%} \), for coarse soil \( (d_{40\%} \geq 60 \mu m) \):

- Uniformly-graded subsoil, \( U \) \( (d_{60\%}/d_{10\%}) < 3 \):
  \[ O_{90\%} < 2.5 \cdot d_{50\%} \]

- Well-graded subsoil, \( U \) \( (d_{60\%}/d_{10\%}) \geq 3 \):
  \[ O_{90\%} < 10 \cdot d_{50\%} \]

Design value of the characteristic opening size, \( O_{90\%} \), for fine soil \( (d_{40\%} < 60 \mu m) \):

\[ 50 \mu m \leq O_{90\%} \leq 10 \cdot d_{50\%} \leq 110 \mu m \]

The lower of the two values from the upper limit is chosen.

**Dynamic water flow**

(railway constructions and other constructions where pump effects may occur)

Dynamic water flow may be a result of a pump effect generated by dynamic loads (e.g. railway constructions). Dynamic water flow can also occur naturally, which is the case with wave action on coastal areas. The function of a geotextile would then be characterised as filtration. For better readability, the required hydraulic properties under dynamic water flow are included in this chapter.

In coarse and uniformly-graded soils \( (U < 3 \text{ and } d_{40\%} > 60 \mu m) \) a dynamic water flow can occur:

For \( U \) \( (d_{60\%}/d_{10\%}) < 3 \text{ and } d_{40\%} > 60 \mu m \):

\[ 0.5 \cdot d_{50\%} \leq O_{90\%} \leq d_{50\%} \]

In dense soils, water is unable to flow dynamically, and the condition is therefore characterised as static.

**Coefficient of permeability, \( k_n \)**

The coefficient of permeability normal to the plane of the geotextile must be larger than the permeability of the soil:

\[ k_{n, \text{geotextile}} > k_{n, \text{soil}} \]

To ensure water flow, a safety factor is often added to the coefficient of permeability of the soil by multiplying by 1-100. This safety factor should be evaluated on the basis of the soil conditions and the desired service life.
To avoid migration of fine material into coarse material as a result of water flow in the soil

To maintain the water flow in the soil with minimum pressure loss

To prevent migration of fine material as a result of pump effects from dynamic loads such as traffic

Geotextiles are widely used for filtration in road works and railway constructions as well as coastal protection. The filtration function of a geotextile serves the same purpose as the separation function, but under different circumstances. In the EN ISO standards the filtration function is defined as “The restraining of soil or other particles subjected to hydrodynamic forces while allowing the passage of fluids into or across a geotextile.”

Geotextile properties

The tensile strength, puncture resistance and elongation properties of the geotextile have to be sufficient not only to fulfil the requirements to a filtrator but also to resist damage during installation.

The characteristic opening size of the geotextile must be sufficient to retain fines and to prevent contamination of the aggregate base while the permeability must be high enough to allow free movement of water.
Required mechanical properties

The required mechanical properties of a geotextile are based on the failure possibilities shown in Fig. 5 - 8.

Fig. 5. High elongation and static puncture resistance allow the geotextile to stretch around the irregular construction surface.

Fig. 6. High elongation and dynamic perforation resistance prevent the geotextile from being damaged when rocks are dropped during installation.

Fig. 7. The correct hydraulic properties of the geotextile ensure that soil fines are retained while maintaining the water flow.

Fig. 8. High elongation allows the geotextile to follow the contours of the irregular construction surface.
**Stressed filtration systems**

Important mechanical properties of a stressed filtration geotextile:

- **T<sub>f</sub>**: Tensile strength at break of the geotextile [kN/m] (Minimum value)  
  According to EN ISO 10319
- **ε**: Elongation at break [%] (Minimum value)  
  According to EN ISO 10319
- **F<sub>p</sub>**: Static puncture resistance (CBR-test) [N] (Minimum value)  
  According to EN ISO 12236
- **D<sub>c</sub>**: Dynamic perforation (cone drop test) [mm] (Maximum value)  
  According to EN 918

If the geotextile is used in connection with road works, railway constructions, dams or other surfaces stressed by a load, the required strength values are influenced by the size of the load and the following properties of the supporting soil:

- **CBR**: Californian Bearing Ratio [%],  
  Relative value for the plastic deformation properties of a soil.  
  According to EN 13286-47
- **M<sub>EL</sub>**: Deformation modulus [MNm<sup>-2</sup>]

When knowing one of these two parameters and the load the construction is to endure, the minimum cover layer and mechanical properties of the geotextile can be read from table 2.

**Non-stressed filtration systems**

If installation is the only mechanical strain the geotextile must endure, the following minimum values are sufficient:

**Important mechanical properties of a stressed filtration geotextile:**

<table>
<thead>
<tr>
<th>Soil strength</th>
<th>Minimum cover layer</th>
<th>Geotextile properties</th>
<th>Road and Earthworks</th>
<th>Railway construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR [%]</td>
<td>M&lt;sub&gt;EL&lt;/sub&gt; [MNm&lt;sup&gt;-2&lt;/sup&gt;]</td>
<td>T&lt;sub&gt;f&lt;/sub&gt; [kN/m]</td>
<td>ε [%]</td>
<td>F&lt;sub&gt;p&lt;/sub&gt; [N]</td>
</tr>
<tr>
<td>&lt; 3</td>
<td>&lt; 6</td>
<td>0.4</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2000</td>
<td>2400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>3-6</td>
<td>6-15</td>
<td>0.3</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td>40</td>
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<td></td>
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<td>1900</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>&gt; 6</td>
<td>&gt; 15</td>
<td>0.2</td>
<td>6</td>
<td>8</td>
</tr>
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<td></td>
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<td>30</td>
<td>40</td>
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<td></td>
<td></td>
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<td>1250</td>
<td>1450</td>
</tr>
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<td>27</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21</td>
<td>20</td>
</tr>
</tbody>
</table>

* Fill A: Round Gravel ∅≤150mm  
** Fill B: Coarse Gravel ∅≤150mm  
*** Fill C: Other cover materials, Round or Coarse (broken natural stone etc.)  
[1] SVG, The Swiss Confederation of geotextile experts - The geotextile manual, 2001 (in German)

The read values for T<sub>f</sub>, ε and F<sub>p</sub> are minimum values while the read value for D<sub>c</sub> is a maximum value. All these requirements have to be fulfilled to ensure that the geotextile will function as intended.
Required hydraulic properties

To function correctly, the characteristic opening size of the geotextile has to match the soil conditions. If the characteristic opening size is too large the soil particles will pass through the geotextile, whereas if it is too small, the water flow will be insufficient. The important hydraulic parameters of the geotextile are:

$O_{90\%}$ Characteristic opening size [$\mu m$]

According to EN ISO 12956

$k_n$ Coefficient of permeability normal to the plane

[$m/sec$] (Minimum value)

According to EN ISO 11058

The water flow through the geotextile can be divided into two main situations:

Static (one-way) water flow: e.g. drains and dewatering systems.

Dynamic water flow: e.g. hydraulic works and plane filters under e.g. road and track beds.

Characteristic opening size, $O_{90\%}$

Static water flow

(one-way water flow e.g. drains and dewatering systems)

Design value of the characteristic opening size, $O_{90\%}$, for coarse soil ($d_{40\%} > 60 \mu m$):

Uniformly-graded subsoil, $U$ ($d_{60\%}/d_{10\%} < 3$):

$O_{90\%} < 2.5 \cdot d_{50\%}$

Well-graded subsoil, $U$ ($d_{60\%}/d_{10\%} \geq 3$):

$O_{90\%} < 10 \cdot d_{50\%}$

Design value of the characteristic opening size, $O_{90\%}$, for fine soil ($d_{40\%} < 60 \mu m$):

$50 \mu m \leq O_{90\%} \leq 110 \mu m$

The lower of the two values from the upper limit is chosen.

Dynamic water flow

(railway construction and other constructions where pump effects may occur)

Dynamic water flow may be a result of a pump effect generated by dynamic loads (e.g. railway constructions). Dynamic water flow can also occur naturally, which is the case with wave action on coastal areas.

In coarse and uniformly-graded soils ($U < 3$ and $d_{40\%} > 60 \mu m$) a dynamic water flow can occur:

For $U$ ($d_{60\%}/d_{10\%} < 3$ and $d_{40\%} > 60 \mu m$):

$0.5 \cdot d_{50\%} \leq O_{90\%} \leq d_{50\%}$

In dense soils, water is unable to flow dynamically, and the condition is therefore characterised as static.

Coefficient of permeability, $k_n$

The coefficient of permeability normal to the plane of the geotextile must be larger than the permeability of the soil:

$k_{n, \text{geotextile}} > k_{n, \text{soil}}$

To ensure water flow, a safety factor is often added to the coefficient of permeability of the soil by multiplying by 1-100. This safety factor should be evaluated on the basis of the soil conditions and the desired service life.
To ensure that water and/or other fluids are drained with minimum pressure loss
To ensure an ongoing drainage

Geotextiles are widely used for drainage in earth and construction works. In the EN ISO standards the drainage function is defined as “The collecting and transporting of precipitation, ground water and/or other fluids in the plane of the geotextile”. In other words, it is the ability of the geotextile to drain fluids on its own, meaning that it is not part of a drainage system, but is the drainage system itself. The drainage function is often confused with the filtration function. When a geotextile is part of a drainage system, where it is used to separate a soil and a coarse-grained drainage layer, the function is filtration.

Geotextile properties

Usually, the installation strains are limited and use does not apply significant mechanical strains to a drainage geotextile (for special cases design specifications for stressed drains are included in this chapter). Consequently, high mechanical strength is not required, whereas hydraulic properties are decisive for the overall performance of the entire construction, with the water flow capacity in the plane of the geotextile being the most important.
**Required mechanical properties**

Important mechanical properties of a drainage geotextile:

- **Tₚ**: Tensile strength at break of the geotextile [kN/m] (Minimum value) According to EN ISO 10319
- **ε**: Elongation at break [%] (Minimum value) According to EN ISO 10319
- **Fₚ**: Static puncture resistance (CBR-test) [N] (Minimum value) According to EN ISO 12236
- **Dc**: Dynamic perforation (cone drop test) [mm] (Maximum value) According to EN 918

**Stressed drains**

If the drainage geotextile is used in connection with surfaces stressed by a load, the required strength values are influenced by the size of the load and the following properties of the supporting soil:

- **CBR**: Californian Bearing Ratio [%], Relative value for the plastic deformation properties of a soil. According to EN 13286-47
- **Mₑ**: Deformation modulus [MN/m²]

When knowing one of these two parameters and the load that the construction is to endure, the minimum cover layer and mechanical properties of the geotextile can be read from table 4.

### Table 4. Choice of a geotextile, when soil properties and loads are known. [1]

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Minimum cover layer</th>
<th>Geotextile properties</th>
<th>Road and Earthworks</th>
<th>Railway construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil strength</strong></td>
<td><strong>CBR [%]</strong></td>
<td><strong>Mₑ [MN/m²]</strong></td>
<td><strong>Minimum cover layer</strong></td>
<td><strong>Load ≤ 500 MN</strong></td>
</tr>
<tr>
<td><strong>Load ≤ 500 MN</strong></td>
<td><strong>Fill A</strong></td>
<td><strong>Fill B</strong></td>
<td><strong>Fill C</strong>*</td>
<td><strong>Fill A</strong></td>
</tr>
<tr>
<td>Fill A</td>
<td>Fill B</td>
<td>Fill C***</td>
<td>Fill A</td>
<td>Fill B</td>
</tr>
<tr>
<td><strong>Load ≥ 500 MN</strong></td>
<td><strong>Fill A</strong></td>
<td><strong>Fill B</strong></td>
<td><strong>Fill C</strong>*</td>
<td><strong>Fill A</strong></td>
</tr>
<tr>
<td>Fill A</td>
<td>Fill B</td>
<td>Fill C***</td>
<td>Fill A</td>
<td>Fill B</td>
</tr>
<tr>
<td><strong>&lt; 3</strong></td>
<td><strong>&lt; 6</strong></td>
<td>0.4</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td><strong>3-6</strong></td>
<td><strong>6-15</strong></td>
<td>0.3</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td><strong>&gt; 6</strong></td>
<td><strong>&gt; 15</strong></td>
<td>0.2</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

* Fill A: Round Gravel  Ø≤150mm ** Fill B: Coarse Gravel  Ø≤150mm *** Fill C: Other cover materials, Round or Coarse (broken natural stone etc.)

[1] SVG, The Swiss Confederation of geotextile experts - The geotextile manual, 2001 (in German)

The read values for Tₚ, ε and Fₚ are minimum values while the read value for Dc is a maximum value. All these requirements have to be fulfilled to ensure that the geotextile will function as intended.
Fibertex Geotextiles for Drainage

**Non-stressed drains**

To endure installation, the following requirements for the mechanical properties for non-stressed drains (e.g., wall drains) are to be fulfilled:

<table>
<thead>
<tr>
<th>Fibertex Geotextiles for Drainage</th>
<th>Table 5. Mechanical properties required to endure installation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>T [KN/m]</td>
<td>ε [%]</td>
</tr>
<tr>
<td>Vertical drain</td>
<td>8</td>
</tr>
</tbody>
</table>

[1] SVG, The Swiss Confederation of geotextile experts - The geotextile manual, 2001 (in German)

**Required hydraulic properties**

To function correctly, the characteristic opening size has to match the soil conditions. If the characteristic opening size is too large, the soil particles will pass through the geotextile, whereas if it is too small, the water flow will be insufficient. The important hydraulic parameters of the geotextile are:

- **qp:** In plane water flow capacity [m^2/s] (Minimum value) According to EN ISO 12958
- **O_{90%}** Characteristic opening size [μm] According to EN ISO 12956
- **kₙ** Coefficient of permeability normal to the plane [m/sec] (Minimum value) According to EN ISO 11058

When constructing drains, the geotextile can be placed in a vertical, horizontal or inclined position. To ensure an ongoing drainage function, the in plane water flow capacity, characteristic opening size and coefficient of permeability have to be sufficient.

**In plane water flow capacity, q_p**

The required in plane water flow capacity is calculated on the basis of the amount of water to be drained. The in plane water flow capacity is expressed as an amount of drained water within a given time in a given width of the geotextile [m^3/sec/m = m^2/sec]. The necessary in plane water flow capacity q_p can be found as:

\[ q_p = \frac{Q}{W \cdot i} \]

Where,

- **Q:** amount of water to be drained in the full width of the drain [m^3/sec]
- **W:** width of the drain [m]
- **i:** hydraulic gradient (h/l) see fig. 9. [-] (i=1 for vertical drains)

\* 1 m^3/sec = 3.6E6 L/h/m ⇒ 1 L/h/m = 2.78E⁻⁷ m^2/sec

To ensure ongoing drainage, a safety factor is often added to the in plane water flow by multiplying by 1.5. This safety factor should be evaluated on the basis of the soil conditions and the desired service life.

**Fig. 9. Calculation of the hydraulic gradient for inclined drains.**
Characteristic opening size, $O_{90\%}$

Design value of the characteristic opening size, $O_{90\%}$, for coarse soil ($d_{40\%} > 60 \mu m$):

Uniformly-graded subsoil, $U$ ($d_{60\%}/d_{10\%}) < 3$:

$$O_{90\%} < 2.5 \cdot d_{50\%}$$

Well-graded subsoil, $U$ ($d_{60\%}/d_{10\%}) \geq 3$:

$$O_{90\%} < 10 \cdot d_{50\%}$$

Design value of the characteristic opening size, $O_{90\%}$, for fine soil ($d_{40\%} < 60 \mu m$):

$$50 \mu m \leq O_{90\%} \leq 10 \cdot d_{50\%} \leq 110 \mu m$$

The lower of the two values from the upper limit is chosen.

Coefficient of permeability, $k_n$

The coefficient of permeability normal to the plane of the geotextile must be larger than the permeability of the soil:

$$k_{n,\text{geotextile}} > k_{n,\text{soil}}$$

To ensure water flow, a safety factor is often added to the coefficient of permeability of the soil by multiplying by 1-100. This safety factor should be evaluated on the basis of the soil conditions and the desired service life.
Geotextiles are widely used for protection in waste disposal systems and tunnel constructions to ensure the integrity of a sealing material (e.g. geomembrane) when fill material and/or loads are applied. In the EN ISO standards the protection function is defined as "The prevention or limiting of local damage to a given element or material by the use of a geotextile".

**Combined function of the geotextile**

A geotextile often has several functions in the same construction. For example it can protect a membrane and at the same time, drain water in its plane. In this case, puncture resistance is important for the protection function and as described in the Drainage section, the hydraulic properties are important in order to drain water.

The different values should be combined, so that the most stringent requirements are indicated in the specification.

**Geotextile properties**

As the sole purpose of this function is to protect a given element or material, the mechanical properties are essential, whereas the hydraulic properties are of less importance. The geotextile must withstand and distribute any local pressure from the layer above, ensuring that the protected material is not stressed to failure.
Important mechanical properties of a protection geotextile:

- **D<sub>c</sub>:** Dynamic perforation (cone drop test) [mm] (Maximum value)
  According to EN 918

- **F<sub>p</sub>:** Static puncture resistance (CBR-test) [N] (Minimum value)
  According to EN ISO 12236

- **d:** Thickness at 2 kPa [mm] (Minimum value)
  According to EN 964-1

The requirements for the properties are influenced by the following properties of the supporting soil:

- **Grading:** XX/YY means that all particles have grain sizes between XX and YY [mm] (e.g. 4/8)

- **p:** Pressure from the overlying materials (e.g. waste and drain materials)

Based on the grading of the sand/gravel and the pressure from the overlying layers, the properties required of a geotextile for protection can be read from fig. 12.

Fig. 12. **D<sub>c</sub>, F<sub>p</sub> and d** can be read when a straight line is drawn from the sand/gravel axis to the overlay pressure axis.

* 1 kg vertical pressure ≈ 10N = 0.01 kN

[2] DS, Danish standardisation association – DS/INF 466, 1999 (in Danish)

The read values for **F<sub>p</sub>** and **d** are minimum values, while the read value for **D<sub>c</sub>** is a maximum value. All these requirements have to be fulfilled to ensure that the geotextile will function as intended.
Fibertex Geotextiles, Fibertex Fiberforce and Fibertex GeoGrid for Reinforcement

■ To avoid collapse of vertical soil walls or steep soil slopes
■ To avoid rutting when dealing with poor subsoils

For minor reinforcement jobs, nonwoven Fibertex Geotextiles can be sufficient, but generally the reinforcement function calls for more rigid materials than nonwoven geotextiles. The excellent elongation properties of nonwoven Fibertex Geotextiles are not appropriate with the reinforcement function, which is why Fibertex Fiberforce, Fibertex HS woven and Fibertex GeoGrid should be considered for larger projects. Fibertex Fiberforce is a nonwoven geotextile strengthened with a woven structure to maintain the good separation and filtration properties of the Fibertex Geotextile and to increase the tensile strength and to decrease the elongation properties significantly. Fibertex HS woven is a woven geotextile made from 100% polyester. It is used solely for reinforcement and has a high modulus (high strength at low elongation), making it suitable for reinforcement as hydraulic properties are not in focus. Fibertex GeoGrid is a 100% polyester grid solely for reinforcement. It has a large mask width, and consequently it should be combined with a nonwoven geotextile for separation.

In the EN ISO standards the reinforcement function is defined as “The use of the stress-strain behaviour of a geotextile or a geotextile-related product to improve the mechanical properties of soil or other construction materials”.

Geotextile properties

When dealing with reinforcement, the important parameters are tensile strength and elongation. Normally, a max elongation of 12% is specified for large projects, but for minor projects (e.g. small slopes) elongation is of less importance.
Minor slopes with nonwoven Fibertex Geotextiles

Nonwoven geotextiles should not be used for reinforcement of steep and high slopes, see max slope sizes for nonwoven geotextiles in Fig. 13. The lateral (horizontal) earth pressure can be found as:

\[ \sigma_h = K \cdot (\gamma \cdot h + q) \]

Where,

- \( \sigma_h \): the total lateral earth pressure on the slope [kN/m²]
- \( K \): the lateral earth pressure coefficient (Horizontal pressure in percent of the vertical pressure) [-] (can be read from Fig. 17 on page 21.)
- \( \gamma \): the unit weight of the fill material [kN/m³]
- \( h \): the vertical height of the slope [m]
- \( q \): the surcharge load [kN/m²]

When the total horizontal pressure on the wall is known, a suitable geotextile can be found. The number of reinforcement layers depends on the strength of the geotextile as shown in the equation below.

\[ n = \frac{\sigma_h \cdot f_s}{T_f} \]

Where,

- \( n \): the number of reinforcement layers [-]
- \( \sigma_h \): the total lateral earth pressure on the slope [kN/m²]
- \( f_s \): a safety factor, normally 4-5 for minor slopes. [-]
- \( T_f \): the tensile strength at break of the geotextile [kN/m] (According to EN ISO 10319)

Now the only parameter to be determined is the anchoring length. Knowing the slope height and angle it can be read from Fig. 14.
Steep reinforced slopes

The design of a steep reinforced slope can be divided into four stages:

1. Calculation of the total earth pressure
2. Choice of reinforcement
3. Determination of reinforcement spacing
4. Determination of reinforcement anchoring length

1. Calculation of the total earth pressure

The vertical pressure from the soil and a possible surcharge, \( \sigma_v \), is used later to calculate the necessary anchoring length:

\[
\sigma_v = q + \gamma \cdot z
\]

Where,

- \( \sigma_v \) the vertical earth pressure [kN/m²]
- \( q \) the surcharge load [kN/m²]
- \( \gamma \) the unit weight of the fill material [kN/m³]
- \( z \) the vertical distance from the top of the slope to the depth in question [m]

The total lateral (horizontal) earth pressure can be calculated as a percentage of the total vertical earth pressure. This percentage is called the lateral earth pressure coefficient, \( K \):

\[
\sigma_h = K \cdot \sigma_v = K \cdot (q + \gamma \cdot z + P \cdot x^2 \cdot \frac{z}{R^2})
\]

Where,

- \( \sigma_h \) the lateral (horizontal) earth pressure [kN/m²]
- \( K \) the lateral earth pressure coefficient [-]. See fig. 17
- \( \varphi \) the angle of internal friction in the fill material [˚]
- \( \gamma \) the unit weight of the fill material [kN/m³]
- \( z \) the vertical distance from the top of the slope to the depth in question [m]

---

**Fig 15. Reinforced slope**

**Fig 16. Total earth pressure**
2. Choice of reinforcement

Based on the calculations, a Fibertex reinforcement is chosen, and the design long-term tensile strength of the product, \( T_{lt} \), is calculated:

\[
T_{lt} = \frac{T_k}{f_c \cdot k_i \cdot k_d \cdot \gamma_m}
\]

Where,

- \( T_{lt} \): the long-term tensile strength of a reinforcement product [kN/m]
- \( T_k \): the short-term tensile strength of a product (see datasheet) [kN/m]
- \( f_c \): the creep reduction coefficient [-] (1.6 for Fibertex reinforcement)
- \( k_i \): the installation damage coefficient [-] (see table 6)
- \( k_d \): the chemical degradation coefficient [-] (1.1 for Fibertex reinforcement)
- \( \gamma_m \): the partial material coefficient [-] (normally set to 1.4 for material security)

### Table 6. Recommended installation damage coefficients for various fill materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>( k_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay/silt</td>
<td>1.1</td>
</tr>
<tr>
<td>Sand</td>
<td>1.2</td>
</tr>
<tr>
<td>Gravel (natural)</td>
<td>1.3</td>
</tr>
<tr>
<td>Crushed gravel</td>
<td>1.4</td>
</tr>
<tr>
<td>Crushed rock</td>
<td>1.5</td>
</tr>
</tbody>
</table>

![Lateral earth pressure coefficient at different pore water pressure (\( r_u \)).](image)

Fig 17. Lateral earth pressure coefficient at different pore water pressure (\( r_u \)). [Jewel, 1990]
3. Reinforcement spacing

The reinforcement spacing, \( S_v \), at a given depth, \( z \), is calculated by:

\[
S_v = \frac{T_{lt}}{\sigma_{h,z}}
\]

Where,

- \( S_v \): the reinforcement spacing [m]
- \( T_{lt} \): the long-term tensile strength of a product [kN/m]
- \( \sigma_{h,z} \): the lateral (horizontal) earth pressure at the depth \( z \) [kN/m²]
- \( z \): the vertical distance from the top of the slope to the depth in question [m]

In theory the height of each reinforcement layer, also referred to as spacing, should be calculated individually to minimize product consumption. However, in practice this is extremely work intensive/time-consuming, so normally calculation of the spacing is done in 4-5 intervals throughout the entire construction. Knowing the total height of the finished slope, a spacing matching the stresses on the bottom is chosen. This spacing is held for a given height, until a new spacing matching the stresses at this height is calculated and so on.

The reinforcement spacing must not exceed 1 m. If the stresses at the top are very low, the equation will compute a higher spacing which must be regulated to 1 m. The distance from the top where a spacing of 1 m is sufficient, can be calculated as:

\[
z = h - \frac{(T_k - \sigma_{h,\text{bottom}})}{\sigma_{h,\text{top}} - \sigma_{h,\text{bottom}}} \cdot h
\]

Where,

- \( z \): the vertical distance from the top of the slope to the depth in question [m]
- \( h \): the vertical height of the slope [m]
- \( T_k \): the long term tensile strength of a product [kN/m]
- \( \sigma_{h,\text{bottom}} \): the lateral (horizontal) earth pressure at the bottom of the slope [kN/m²]
- \( \sigma_{h,\text{top}} \): the lateral (horizontal) earth pressure at the top of the slope [kN/m²]

4. Anchoring length

The anchoring length is determined by one of two different situations. The length needed for internal stability and the length needed for external stability. The greater of the two anchoring lengths will be the design anchoring length.

**Internal stability**

\[
L = L_A + L_c
\]

Where,

- \( L \): the total anchoring length [m]
- \( L_A \): the anchoring length before the potential failure plane [m]

\[
L_A = \left( \tan \left( \frac{45 - \frac{\rho}{2}}{2} \right) - \tan \left( 90 - \beta \right) \right) \cdot h
\]
Table 7. Recommended friction reduction coefficients for various fill materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>α</th>
<th>0.7</th>
<th>0.7</th>
<th>0.7</th>
<th>0.8</th>
<th>0.8</th>
</tr>
</thead>
</table>

External stability

The greater of the two anchoring lengths read in fig. 19 for direct sliding and overall stability is the minimum anchoring length for external stability.

Fig. 19. The relation between the anchoring length and the slope height for the overall stability and direct sliding at different pore water pressure. [Jewel, 1990]
www.fibertex.com

Visit our website for detailed information on Fibertex Geotextiles. Enter the “Construction” area. Here you will find our product range, datasheet, brochure downloads and contact information with e-mail addresses.

Facts about Fibertex

Fibertex is a market leading manufacturer of needlepunch and spunbond/spunmelt nonwovens. Based in Aalborg and with production facilities both in Aalborg and in Kuala Lumpur, Malaysia. Since the foundation in 1968 Fibertex has undergone continuous expansion and today nonwovens are manufactured for customers all over the world and for many different applications. Our main application areas are Personal Care, Furniture and Bedding, Flooring, Construction, and special areas such as Packaging, Filtration, Automotive, Horticulture and Do-it-Yourself.

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