Introduction

The use of geosynthetics in the construction of transportation structures is diverse, both for temporary and permanent structures with mainly dynamic traffic loads. The goal is to improve the load-bearing capacity. Besides the classical geotextile functions of separation and filtration, a reduction in deformations and in absolute and differential settlements are of importance, especially on soils of low bearing capacity and high compressibility.

Applications

In many cases, even a base-course thickness of 1 m over an extremely weak subgrade does not guarantee adequate bearing capacity and/or the required degree of compaction.

The use of a geosynthetic reinforcement layer between the subgrade and the base course, or in the lower half of the base course, provides the following benefits:

- Reduction of the base-course depth required to achieve the specified degree of compaction and bearing capacity.
- Reduction of the rut depth, depending on the traffic load applied.
- Increase in the service life of transportation structures.

The following main fields of application can be distinguished:

Permanent applications

- Reinforcement of the base course of a permanent road, usually with a standardised pavement structure with the goal of an improvement and homogenisation of bearing capacity and deformations, thereby increasing the service life of the structure.

Temporary applications

- Reinforcement of a working platform for heavy construction equipment
- Reinforcement of the base course for a temporary access road with or without a pavement both with the aim of saving granular fill material.
Geosynthetics in the Design of Unpaved Road Structures

General

Unpaved roads are mainly constructed for temporary purposes, as is the case with access roads or working platforms, but they may also be permanent, in cases such as agricultural and forestry roads.

The goal of using high-strength geosynthetics is to improve the practical performance of the road. For the same number of vehicle passes, the permissible axle loads can be increased, and at the same time deformations can be reduced. Alternatively, the required base-course thickness can be reduced. In the case of extremely weak subgrades, even walking on the subgrade is impossible without a geosynthetic.

Functions of Geosynthetics

The bearing capacity of the subgrade and the hydrologic conditions will determine which functions the geosynthetic will fulfil.

Depending on the type of subsoil, the geosynthetic will fulfil a separation function, maintaining the thickness and the properties of the base course. An additional reinforcement function is required to reduce deformations. The lower the bearing capacity of the subgrade, the greater the importance of the reinforcement function, whereas higher bearing capacities will emphasise the separation function.

For the correct choice of the appropriate geosynthetic, the hydrologic conditions must be considered as well. When the dissipation of pore water is essential, the filtration function of the geosynthetic is another important criterion.

Separation and reinforcement are "overlapping" functions; however, a limit value of subgrade bearing capacity can be defined, above which the improved performance of the structure is due solely to the separation function. Based on experience, a deformation modulus (initial loading curve) of $E_{V1} \geq 5 \text{ MN/m}^2$ has been established. In English-speaking countries, this corresponds to a California Bearing Ratio CBR $\geq 3\%$.

Comparison of different parameters for the bearing capacity of subgrades acc. to HAASE (2004)

<table>
<thead>
<tr>
<th>SOIL</th>
<th>very soft</th>
<th>soft</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{V1} (\text{MN/m}^2)$</td>
<td>1 2 3 4</td>
<td>5 6 7</td>
</tr>
<tr>
<td>CBR (%)</td>
<td>1 2</td>
<td>3 4</td>
</tr>
<tr>
<td>$E_{V2} (\text{MN/m}^2)$</td>
<td>10 15</td>
<td>20</td>
</tr>
<tr>
<td>$c_u (\text{kN/m}^2)$</td>
<td>30 60</td>
<td>90 120</td>
</tr>
</tbody>
</table>
Geosynthetics in the Design of Unpaved Road Structures

The following criteria must be considered in the selection of a reinforcement product:

- axle load of the construction vehicles
- expected traffic (number of passes) during the working life of the road
- permissible rut depth in the base course
- bearing capacity of the subgrade (e.g. EV₁, CBR, …)

Influence of the Geosynthetic on the Bearing Capacity

In general, the bearing capacity is influenced by the depth of the base course, and the shear strength of both base course and subgrade. These values depend on the degree of compaction which can be achieved.

On the one hand, the installation of geosynthetic reinforcement increases the bearing capacity of the system by introducing a restraining tensile force. On the other hand, the load distribution is improved, resulting in a reduction of vertical stress on the subgrade.

In order to activate tensile forces in the geosynthetic, some deformation is required. In general, the deformation of the system is limited by the allowable rut depth. For temporary construction roads, a rut depth of 100 mm should not be exceeded. If this road is subsequently to be part of a paved road, the rut depth should be limited to 50 mm.

Design

The design methods developed for this field of application is mainly based on empirical results obtained from practical experience. The following table, and the design curves obtained using the Giroud/Noiray method (1981), have been drawn up to assist the design engineer in the choice of the appropriate geosynthetic.

<table>
<thead>
<tr>
<th>Subgrade Bearing Capacity</th>
<th>EV₁ [MN/m²]</th>
<th>0.5 - 1.5</th>
<th>1.5 - 2.5</th>
<th>2.5 - 5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR [%]</td>
<td></td>
<td>0.5 - 1.0</td>
<td>1.0 - 1.5</td>
<td>1.5 - 3.0</td>
</tr>
<tr>
<td>Consistency</td>
<td></td>
<td>liquid</td>
<td>viscous</td>
<td>soft</td>
</tr>
<tr>
<td>visual appearance</td>
<td></td>
<td>standing person sinks &gt; 75 mm</td>
<td>walking person sinks 40 - 75 mm</td>
<td>walking person sinks &lt; 40 mm</td>
</tr>
<tr>
<td>required functions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended Geosynthetic</td>
<td>separation filtration</td>
<td>Rock PEC 75/75</td>
<td>Rock PEC 55/50</td>
<td>Rock PEC 35/35</td>
</tr>
<tr>
<td>separation reinforcement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>recommended minimum fill thickness</td>
<td></td>
<td>0.2 m</td>
<td>1.0 m</td>
<td>2.0 m</td>
</tr>
</tbody>
</table>

Design of unpaved roads, with or without reinforcement, rut depth ≤ 100 mm

Design of unpaved roads, with or without reinforcement, rut depth ≤ 50 mm
Geosynthetics in the Design of permanent Paved Roads

General

In permanent road construction, standardized cross sections and layer thicknesses are defined based on decades of practical experience. In general, a certain minimum value of subgrade bearing capacity is required.

If the in-situ subgrade does not reach these values, appropriate measures must be taken to improve it. In such cases, the recommendations regarding the selection of geosynthetics for unpaved roads can be used.

A guide to product selection in combination with the design diagram is given in the table below.

For subgrades with extreme low bearing capacity (CBR ≤ 1,5%) the use of an additional geogrid layer in the base course is recommended in order to improve the stiffness of the entire structure. The geogrid should be positioned under the final fill layer.

<table>
<thead>
<tr>
<th>Subgrade bearing capacity</th>
<th>0.5 - 2.5</th>
<th>2.5 - 5.0</th>
<th>5.0 - 9.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR [%]</td>
<td>0.5 - 1.5</td>
<td>1.5 - 3.0</td>
<td>3.0 - 5.0</td>
</tr>
</tbody>
</table>

Recommended Geosynthetic

- **separation**
  - Rock PEC 75/75
  - Rock PEC 55/50
  - Rock PEC 35/35

- **reinforcement**
  - Geolon PP 120S
  - Geolon PP 80
  - Geolon PP 60

- **reinforcement**
  - Miragrid GX 35/35

Recommended product based on the subgrade bearing capacity

Reinforced soil-improvement layer for paved roads

In contrast to unpaved roads, the long-term behaviour plays a decisive role in classified road construction. The geosynthetic must improve the stability of the entire structure whilst minimising deformations. For this criterion, the stress-strain-performance (or stiffness modulus) is of great importance.

Design

There are no generally accepted methods for the calculation of base-course thickness and the expected bearing capacity with geosynthetics, as common theoretical models cannot fully take account of the inhomogeneity and anisotropy of the soil. In the Swiss Geotextile Manual (SVG 2003) empirical values for the required thickness of soil replacement layers to achieve a bearing capacity of $E_{V2} = 45 \text{ MN/m}^2$ are documented (see diagram).

![Diagram of pavement structure with geosynthetic layers]

Base-course depth required to achieve a given bearing capacity with and without reinforcement ($E_{V2}$ 45 MN/m² = CBR 12.5% and $E_{V2}$ of 80 MN/m² = CBR 15%)

For larger projects we recommend on-site full-scale tests in order to confirm the improvement in bearing capacity.