

Geosynthetics in geotechnical and hydraulic engineering

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Abstract

Although geosynthetics in the form of, for example, geotextiles and geomembranes have been used in geotechnical and hydraulic engineering since 1957, they must be considered as comparably new construction materials. Over the last few years, the field of geosynthetic applications has expanded constantly, and their use, based on technical and economical advantages, compared to conventional building materials has increased steadily. They are used in coastal protection, agricultural waterway engineering, waterway engineering, railway construction, road and tunnel construction, waste management, as well as on the construction of dams and covering tailings.

After a short description of basic parameters and terms, the use of geosynthetics in their different functions and applications will be described (see also Saathoff/Zitscher 2001).

1 Basic parameters and terms

The development of geosynthetic applications in geotechnical and hydraulic engineering has been very rapid. In the beginning the terms filter mats and woven geotextiles were used for all water-permeable geosynthetics, and the term membrane was used for all water-impermeable geosynthetics.

To follow the development of geosynthetics and its recent applications *EN ISO 10318* was introduced in 2000, subdividing geosynthetics as shown in figure 1. Pipes, manholes and other elements in civil engineering, which are also made from plastic (in the sense of polymer/synthetic materials), are not to be included under the term “Geosynthetics”. On the other hand geotextiles made from natural fibres (depending on their use and compared to synthetic geotextiles using similar or identical production techniques) can be associated with the term “Geosynthetics”.

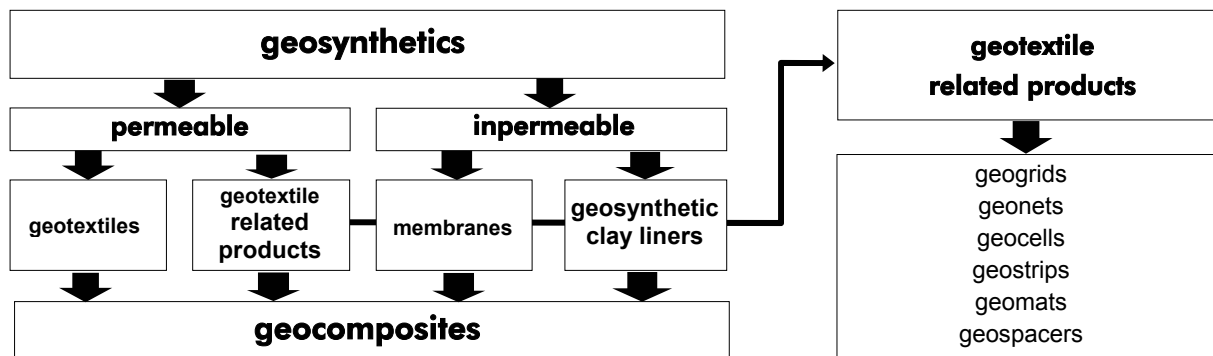


Figure 1: Subdivision of geosynthetics

For the different applications, a wide variety of different products is available. Product selection always demands the verbalisation of the application specific requirements. Due to the current strict long term stability requirements, the synthetic raw materials polyethylene, polypropylene, polyester, polyamide and polyacrylnitrile are used for geotextiles and geotextile-related products. When evaluating the long term stability, one must take into consideration that with increasing yarn thickness the risk of damage decreases and the properties of single raw materials can be improved by stabilisers.

2 Functions

2.1 Overview and Geosynthetic Systems

Geotextiles are used for the functions

- filtration,
- drainage,
- separation,
- reinforcement,
- packing and
- protection (including erosion control).

A geosynthetic often has to fulfil several of these functions at the same time. Combining geosynthetics results in application- and requirement-specific geosynthetic systems, exemplary shown in figure 2.

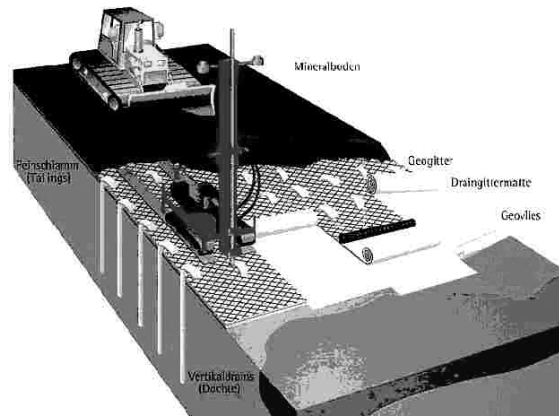


Figure 2: Geosynthetic system capping a tailings pond at WISMUT (BMW, 2000)

2.2 Filtration

Filters are mainly used in hydraulic engineering and drainage systems to retain solid components, whilst allowing liquids to pass almost freely perpendicular to the filter plane. For physical reasons, a filter must fulfil contradictory requirements, namely, the mechanical filter effectiveness (soil retention capacity) and the hydraulic filter effectiveness (water drainage with low pressure loss, i.e. small hydraulic gradients).

The soil retention capacity may be described, inter alia, by the characteristic opening size O_{90} . Wovens and thermally bonded nonwovens are comparable to sieves with uniform or non-uniform openings. The affinity for granular filters is only attained through the *filtration length/thickness* of mechanically bonded nonwovens and composite materials. The thickness and pore structure of a geotextile should guarantee a depth filtration analogous to a mineral grain filter and prevent the formation of a filter cake on the contact surface between the soil and the filter. *The characteristic opening size O_{90} alone is therefore insufficient for determining the filter stability.* Filtration rules can, for example, be found in Zitscher (1993).

2.3 Drainage

Drainage is the surface collection of liquids or gases which have to be discharged.

In engineering applications mineral seepage systems with embedded drainage pipes are often encased in a geotextile to guarantee a filter stable separation against the soil and an additional hydraulic effectiveness. Drainage systems are supplied as single elements or composites consisting of at least one filtering layer and one percolation layer. The latter absorbs the liquid and discharges it with a minimum loss of pressure.

A geosynthetic drainage system consists of a drainage core, which absorbs water at right angles to its horizontal plane and transports the water within the latter, combined with a filter layer which prevents clogging of the drainage core. Composite materials and composite structures are especially suitable for this purpose.

Geosynthetic drainage elements offer the ability to be used as vertical drains, dewatering sludge and tailings. The current state of dimensioning vertical drains is presented by Kirsch & Sondermann (2001).

2.4 Separation

Geotextiles separate adjacent soil types or fill materials to prevent them from becoming intermixed. When employing geotextiles as separating layers, the main factors to be considered are the mechanical filter effectiveness and the mechanical loading on the

geotextile. The permeability of the geotextile promotes the consolidation of the boundary layer.

This critical mechanical stress caused by single grains as well as by stress due to deformations of the interface cannot be designed. Empirical site specific perceptions are therefore often used for a “design” or a “classification”. The German standard definition of "Geotextil Robustheits Klasse" (GRK), developed for road applications, has found international acceptance. By empirical findings and definitions of criteria for e.g. mass, strength, puncture resistance etc. different geotextile groups can be classified (*Wilmers & Saathoff 1995*).

2.5 Reinforcement

When used for reinforcement purposes, geotextiles -especially wovens- and geotextile-related products -especially geogrids- and composites are placed below or between soil layers to take up tensile forces and thereby improve their mechanical properties. The elongation of these products therefore has to be considered at low stresses as well as under constant loading (creep tendency). The reinforcing element has to absorb the required tensile forces at acceptable deformations in the long term.

The use of geosynthetic reinforced soil structures has now been successfully practised for more than 30 years. They are preferably used in retaining structures based on the principle of “reinforced earth”, or for stabilising embankments on soils with a poor load-bearing capacity. Geotextiles and geogrids are also used to increase the stability of load bearing layers in road and railway construction as well as for capping systems on very poor soils. The transition from the “separation” function to the “reinforcement” function can be smooth. The geotextile-soil-interaction cannot currently be described using known soil mechanic approaches. An overview about the current state of the art for calculations can be found in the *Secugrid-Manual (2001)* (fig. 3).

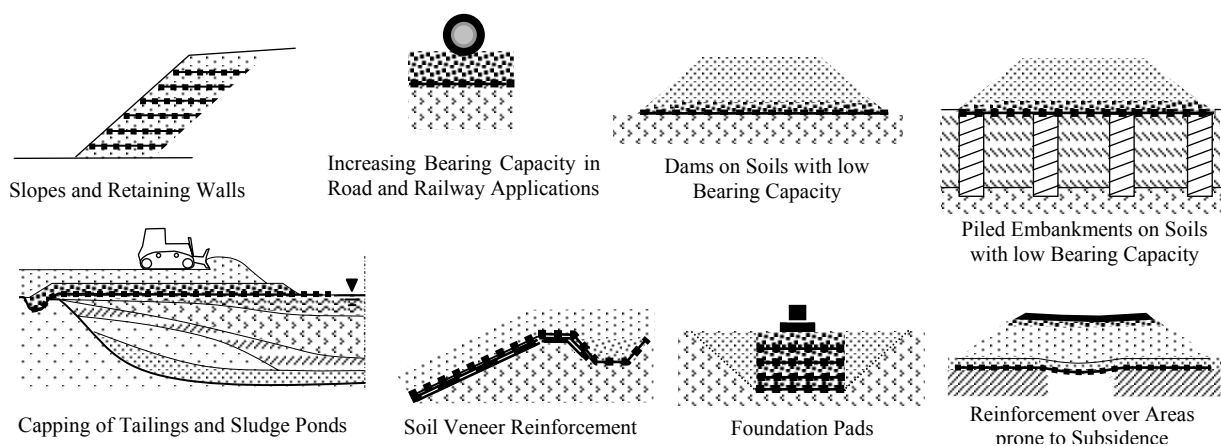


Figure 3: Application and variability of reinforced soil

2.6 Packing

In geotechnical and hydraulic engineering, earth materials in particular are “packed” in flexible tubes, sacks and containers. Such large format construction elements allow the use of soils available on site, which would otherwise be useless. The particle size distribution of the soil, the physical dimensions of the construction elements and the installation and long term loads determine the requirements of the geotextile to be used.

Here the geosynthetics perform separating, filtering, protecting and/or reinforcing functions, depending on the type of application involved. The materials used include nonwovens, wovens, geogrids and composites.

2.7 Protection

Geotextiles can be used as protection layer for geomembranes, for coated components or other structural parts, which are vulnerable to mechanical damage from sharp edged unevenness of the subsoil, the fill material or the cover soil. The effectiveness of the protection against sharp-edged irregularities of the subsoil or the filling material depends on the thickness of the geosynthetics and their mass per unit area, as well as their resistance to perforation by impact or compression. Mechanically bonded nonwovens with a mass per unit weight of at least 400 g/m² are often well suited for this purpose.

The compatibility between the geomembrane and the geotextile and, where applicable, between the sealing paint and the geotextile has to be provided (*Saathoff 1991*).

2.8 Erosion control

Three-dimensional geosynthetics and composites prevent the removal of soil particles by water and wind. In nature, it is plants and their roots that prevent soil from being carried away. The natural formation of vegetation layers, which often takes years or is nearly impossible due to contamination, can be speeded up, supported or single given by the use of erosion control matting or geotextiles.

2.9 Sealing

Sealing is indispensable for environmental and ground water protection and contributes substantially to the fitness for purpose and service life of buildings, especially in waste management, tunnelling and hydraulic engineering, but also in the field of groundwater protection. Geomembranes of varying thickness, depending on the intended purpose, are used as barriers to liquids and gases mainly in landfills and tunnel construction and in hydraulic engineering. Geosynthetic clay liners as prefabricated high quality mineral sealing element can be used as economical alternative to natural mineral clay layers or as artificial reinforcement for geological barriers.

3 Literature

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