Civil engineering

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Building on sustainable ground.

Civil engineering

Naue geosynthetics may be used in various system solutions, such as in road construction to increase the bearing capacity and to reduce rutting ...

Geosynthetics are used in all fields of civil engineering to increase the safety and life span of structures in addition to satisfying necessary functions. These may include:

... on steep slopes to improve slope stability and erosion control, ...

separation, drainage, filtration, reinforcement, protection, sealing and erosion control. Geosynthetics can either replace or augment conventional construction methods.

... in the construction of transportation routes to seal the subgrade in sensitive groundwater protection areas ...

Compared to conventional construction materials, the use of geosynthetics has continually increased over the past few decades. Hence they have been included in several guidelines as state-of-the-practice materials. Their efficient installation results in rapid and economic construction and they help to preserve our precious natural resources. Project-specific geosynthetic designs also ensure long-term performance of the structure.

... in structural engineering to drain localised areas or surfaces while offering protection for existing waterproofing.

The following chapters will illustrate and explain the different geosynthetic fields of application as well as methods used to design with the various geosynthetic products available from Naue.

Geosynthetic functions

Sealing

Acting as liquid and gas barriers, geomembranes have become a fundamental component in civil engineering, due to the increased need for groundwater protection. High density polyethylene (HDPE) geomembranes, specifically those with a certification by government regulators and thicknesses of more than 1.5mm, are most commonly used. Personnel from those companies that have been approved by the certifying agency, are employed to both install and weld the geomembranes where an area needs to be sealed.
For sealing purposes in road construction and environmental protection, HDPE geomembranes and geosynthetic clay liners are gaining use due to the importance of a quality seal.

Protection

Geomembranes, structures, coated materials as well as related construction elements must often be protected from potential mechanical damage. Without suitable protection damage may occur from sharp edged objects such as stones due to the unevenness of the subsoil or even by the cover material. Mechanically bonded needle-punched nonwovens as well as composite materials manufactured from polypropylene (PP) or HDPE are commonly used for protection layers. Specific to nonwoven geotextiles, the protection function is directly related to the thickness and mass per unit area, as a heavier and thicker nonwoven is more likely to provide better protection.

Drainage

Drainage materials are required for the surface collection of precipitation, the subsurface collection and diversion of groundwater, the general collection of fluids and their discharge into a drainage system. Drainage systems are typically designed with individual material layers or in combination with other components to create pre-formed composite drainage elements. Composite drainage elements consist of at least one filter layer and one collection layer. The percolation layer is required for the flow and discharge of fluids at a collection point, without the build-up of pressure. Single and multiple component geosynthetic drainage systems made from high density polyethylene as well as polypropylene, often replace the conventional thick aggregate drainage layer.

Erosion control

Geotextiles or three-dimensional open structured geosynthetics can be used to minimise the movement of soil particles due to flow of water.
By preventing soil particles from being washed off slopes or channels, rapid vegetation is ensured when erosion control mats are used.

Reinforcement

Geosynthetics are installed beneath or between soil layers to improve the mechanical properties of soil layers by absorbing the tensile forces and minimising deformation. Geotextiles, geogrids and composite synthetic materials are used in applications such as retaining structures according to the principles of "reinforced soil", slope stabilisation or for foundation reinforcement of earthen dams where the subsoil exhibits poor bearing capacity. The use of geosynthetics for reinforcement applications minimises expensive constructive measures and can reduce soil intermixing eliminating the need for additional soil layers.

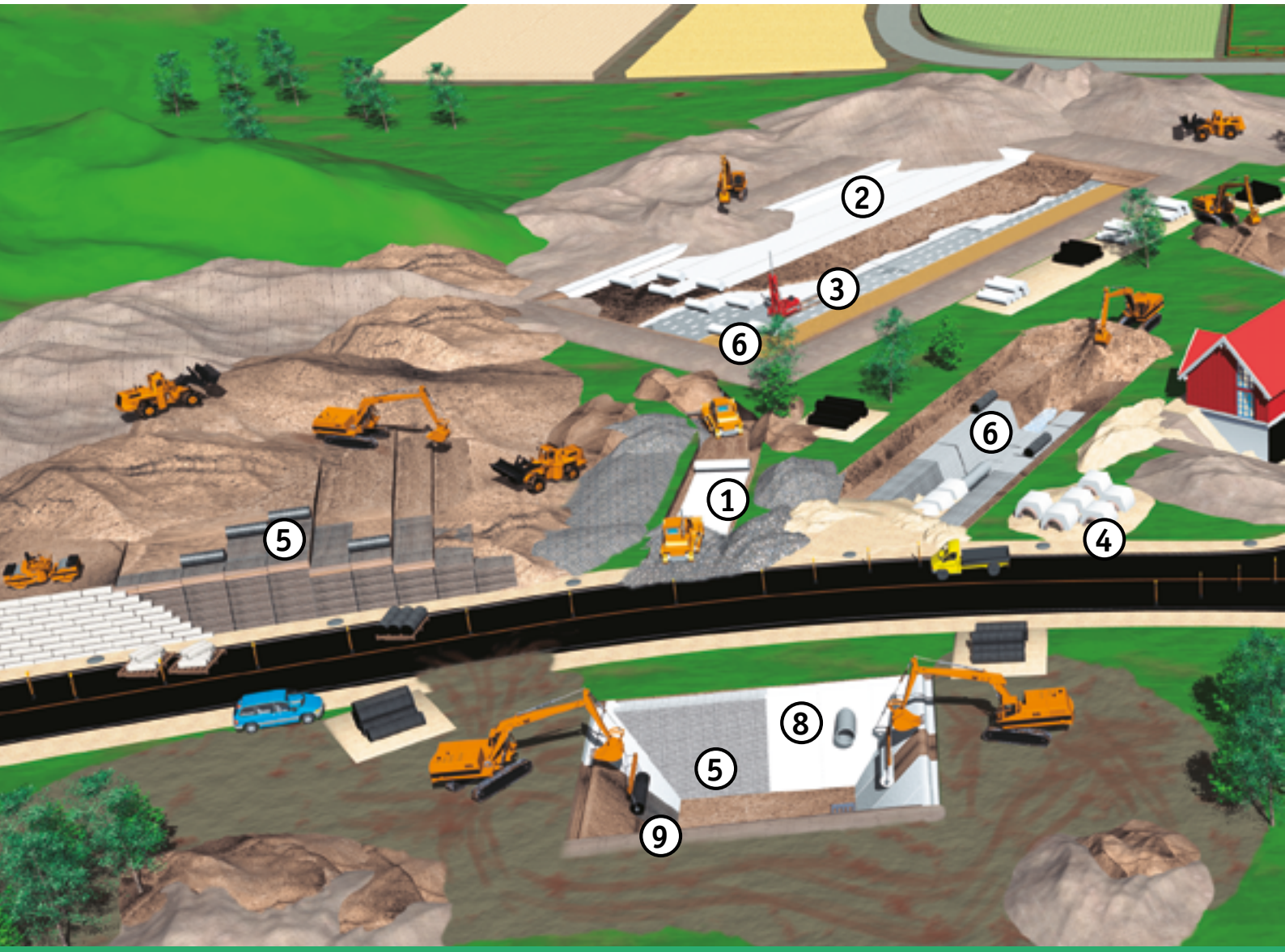
Separation

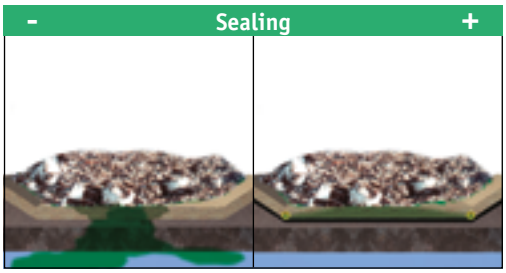
As a separation layer, geotextiles are used to prevent adjacent soil layers or fill materials from intermixing.
Synthetic nonwovens that exhibit an elongation capacity, are the materials of choice in most applications. The selection of a suitable product is dependant upon the base course grain size and the operational loads to be expected. The main use of separation nonwovens are in road and railway construction, hydraulic and landfill engineering and field construction.

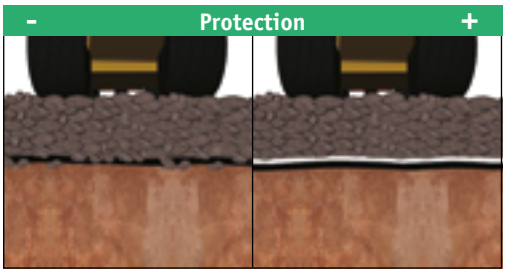
Filtration

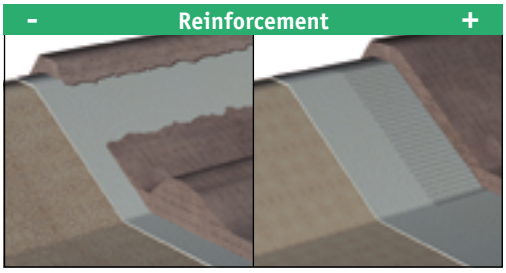
In filtration applications such as hydraulic engineering and drainage systems, nonwoven geotextiles are used to retain soil particles while allowing the passage of liquids through the filter media. There are two aspects to filtration that should be evaluated when designing. The mechanical filter efficiency (does the fabric have sufficient soil retention capacity) and the hydraulic filter efficiency (does the water discharge without a hydraulic pressure build-up).
As with aggregate filter layers, the geotextile thickness directly benefits the long-term mechanical and hydraulic efficiency of the filter.

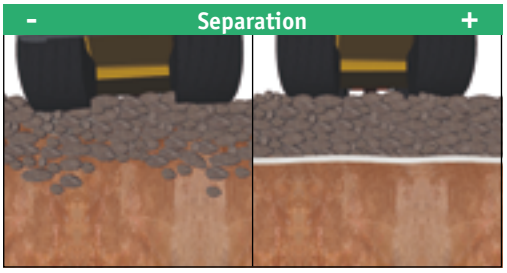
1 Separation with Secutex®
2 Filtration with Secutex®
3 Drainage with Secudrain®
4 Protection with Secutex®
5 Reinforcement with Secugrid®
6 Reinforcement with Combigrid®







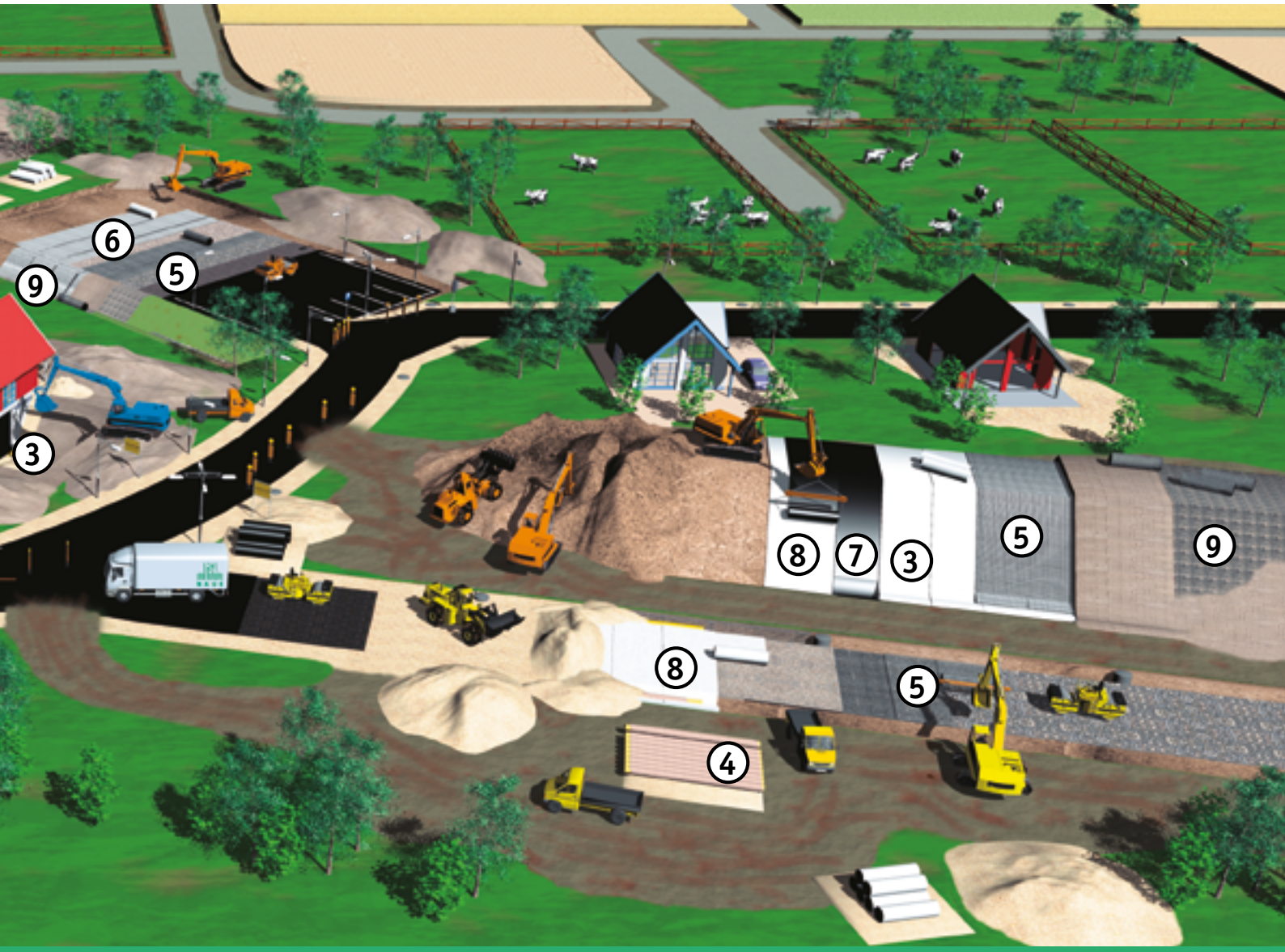


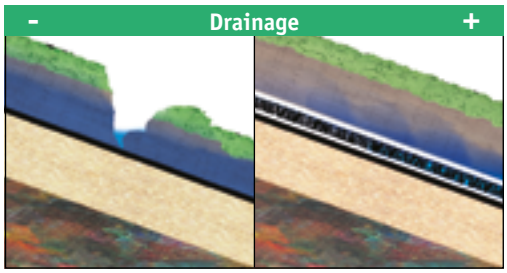


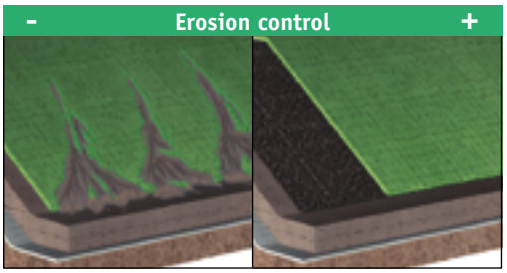
7 Sealing with Carbofol®

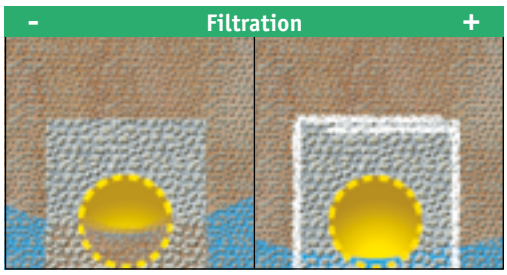
8 Sealing with Bentofix®

9 Erosion control with Secumat®









Naue

Separation with geotextiles

Secutex® needle-punched nonwoven geotextiles (some types are additionally calendered) are used in civil engineering applications for the separation of soil layers with different grain sizes. When correctly dimensioned and specified, Secutex® prevents soil layers from intermixing or from being penetrated if a cover is installed over a soil with poor bearing capacity.

Geotextile types

Depending on the expected formation of ruts, one of the most important criteria to consider when selecting a separation nonwoven geotextile is the mechanical load caused by single grains or stones in the cover material.

The selection of the geotextile types should be based on a classification of the cover material into the classes AS 1 to AS 5, and on the determination of the installation load (load case AB 1 to AB 5). Using these two parameters, the geotextile type can be determined according to table 1.

Elongation capacity

When applying additional earth layers over a soil with a poor bearing capacity, the elongation characteristics of the Secutex® nonwoven will minimise damage to itself during the installation process.

The high elongation capacity of the Secutex® nonwoven geotextiles ensures excellent resistance to damage. This characteristic of Secutex® products allows them to easily accommodate irregular or soft subgrades. Especially when covered with stone material, the Secutex® nonwoven geotextile fibres are reoriented around the stones, preventing damage to the nonwoven structure.

The cone drop test (EN 918) can be used to simulate the deployment of cover stone puncture loads on the separation nonwoven geotextile (see page 30). The high elongation of Secutex® ensures a high resistance against dynamic forces.

Durability

In general, the chemical resistance of the Secutex® nonwoven geotextile will exceed the expected service life of a structure. Using polypropylene (PP) resins ensure sufficient resistance to all natural soil and water chemicals or microorganisms.

Immediate covering is the best protection from UV radiation for all geosynthetic products. For typical German or Middle European conditions, Secutex® nonwoven geotextiles should not remain uncovered for longer than two weeks. UV stabilised Secutex® products are available to provide resistance to UV radiation damage for longer periods of exposure.

Mechanical filter effectiveness

When used in a separation function, the soil retention capacity (mechanical filter effectiveness) of the geotextile will in most cases play an important role in successful performance. Secutex® nonwoven geotextiles prevent interlayer mixing of dissimilar soils that are not filter-stable and ensures the long-term performance of the cover layer. The product selection approach is described in greater detail in the chapter titled "Filtration with geotextiles".

Conclusion

Environmentally durable PP Secutex® nonwoven geotextiles are used in embankments, for preventing soil exchange, under roads, along traffic routes, parking areas and wherever a long-term performance of the cover layer is required. With project-specific product selection, the robust characteristics of the Secutex® nonwoven geotextiles prevent the risk of intermingling and create the necessary filter stability between different soil layers.

Figure 1 **Secutex® used as separation geotextile between a pipe bedding and the silty subsoil**

Figure 2 **The high elongation capacity of Secutex® ensures excellent damage resistance**

Table 1
Determination of the geotextile type

		Stress loading conditions				
		AB 1: Manual soil placement, no compaction effects; no traffic	**AB 2:** Mechanical soil placement and compaction; < 5cm rutting from traffic	**AB 3:** Mechanical soil placement and compaction; 5cm - 15cm rutting from traffic	**AB 4:** Mechanical soil placement and compaction; 15cm - 30cm rutting from traffic *see also (b)*	**AB 5:** Mechanical soil placement and compaction; > 30cm rutting from traffic *see also (b)*
Application	**AS 1:** Installation method, load from cover soil and usage of the geotextile does not influence its selection	**R 151 C**				
	AS 2: Geotextile between fine and coarse/mixed soils (DIN 18 196)	**R 151 C**	**R 201 C**	**R 201 C**	**R 251 C**	**R 301 C**
	AS 3: Geotextile between fine and coarse/mixed soils with up to 40% cobbles or crushed material as defined in AS 2	**R 201 C**	**R 201 C**	**R 251 C**	**R 301 C**	**(a)**
	AS 4: Geotextile between fine and coarse/mixed soils with more than 40% cobbles and boulders or sharp-edged, crushed material as defined in AS 3	**R 251 C**	**R 251 C**	**R 301 C**	**(a)**	**(a)**
	AS 5: Geotextile between fine and coarse/mixed soils with more than 40% cobbles and sharp-edged boulders	**R 301 C**	**R 301 C**	**(a)**	**(a)**	**(a)**

a) To reduce rutting the thickness of the base course layer can be increased and/or the shear strength of the base course can be improved and/or the base course can be reinforced. Test trials can be carried out to prove the efficiency.
b) To ensure the separation performance products with a high elongation (≥ 50%) are recommended.

Figure 3 **Secutex® nonwoven geotextiles can resist high dynamic installation forces**

Figure 4 **Concrete placement over Secutex®, which acts as a separator, filter and drainage layer between the subsoil and the road**

Filtration with geotextiles

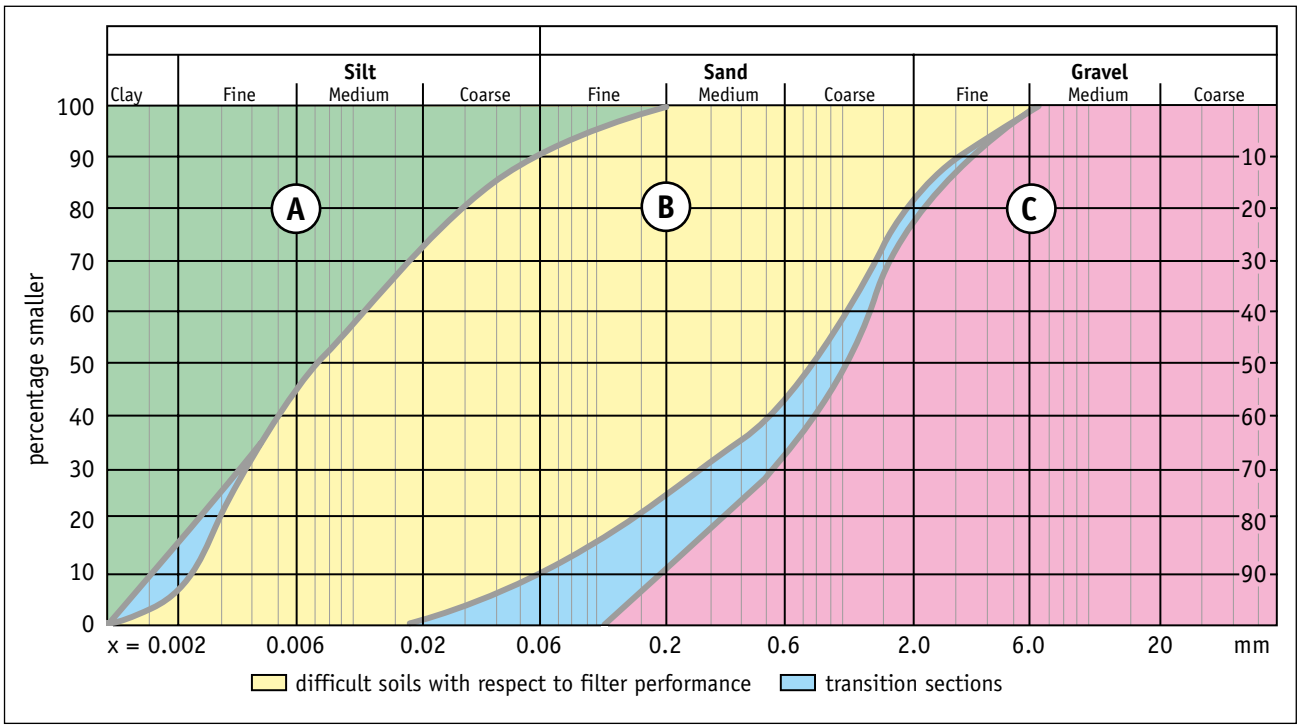
For decades Secutex® geotextiles have been used successfully as three-dimensional filters in earth and road construction. They are used between fine, coarse or mixed grained soils to provide filter stability between two distinct grain sizes.

Mechanical filter effectiveness

As with mineral filter layers, soil retention capacity also plays an important role when using Secutex® nonwoven geotextiles. Geotextile filters must be engineered such that the mechanical effectiveness as well as hydraulic filter effectiveness (water discharge without loss of pressure) are equally achieved. In the determination of the nonwoven geotextile maximum allowable effective opening size $O_{90,\ allow}$, product selection is differentiated by three different hydraulic safety conditions (I, II and III) for an easy filter calculation. However a detailed filter calculation based on national guidelines may supersede this easy filter calculation approach.

Hydraulic safety condition	Filtration condition	$O_{90,\ allow}$
I	· small water amount · single sided water flow · low hydraulic gradient	$0.06mm \leq O_{90,\ allow} \leq 0.20mm$
II	· small water flow in changing directions · medium water flow in one direction	Cohesive soils: $0.06mm \leq O_{90,\ allow} \leq 0.20mm$ Coarse silt - fine sand: $0.06mm \leq O_{90,\ allow} \leq 0.11mm$ Fine sand: $0.06mm \leq O_{90,\ allow} \leq 0.13mm$ Middle sand: $0.08mm \leq O_{90,\ allow} \leq 0.30mm$ Coarse sand: $0.12mm \leq O_{90,\ allow} \leq 0.60mm$
III	· single sided concentrated water flow · large water flow in changing directions · failure of geotextile filter endangers the design	Analysis of the hydraulic conditions and filter dimensioning carried out by an expert

Figure 5
Grain size distributions for soil types with distinct hydraulic behaviour



Design Cross sections Details

Figure 6 Secutex® as a geotextile filter in a retaining wall to prevent the washing out of fines at the front face

Figure 7 Secutex® geotextile filter ensures that the fines are not washed out of the filter dam

Based on filtration characteristics the grain size distribution area B from figure 5 is considered as a technically difficult soil to filter (risk of soil wash-out, failure of grain or geotextile filters and clogging of drainage layers). To ensure that the correct engineering approach is used to calculate the mechanical filter effectiveness, it should first be determined whether a hydrostatic or hydrodynamic load is present, and whether there is a soil with high single grain mobility. The criteria for such a soil are:

1. large portion of coarse silt and fine sand,
2. $U = d_{60} / d_{10} < 5$

some recommendations also consider these criteria:

3. more than 50% of the existing soil is in the range of 0.02mm to 0.1mm,

4. the plasticity index I_P for fine grained soils according to DIN 18196 (40% of the mass is smaller than 0.063mm) is smaller than 0.15 or the clay portion / silt portion < 0.5.

The soil retention capacity is sufficient if the allowable opening size of the geotextile filter $O_{90,\ allow}$ is determined as follows:

a) fine grained soils ($d_{40} \leq 0.06$mm)
$O_{90,\ allow} \leq 10 \bullet d_{50}$
restriction: for filter technically difficult soils
$O_{90,\ allow} < d_{90}$

b) coarse and mixed grained soils ($d_{40} \geq 0.06$mm)
$O_{90,\ allow} < 5 \bullet d_{10} \bullet \sqrt{U}$, or
$O_{90,\ allow} < d_{90}$ (smaller value is decisive)

The highest possible hydraulic efficiency of the Secutex® filter nonwoven geotextile is achieved when the selected opening size $O_{90,\ sel}$ is closest to the largest allowable value $O_{90,\ allow}$ (e. g. 0.8 to 1.0 • $O_{90,\ allow}$). Under no circumstances should this value be less than 0.2 • $O_{90,\ allow}$ as a deposition of fine soil particles on the geotextile surface could occur. Allowing a selected opening size $O_{90,\ sel}$ in the low range of $\geq 0.2 \bullet O_{90,\ allow}$ may only be excepted if the above deposition of fine particles as well as soil settlement in the drainage system does not effect the performance of the design. Another advantage of Secutex® nonwoven geotextiles is that the effective opening size will change only slightly when subjected to elongation stresses. Consequently, the filter dimensioning is also valid, even if a coarse grained material causes nonwoven geotextile deformation when being installed on a soft subgrade.

Hydraulic filter effectiveness

In the long-term, geotextile filters must have the same hydraulic conductivity as the soil to be drained or at least $1 \cdot 10^{-4}$ m/s. The value should be determined under the site confining stress and with a hydraulic gradient of i = 1. In this case a pressure build-up is avoided and free drainage is achieved. For Secutex® nonwoven geotextiles with a thickness of more than 2.0mm, the laboratory hydraulic conductivity coefficient in the past was reduced with a factor of 50 (η = 0.02), if the soil to be drained was a coarse silt or sand. In all other cases, a reduction factor of 100 (η = 0.01) was recommended. In these cases long-term hydraulic conductivity was assured if the geotextile hydraulic conductivity reduced by η, was larger than the hydraulic conductivity of the soil to be filtered. Therefore:

$$\eta \cdot k_{geotextile} \geq k_{soil}$$

Geotextile robustness classes (GRK)

Long-term performance can only be assured when the nonwoven filter geotextile is not damaged upon installation. Therefore, the German "Guidelines for the Application of Geotextiles and Geogrids in Earth Construction of Road Construction (M GeoK E), 2005" recommends a geotextile robustness class of at least GRK 3, and as high as GRK 5 for higher installation loads (see chapter "Separation with geotextiles").

Additional requirements

For Secutex® nonwoven geotextiles for filter applications, the same elongation capacity and resistance requirements are valid as those already described in the chapter "Separation with geotextiles".

Conclusion

Secutex® filter nonwovens are used in projects where filter stability between distinct soils does not exist. This is the case mainly in water collection systems, drainage systems, gabion retaining elements and most separation applications. Correctly selected Secutex® nonwoven geotextiles with a high elongation capacity ensure the mechanical and hydraulic filter effectiveness between two adjacent soils where filter stability is missing.

Figure 8 The side rainwater collection pipe and drain is wrapped with a Secutex® geotextile to prevent fines from clogging the drain

Figure 9 Secutex® separates the gravel drainage layer from the silty subsoil

Drainage with geotextiles

Secudrain® WD is a three-dimensional geosynthetic drainage system, which consists of a statically stable drainage layer (wave-structured monofilament core) and at least one Secutex® separation/filter nonwoven geotextile. Secudrain® WD drainage systems as well as special types of Secutex® geotextiles are used in civil engineering applications where the efficient collection and drainage of precipitation or groundwater are required. All Secudrain® layers are physically connected allowing for the effective transfer of shear stresses.

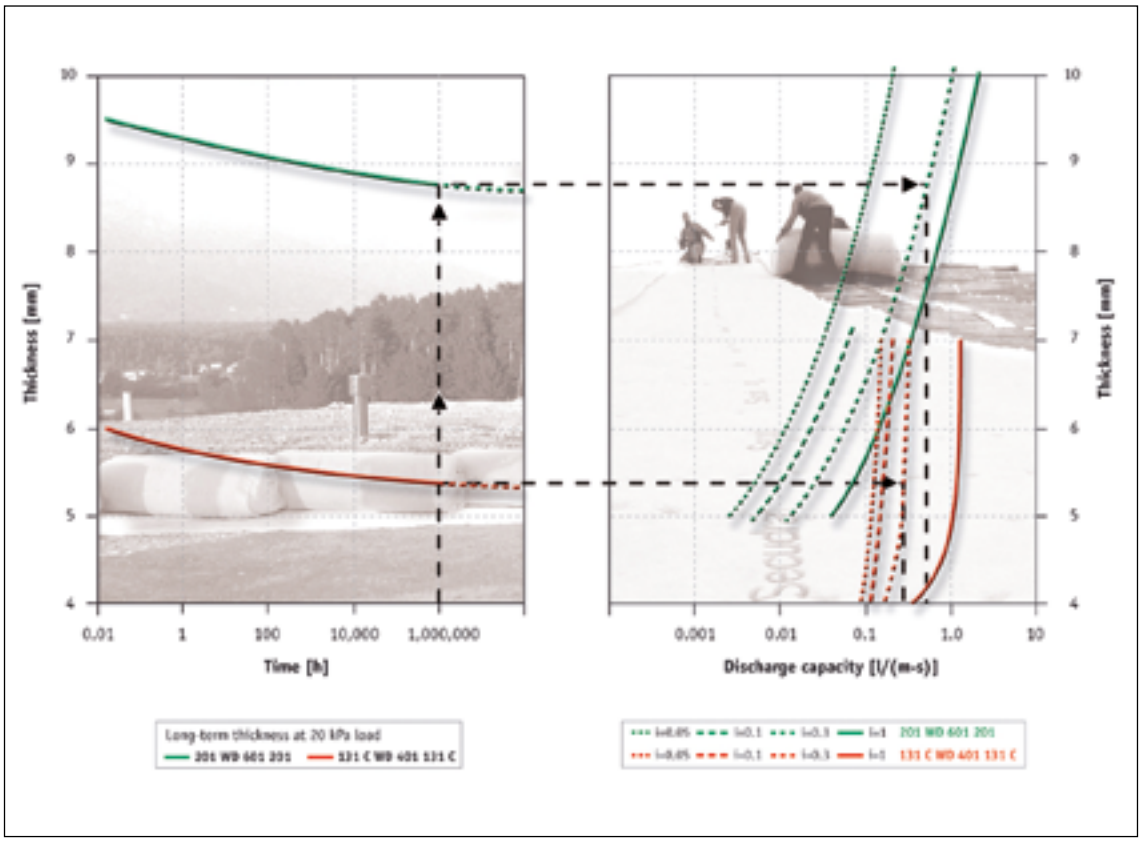
Drainage capacity calculation

To determine the anticipated drainage capacity of a Secudrain® drainage system, the total outflow is compared to the total inflow. The total long-term water outflow (Q_A) expected from Secudrain® is calculated from the laboratory determined drainage capacity $Q_{lab,i,\sigma}$ (dependant on the drainage gradient i and the normal stress σ), the slope inclination (β) and a total reduction factor (η_{total}):

$$Q_A = Q_{long\text{-}term} = Q_{lab,i=1,\sigma} \bullet \sin\beta \,/\, \eta_{total}$$

Numerous excavations and laboratory scale creep tests have generated abundant data on the long-term behaviour of Secudrain® under constant loads. It is therefore possible to assume a reduction factor FS_{CR} of 1.0 and to use laboratory determined discharge capacities under the historical long-term

Figure 10
Design chart to determine the water discharge capacity of Secudrain® WD as a function of the long-term thickness



Design Cross sections Details

Figure 11 Secudrain® in a bridge abutment ensuring long-term drainage

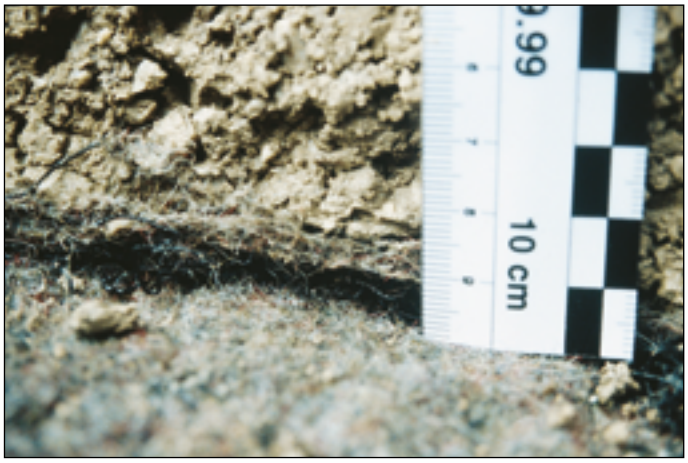


Figure 12 In-situ measured thickness of Secudrain® after over 12 years with a confining stress of 1.20m cover soil

thickness when specifying products (Fig. 10). The total reduction factor may be calculated as:

$$\eta_{total} = FS_{IN} \bullet FS_{CR} \bullet FS_{CC} \bullet FS_{CB} \bullet FS_{SY}$$

FS_{IN} = Reduction factor for localised deformation caused by installation loads. Recommendation: 1.0 to 1.5. (With coarser cover material, a higher reduction factor should be used.)

FS_{CR} = Reduction factor for creep deformation of the drainage core. (Long-term pressure-creep-curves for Secudrain® drainage systems are available. As discharge capacities $Q_{lab,i,\sigma}$ have been determined for various Secudrain® thicknesses, and have been correlated with excavation results, a 1.0 reduction factor FS_{CR} can be assumed.)

FS_{CC} = Reduction factor for the discharge cross section decrease caused by chemical sediments. Recommendation: 1.0 to 1.2. (Excavation results for Secudrain® drainage systems buried up to 15 years illustrate, that typical soils have an insignificant chemical sediment impact. Therefore, FS_{CC} can be assumed to be 1.05.)

FS_{CB} = Reduction factor for biologically induced decreases to the flow cross section. Recommendation: 1.2 to 1.5. (Similar to chemical sediments, no bacterial influence could be proven in the excavations. Although low, the potential influence from roots should be considered, and the FS_{CB} can be assumed to be 1.3.)

Therefore, by means of the long-term pressure-creep-curves, reduction factors and the discharge data for various thicknesses (see Fig. 10), the expected long-term outflow (Q_A) of Secudrain® can be determined and compared to the inflow water amount (Q_E):

$Q_A > Q_E$, where

$Q_E = q_E \bullet l_{max} \bullet FS_{SY}$

l_{max} = Maximum length of the Secudrain® drainage system

FS_{SY} = Reduction for typical system faults. Recommendation: 1.0 to 2.0. (If the design is based upon the maximum calculated drainage amount, the FS_{SY} can be assumed to be 1.0.)

q_E = Expected amount of drainage water

It is necessary that the Secudrain® total water outflow is larger than the water inflow over the whole length.

Filtration and separation properties

To ensure the long-term drainage performance, the Secutex® filter and separation nonwoven geotextiles used should be able to withstand the rigors of the installation without any damage, thereby maintaining their long-term filtering capabilities. For this reason the approaches described in the chapters "Filtration with geotextiles" and "Separation with geotextiles" are used. The filter and separation nonwoven geotextile must at least have Class-3 geotextile robustness.

Calculation of the drainage capacity

In the WAS 7, the Federal Bridge and Civil Engineering Commission (BMV Dep. StB) proposed a minimum discharge capacity of 0.3 l/sm under the existing earth pressure for the drainage of surfaces and backfilled structures. Moreover, WAS 7 requires that the drainage system should:

- be highly weather resistant,
- have a thickness of at least 5mm,
- have a separation and filter nonwoven with an effective opening size which lies between 0.06mm and 0.2mm
- have a separation and filter nonwoven with a water permeability which is at least 100 times as high as the water permeability of the soil.

Note: With regard to the necessary discharge capacity, DIN 4095 as well as RAS-Ew allows lower approaches than WAS 7, in special cases that are dependant on the soil type.

Secudrain® products fulfill all these requirements. Due to their flexibility and low mass per unit area, Secudrain® products are easily installed and can accommodate the most challenging structures.

Conclusion

When creating geotextile drainage systems, it is important to consider the nonwoven geotextile robustness, filtering capacity as well as separation capabilities, not just the necessary drainage capacity. The flexibility of Secudrain® drainage systems as well as the easy handling of the 1.9m to 3.8m wide rolls allow a simple and economic installation.

Design Cross sections Details

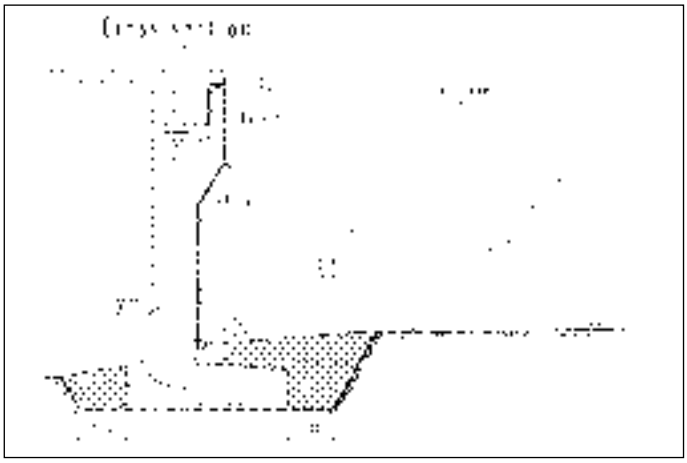


Figure 13 **Typical cross section of a bridge abutment according to the German WAS 7**

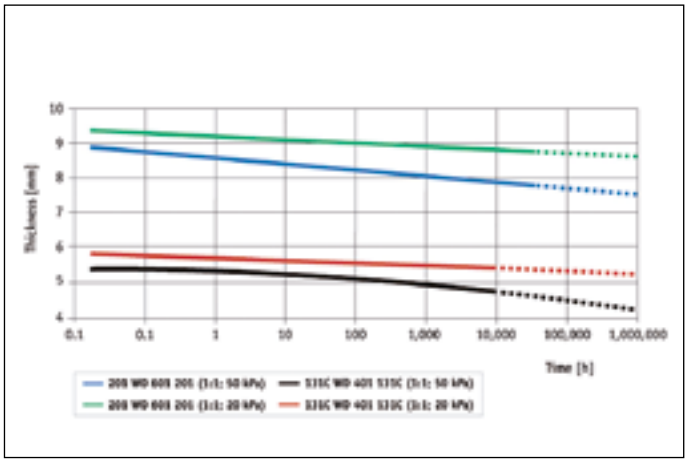


Figure 14 **Secudrain® WD types - creep and creep shear test results according to ENV 1897**

Geosynthetics in classified road construction

Figure 15 **Separation and filtration with Secutex® in a car testing track (Papenburg, Germany)**

In the "Guidelines for the specification of traffic areas", a set of standard construction details are given for specific types of roads depending on their intended usage and service life.
By including separation and reinforcement geosynthetic products in these standard construction details, a technically equivalent (or superior) design can be achieved by reducing the expensive mineral base course material thickness. If the subsoil of the intended road construction does not have sufficient bearing capacity, geosynthetic reinforcement can also be used in the stabilisation of the subsoil.

Separation

In the construction of most types of roads which are covered by national classification systems, a frost protection layer and a base course layer (typically gravel or crushed stone) are placed and compacted over a prepared subgrade. National guidelines also stipulate a bearing capacity requirement, based upon the long-term deformation module (E_{V2}). To achieve and maintain the required design performance, the differing soil types (frost protection, base course and subsoil) must be prevented from intermixing.

Secutex® polypropylene (PP) nonwoven geotextiles are specially designed products for use in road construction as separation components. They are robust, filter-stable products with high puncture resistance, high tensile strength and high elongation properties. They are also rated under the GRK (geotextile robustness classification) system for puncture and resistance to installation damage. For further details on the use of Secutex® geotextiles, please refer to the chapters "Separation with geotextiles" and "Filtration with geotextiles". The high elongation capacity of the Secutex® nonwoven geotextiles ensures excellent resistance to damage. This characteristic of Secutex® products allows them to easily accommodate irregular or soft subgrades. When covered with stone, the Secutex® nonwoven geotextile fibers are reoriented around the stones, preventing damage to the nonwoven structure.

Reinforcing

Secugrid® geogrids are reinforcing geosynthetic products manufactured from high tensile strength extruded monolithic flat polymer bars with high strength welded junctions. Secugrid® absorbs tensile forces induced into the soil and distributes the stresses through the high tensile strength bars. This transfer of forces takes place by two distinct modes: interlock of the granular soil into the grid apertures which physically restrains movement of the granular base course material and frictional force transfer between the soil and the wide flat bars of Secugrid®. By absorbing the tensile forces induced by traffic loading on the road surface, the loading is distributed over a larger base area, minimising localised pressures on the subsoil. An important feature of Secugrid® geogrids is the very high modulus (i.e. they are able to function at their design tensile loading at very low elongation). The high modulus minimises the deformation that can occur at the road surface. Secugrid® also has a very low susceptibility to long-term creep, ensuring the continued integrity of the road surface against deformation.

Figure 16 **Use of Secugrid® for a dam reinforcement (Loxstedt, Germany)**

Design Cross sections Details

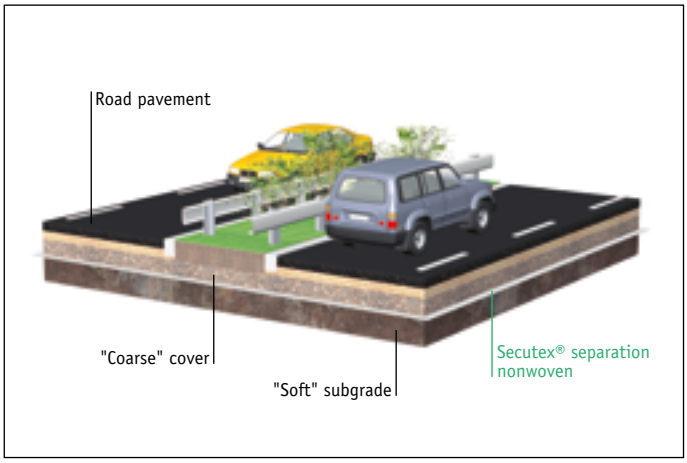


Figure 17 **Application of a Secutex® separation nonwoven geotextiles**

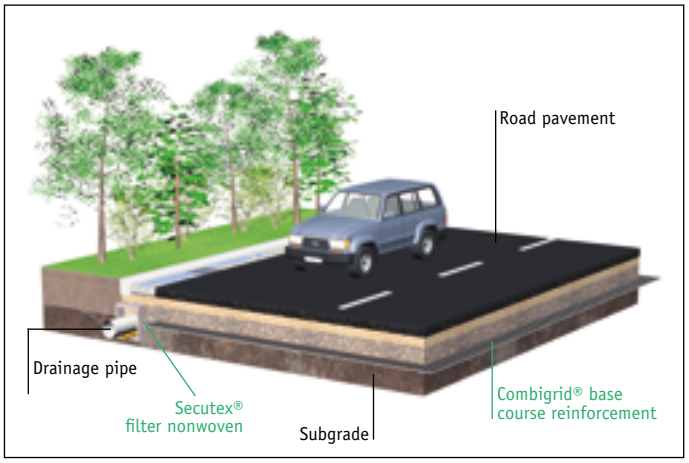


Figure 18 **Base course improvement with the composite product Combigrid® for separation and reinforcement**

Figure 19
Combigrid® increasing the soil bearing capacity (Mersin, Turkey)

Soil reinforcement with Secugrid® can eliminate the need to remove and replace or chemically stabilise subsoils that do not have sufficient bearing capacity for the intended loading (ask for the ***Secugrid® calculation tool***).
Combigrid® (a bonded composite of Secugrid® and Secutex® geotextiles) can be used if the geosynthetic product is required to provide reinforcement functions as well as separation-filter stability between cover layer and subsoil. The Secugrid® component of the composite provides reinforcement while the Secutex® nonwoven geotextile component provides separation and filter stability (see chapters "Separation with geotextiles" and "Filtration with geotextiles").

Drainage

On concrete pavements, cracks and damaged joint seals can allow surface water to penetrate the pavement slab and wash away the subsoil. The hydraulic undermining of the pavement slab can weaken the structure and lead to damage of the paving surface. When the subsoil also is low in permeability and unable to discharge the water that has penetrated the slab, water can build-up at the interface between the slab and the prepared subsoil. Cyclic traffic loading can then subject this water to alternating high and low pressures. This "pumping" action can drive soil out from under the slab, reducing the structural integrity of the pavement. When installed between the pavement slab and its subsoil, Secutex® PP mechanically bonded nonwoven geotextiles provide a horizontal drainage path for water to discharge before it can cause damage to the road structure.

Figure 20
Secutex® as geotextile separator in a road construction (Weißenfels, Germany)

As the drainage capacities of Secutex® geotextiles are considerably higher than that of engineered soils and as they are not affected by wash-out or pooling, they protect the integrity of the pavement against hydraulic damage. The thick three-dimensional geotextile also acts as a cushion against traffic vibration, helping to prevent cracking, while the open porous structure of Secutex® aids the setting and curing of in-situ cast paving slabs.

Typically, a 500g/m² product (Secutex® type R 504) is used for this application.

Figure 21
Prevention of soil failure with Secugrid® 400/60 R 6 (A 31, Emden, Germany)

Long-term resistance

The raw material components used to produce Secugrid®, Combigrid® and Secutex® geosynthetics are carefully selected to ensure that their full performance is maintained during the entire service life.

Conclusion

For the construction of classified roads, geosynthetics are used to fulfill separation, reinforcement, filtration and drainage functions. Separation and soil filter stability can be achieved using Secutex® geotextiles, and the bearing capacity can be increased with either Secugrid® or Combigrid®. Other advantages of using Secutex® nonwoven geotextiles for the construction of concrete pavements include the prevention of cracks upon the casting of the paving slab, cushioning the slab from vibration damage during service, and protection against subgrade erosion.

A solid foundation starts with nonwoven geotextile products from Naue.

Design Cross sections Details

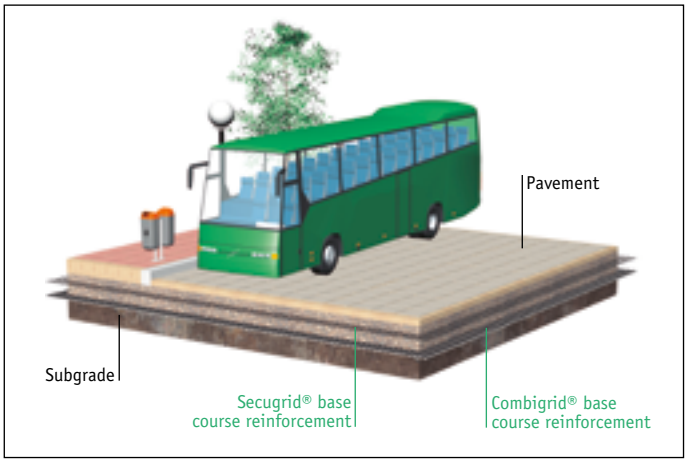


Figure 22 Base course reinforcement for large loads on soils with poor bearing capacity

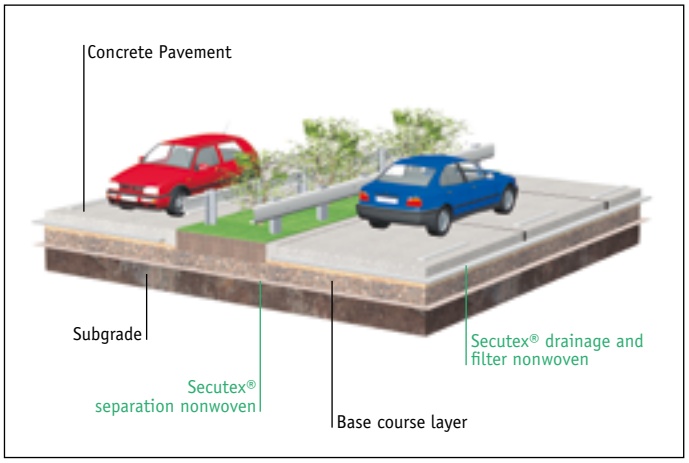


Figure 23 Drainage beneath concrete pavement

Geosynthetics for construction roads and heavily trafficked areas

Figure 24
Secutex® as a separation geotextile between fine and coarse grained soils

Geosynthetic system solutions are used in the construction of temporary roadways and trafficked areas which are not classified under national guidelines, such as construction roads, parking lots, forest paths and access roads.

Improvement to bearing capacity

In the construction of heavily trafficked areas such as parking lots, a stable subgrade with sufficient bearing capacity is required. When installed between the subsoil and the base course, Secugrid® Q geogrids, made from high strength, extruded monolithic flat bars, with welded junctions, are particularly well suited for this application.

Figure 25
Installation of Combigrid® to increase the soil bearing capacity (Bremerhaven, Germany)

The coarse grained cover soil interlocks with the Secugrid® Q geogrid (grid apertures ≥ 28mm) creating a bond. This immediate interlock provides a horizontal force transfer which increases the bearing capacity of the soil due to the high force absorption of Secugrid® - even under low elongation. The required bearing capacity can be achieved without additional expensive soil exchange, and in some cases, the base course thickness can be reduced.

Figure 26
Separation and filtration with Secutex® in a driveway (Gehlenbeck, Germany)

Secutex® separation and filter nonwoven geotextiles are used to prevent the migration of fine particles into the base course. The design approaches for the nonwoven are described in further detail under the chapters "Filtration with geotextiles" and "Separation with geotextiles". To facilitate the installation and create shear strength transfer, Secugrid® and Secutex® components are pre-manufactured into a bonded composite product - Combigrid®. On extremely soft subgrade, the bearing capacity can be markedly improved by using multiple layers of Secugrid® geogrids.

Reduction of rutting

When building unpaved roads (e. g. forest paths and temporary construction roads) on soft subsoil, rutting and intermixing of the cover material into the subsoil should be avoided. Combigrid® or Secugrid® geogrids can significantly improve load distribution, minimising rutting and soil intermixing. The selection of the Secugrid® geogrids is on a project-specific basis according to standard guidelines and site-specific requirements (ask for the ***Secugrid® calculation tool***).

Design Cross sections Details

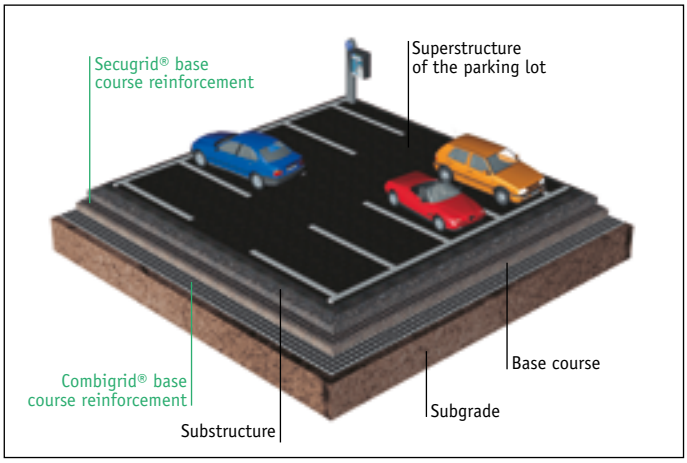


Figure 27 **Base course reinforcement under parking lots**

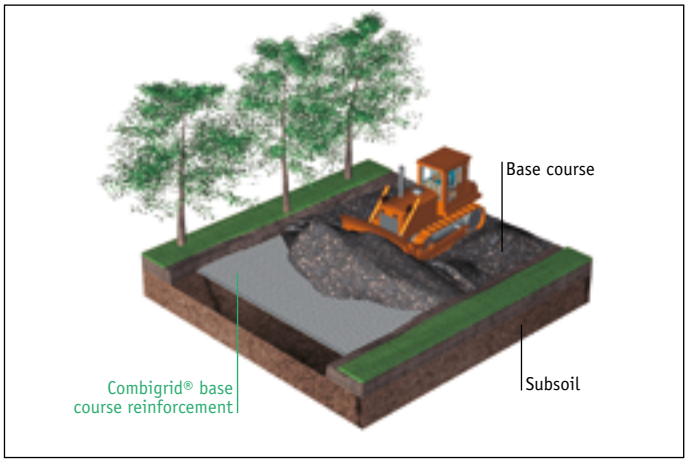


Figure 28 **Base course reinforcement of a construction road**

Figure 29
Pre-stressed Secugrid® installed under a base course for heavy traffic (Luebeck, Germany)

Figure 30
Soil coverage of Secugrid® reinforcement in a base course (Arizona, USA)

Force-elongation-behaviour

Unlike the separation function of geotextiles, reinforcement requires a product with low elongation characteristics. Secugrid® geogrids have no product manufactured elongation. With the stiff junctions of the welded reinforcement bars, Secugrid® has less than 8% elongation at break. For product comparisons and design issues, the force absorption at 2% and 5% elongation are often used.

Installation robustness

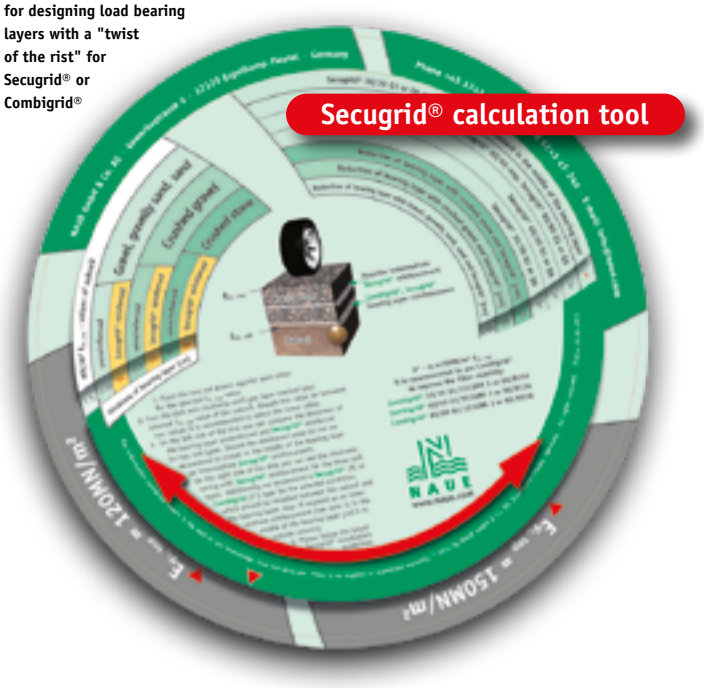
When installing and compacting coarse-grained cover soils and base course materials the reinforcement can be subjected to high dynamic stresses. Due to the thick, robust, monolithic reinforcement bars, Secugrid® geogrids and Combigrid® have a high resistance to installation loads.

Conclusion

In the construction of unpaved roads and highly trafficked areas, geogrid based geosynthetic system solutions are commonly used - especially on soft subsoils. Secugrid® geogrids are installed to improve the soil bearing capacity, to avoid expensive soil excavation and recompaction as well as to reduce the base course thickness in some instances. Combigrid® can effectively prevent the migration of fine particles into the base course.

Compared to conventional construction methods, the use of geosynthetics is an economical and effective alternative.

This design-tool disk performs calculations for designing load bearing layers with a "twist of the rist" for Secugrid® or Combigrid®



Design Cross sections Details

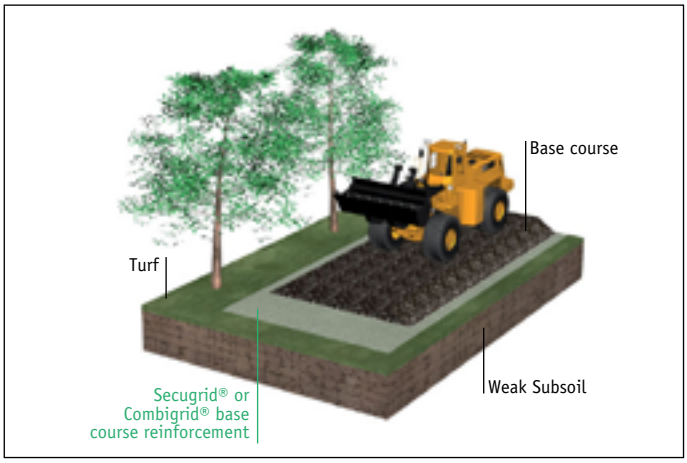


Figure 31 **Base course reinforcement of an access road**

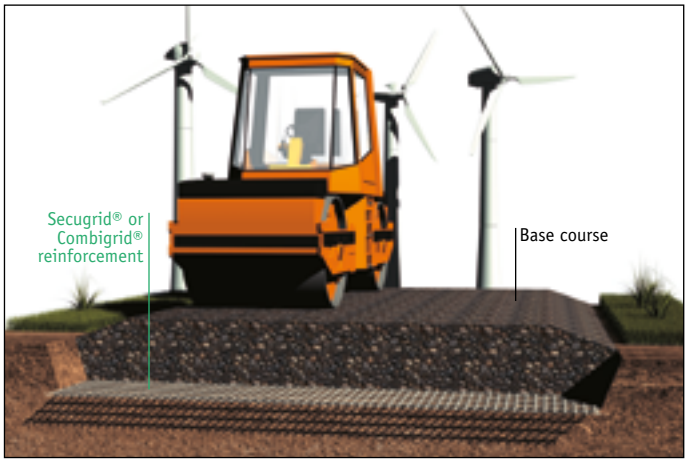


Figure 32 **Base course reinforcement for a windfarm access road over soft subsoils**

Groundwater protection in transport infrastructure

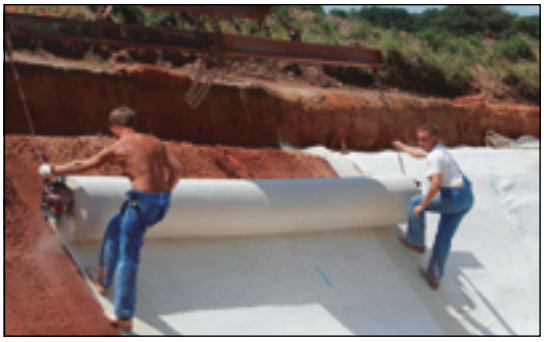


Figure 33 **Installation of Bentofix® with a spreader bar in a road ditch (Muenster, Germany)**

Various national guidelines for road construction in environmentally sensitive areas require the subsoil to be sealed and effective construction measures to be taken to protect the groundwater in transport infrastructure near to water catchment areas. In numerous projects, Bentofix® geosynthetic clay liners and Carbofol® geomembranes have proven to be effective, economical sealing systems. They are used under roads, railways and for retention basins.

Sealing

As an alternative to a 60cm thick compacted cohesive soil, Bentofix® geosynthetic clay liner, approximately 10mm thick and manufactured with high swelling natural sodium bentonite, is used. The robust cover and carrier geotextiles used in the construction of Bentofix® are designed to withstand rough installation loads. Bentofix® is uniformly manufactured with direction-independent needle-punching (fibre reinforcement) over its entire surface area, with more than 2 million fibres per square metre. Depending on the existing soil conditions and slope lengths, slope inclinations of 2.5h:1v or greater are possible, due to the surface structure of the needle-punched cover and carrier geotextiles and the large internal friction angle. In poor soil conditions or on steeper slopes, Secugrid® geogrid can be used to further ensure slope stability.

Due to their thin profile, Bentofix® geosynthetic clay liners consume less airspace than compacted clay and can require less soil excavation and removal. The Bentofix® BFG 5000 features a cover geotextile that has been uniformly impregnated with bentonite powder over its entire surface area. This bentonite treatment in the cover geotextile can make the installation more efficient as the field application of bentonite paste to the overlaps is not required.

The Bentofix® encapsulating geotextiles are typically made from polypropylene (PP) resin and therefore sufficiently resistant to a wide range of conventional chemicals, such as diesel fuel, oil and benzene. Alternatively, 2.0mm thick Carbofol® HDPE geomembranes can be installed. Carbofol® HDPE geomembranes are best suited to aggressive conditions due to their wide range of chemical and natural element resistance (e. g. to UV-radiation, rodents, chemicals). Not only is placement easy, it is also easy to weld Carbofol® HDPE geomembranes due to the favourable Melt Flow Index of the base resin.

Structured and friction Carbofol® geomembranes are available to effectively transfer shear forces on the most challenging of slope locations. Regardless, project-specific direct shear tests should be performed to verify that the required shear strength parameters are being met by the components selected for use.

Figure 34 **Installation of Bentofix® GCL as groundwater protection under the B 82n highway (Langelsheim, Germany)**

Design Cross sections Details

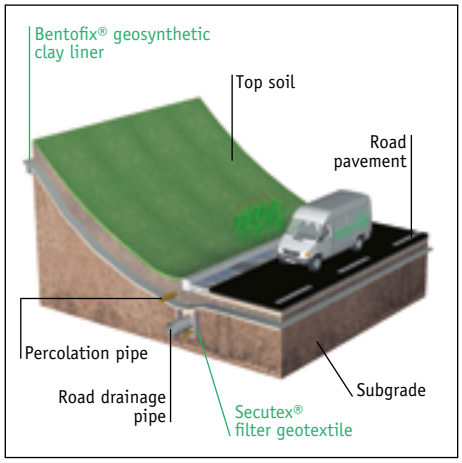


Figure 35 **Bentofix® road sealing system**

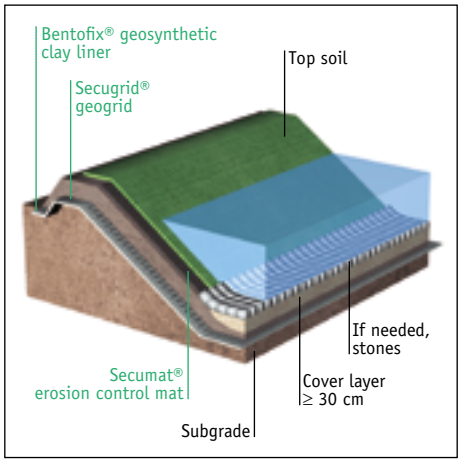


Figure 36 **Naue complete system solution for retention basins**

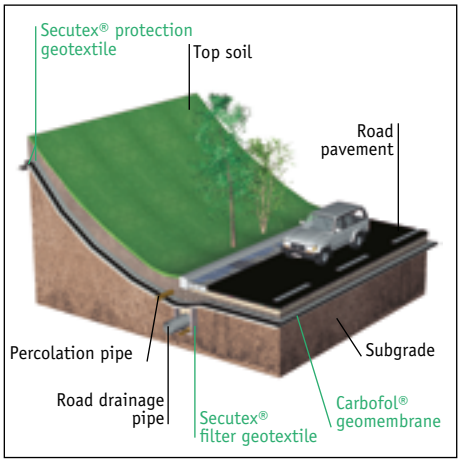


Figure 37 **Carbofol® road sealing system**

Figure 38
Bentofix® GCL installation in a stormwater retention pond

Protection

The encapsulating geotextiles of Bentofix® geosynthetic clay liners protect the bentonite, as well as providing sufficient robustness for on-site handling. When higher than normal installation loads are anticipated, GCLs should be manufactured with more robust geotextile nonwovens, typically with ≥ 270g/m².

Sealing performance of the Carbofol® HDPE geomembrane is assured when the installation is carried out by industry experts. Depending on the regulatory requirements as well as site conditions, needle-punched protection nonwoven geotextiles, such as Secutex® (from PP) may be installed both above and below the Carbofol® geomembrane.

For slightly gravelly sand (gravel portion < 30%), the Secutex® protection nonwovens with a mass per unit area of 400g/m² should be used to protect the Carbofol® geomembrane. Coarser grained soils may require heavier styles of Secutex® protection nonwovens, normally with a mass per unit area of 1,200g/m².

Figure 39
Carbofol® geomembranes in a groundwater sensitve area (UK)

Erosion control

In steep slope areas, heavy rainfall may cause erosion chanels or wash away the young grass seed. Secumat® erosion control mats prevent surface erosion and rutting by retaining the soil and seed in a convoluting three-dimensional structure. Secumat® is installed directly on the slope and filled with soil. Roots of the vegetation gradually enclose the convoluting layer of Secumat®, efficiently interlocking it with the surrounding soil.

Conclusion

When constructing roads, railways or retention basins in groundwater protection areas, Bentofix® geosynthetic clay liners and Carbofol® geomembranes can be effectively used.

Figure 40
Use of Bentofix® GCL under railway tracks for groundwater protection (Dresden to Leipzig, Germany)

Needle-punched Secutex® protection nonwoven geotextiles ensure a long-term protection of the Carbofol® geomembranes. Secugrid® geogrids can ensure the stability of steep slopes while Secumat® helps to prevent surface erosion. Complete geosynthetic system solutions from Naue are economical alternatives for groundwater protection applications that, due to their low construction height, require considerably less soil excavation and disposal than conventional mineral sealing layers.

Design Cross sections Details

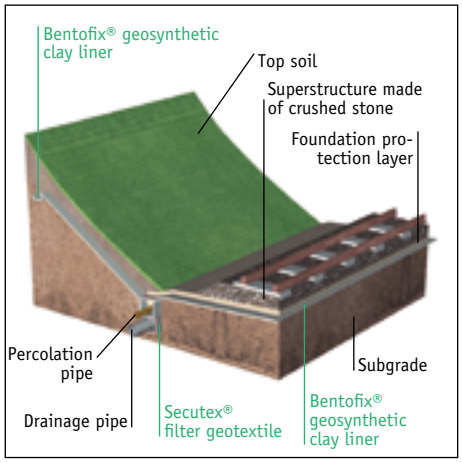


Figure 41 **Bentofix® sealing system in the construction of railways in groundwater protection**

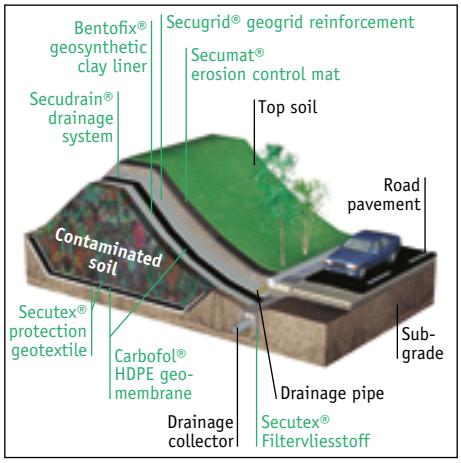


Figure 42 **Encapsulation of contaminated soil**

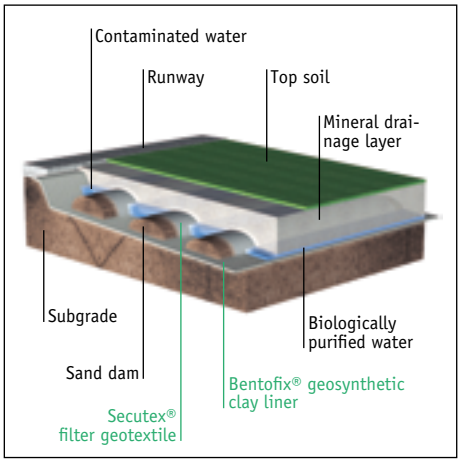


Figure 43 **Groundwater protection with Bentofix® at the Munich Airport, Germany (biological in-situ degradation system)**

Geosynthetics in slope stabilisation

Figure 44
Secugrid® ensures the slope stability on a noise barrier dam (A33 Bielefeld, Germany)

Secugrid® reinforcing geogrid products are commonly used to stabilise steep slope soil veneers. Secumat® erosion control mats are used on slopes to prevent soil erosion, as well as vegetation or seed wash-out due to rainfall. In either case, Secugrid® and Secumat® geosynthetic products can be effectively used to help protect slopes from erosion and veneer failure.

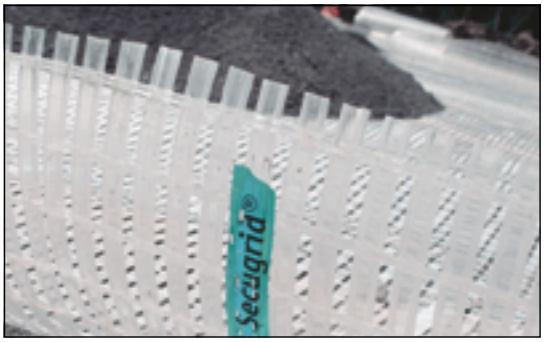


Figure 45
Secugrid® R-geogrids are suitable for uniaxial reinforcement applications

Stability

It is common to design slopes as steep as possible to optimise land use. This can lead to a larger crest area or a reduction of the embankment area. If the frictional and strength characteristics of the soil cannot provide a stable structure, special reinforcing measures are required. Secugrid® geogrids are an economical alternative to modifying the slope geometry. Made from extruded high strength monolithic flat polyester PET or polypropylene PP bars, Secugrid® reinforces the soil structure by carrying excess slope forces.

With the optimised Secugrid® product design, the flat Secugrid® bars have maximum interlocking with the surrounding soil. The junction stiffness and negligible product construction elongation of Secugrid® allows immediate force absorption when confining stress is applied. Compared to other geosynthetic reinforcement products, Secugrid® geogrids show a steeper increase in the force-elongation diagram. Higher stress absorption and lower product elongation result in more economical construction methods.

Figure 46
Erosion control on a slope. The open pore structure of Secumat® allows easy filling of the top soil

Different national guidelines for slope stability calculations can be used. The Naue Secugrid® Design Manual also contains design and product selection guidelines for proper use of the Secugrid® geogrid products. These include guidelines for the application of geotextiles and geogrids in the construction of roads, and recommendations for geosynthetic reinforcement.

The PET and PP resin used in Secugrid® provides excellent physical characteristics and helps to allow more economical product selections. Secugrid® can withstand higher long-term creep stresses than other polyolefin products due to the unique manufacturing process.

Design Cross sections Details

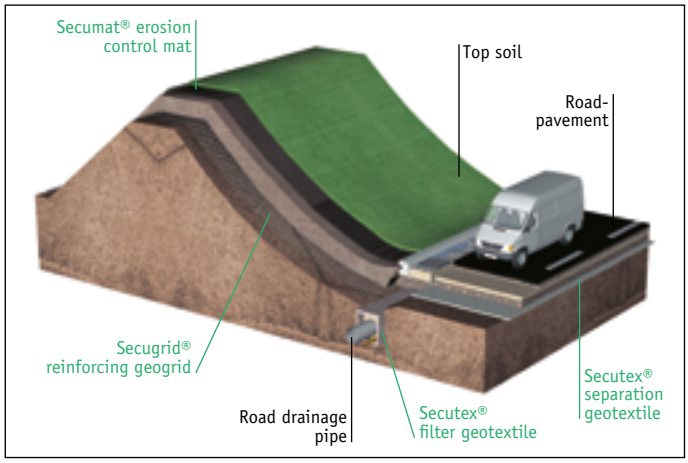


Figure 47 Noise barrier slope stabilisation

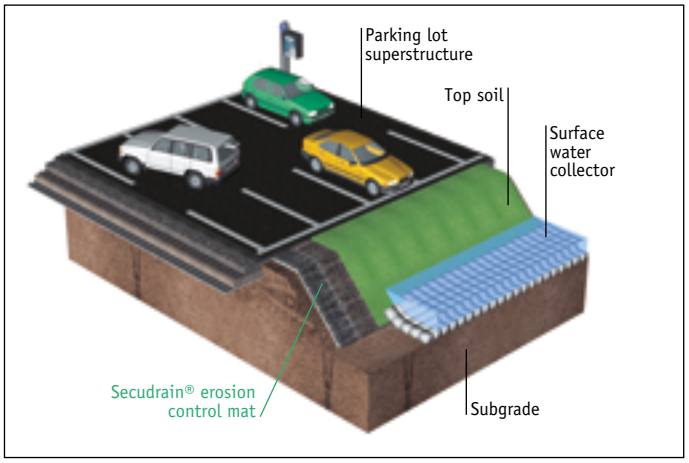


Figure 48 Erosion control for a surface water collection trench

Figure 49
Slope stabilisation and collection of seepage water with Secudrain®

Erosion control

On slopes, especially with fine grained soils, heavy precipitation may erode surface soils. Greater erosion and ruts can occur if the slope is poorly vegetated. Geosynthetic erosion control mats are commonly used to address difficult, erosion prone slope conditions.

Figure 50
Soil coverage of Secumat® for erosion control in a rainwater collector (Albertville, France)

Secumat® erosion control mat can significantly reduce soil wash-out during the heavy rainfalls common to Middle Europe. The three-dimensional, irregular labyrinth-like structure of Secumat® is designed to allow both fine grained and gravel soils to fill the open convoluted structure. The irregular Secumat® structure holds the soil in position on steeper slopes and provides the structural support to the vegetation during the early stages of plant growth.

The use of high quality polypropylene (PP) resins make Secumat® resistant to naturally occurring soil chemicals, soil microorganisms and UV-radiation. When used in conjunction with a carrier nonwoven geotextile, the structure of the Secumat® erosion control product is virtually identical to the Secudrain® drainage system. Installed with the convoluting surface side-up, it will then perform two functions - separation and erosion control.

Figure 51
Embankment reinforcement with Secugrid® in a road-widening project (Tabing-Duko, Indonesia)

Conclusion

Secugrid® geogrids ensure the stability of noise barriers and retention basins, as well as dams and other steep slopes where space saving, steep embankments are often necessary.

Secumat® erosion control products are employed to prevent erosion on slopes or areas subjected to periodic turbulent flow. It prevents soil wash-out during heavy rain, and provides structural support to the vegetation - especially important during the early stages of plant growth. In drainage trenches, Secumat® also prevents soil particle wash-out, thus ensuring the proper performance of the system.

Design Cross sections Details

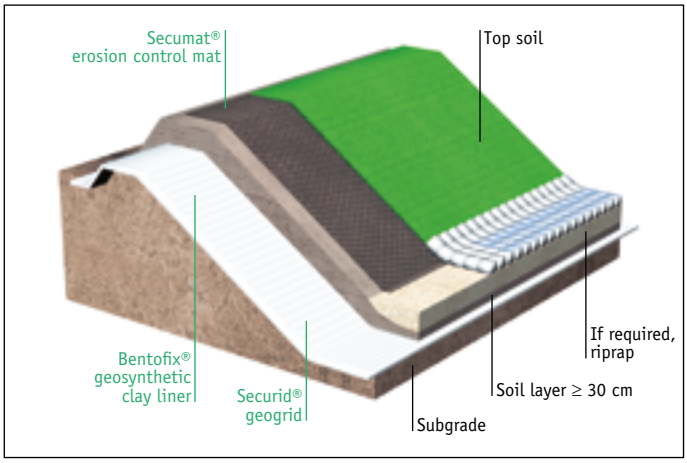


Figure 52 Sealing and stabilisation of a rentention basin slope

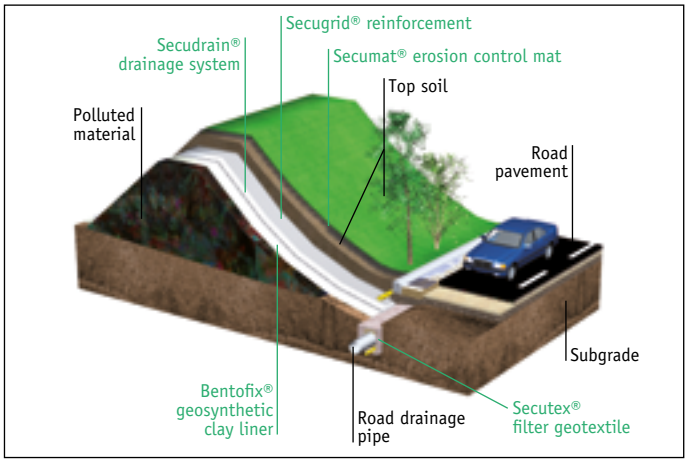


Figure 53 Sealing of a noise barrier

Geosynthetics for retaining walls

Figure 54
Secugrid® reinforced earth wall (Vignale, Italy)

With complete geosynthetic system solutions, noise barriers, retaining walls, reinforced embankments or other structures with inclinations of up to 90° can be built.

Reinforcement

The use of Secugrid® geogrids for the reinforcement of steep walls and retaining structures is necessary in cases where the shear strength of the soil material alone is insufficient to provide the required stability. Uniaxial Secugrid® R geogrids are designed, and especially well suited, for this purpose. They are made from high strength polyester (PET) or polypropylene (PP) resin which has been extruded into flat monolithic bars, and welded together to create junction stiffness.

This special grid design provides an immediate interlocking with the surrounding soil. Its frictional properties further enhance the structural strength of the application. Secugrid® is designed to accept high construction stresses with low elongation, as it is necessary to minimise unacceptable deformation. A tensile strength of up to 400kN/m can be achieved with an extremely low strain at failure of ≤ 8%.

In addition to bearing capacity as well as frost and drainage behaviour, the bond strength and robustness of the reinforcement should also be taken into consideration when installing the backfill. The required compaction of the backfill material will typically create high installation loads. Due to their large surface area and as demonstrated in numerous tests as well as field trials, the flat monolithic bars of Secugrid® are extremely robust and resistant to dynamic installation loads. Secugrid® geogrid design and specification recommendations are available in our Secugrid® Design Manual.

Construction of a wall facing

To create low impact structures that blend into the landscape, there are different types of faces for reinforced steep slopes and walls that can be constructed. For steep reinforced slopes with inclinations up to 45°, Secugrid® can be installed horizontally, without special face elements. For protection against potential wash-out of the fill soil between the reinforcing layers, a filter-stable soil or Secumat® erosion control mat infused with grass seed is especially well suited.

On steeper slopes with inclinations up to 60°, the enveloping method for Secugrid® geogrid installation is necessary. To facilitate this construction technique, temporary or expendable formworks must first be installed. To prevent erosion or soil wash-out, it may be necessary to use a Secutex® nonwoven geotextile on the inner side of the reinforcement. The filter stability calculation of Secutex® is described in the chapter "Filtration with geotextiles". Using vegetated Secumat® erosion control mats may also prevent soil wash-out.

Figure 55
Construction of a retaining wall using Secugrid® (Marbella Hill, Spain)

The facing of steep walls with inclinations of up to 90° can also be designed to use natural stones, gabions, broken rocks and prefabricated concrete units. If one of these methods is desired, it should first be determined if these materials can

Design Cross sections Details

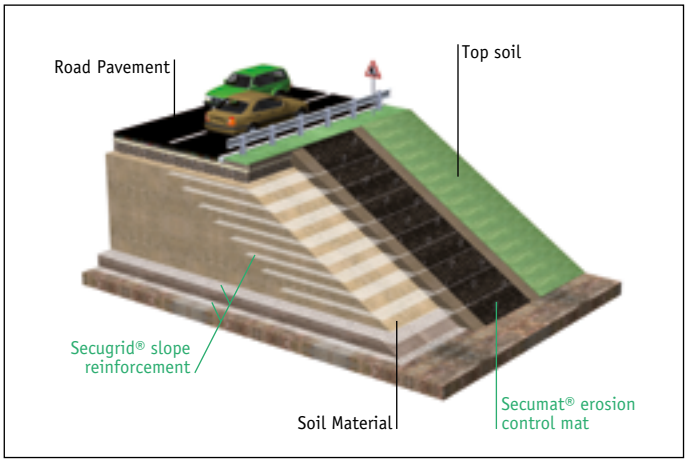


Bild 56 Secugrid® reinforced slope with 45° inclination

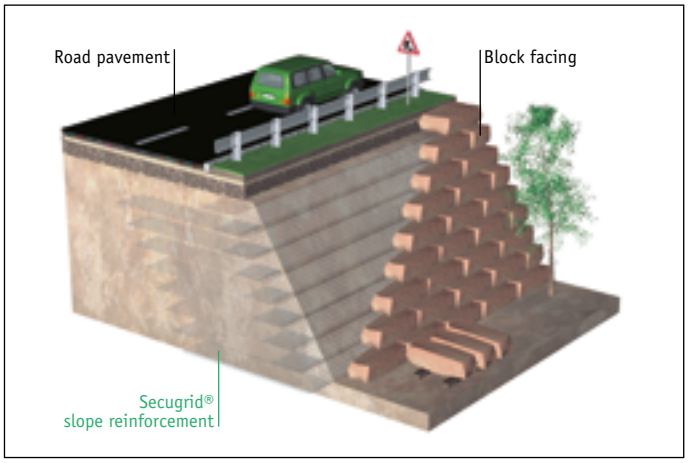


Bild 57 Secugrid® reinforced slope with 70° inclination, using enveloping method and free standing block facing

be vegetated. The outer face/geosynthetic connection is made with either factory-made connections or with special clamping or on-site fastening methods.

Figure 58
Absorbing the earth pressure against a house wall with Secugrid® (Heilbronn, Germany)

Foundation of massive face elements

Foundation requirements for massive face elements are described in the different national recommendations for geosynthetic reinforcement. In principle, the general engineering standards for earth and concrete construction are valid. In wrap-around walls, a special foundation is not typically required.

Figure 59
Secugrid® reinforced gabion wall (Tman, Czech Republik)

Figure 60
Secugrid® reinforced wall with a rock facing (Egypt)

Conclusion

The robust Secugrid® products excel with their superior chemical resistance, low creep tendency, and their extremely low elongation (high initial modulus). Secugrid® geogrids, Secutex® filter nonwovens and Secumat® erosion control mats are all used for the construction of reinforced steep slopes and walls. These geosynthetic systems are easy to install compared to conventional construction techniques and can accommodate differential settlement without any damage. The wall facing can also be connected to the geosynthetics without performance complications.

NAUE m3 provides a system approach to slope reinforcement, including design.

Contact info@naue.com for more details.

Design Cross sections Details

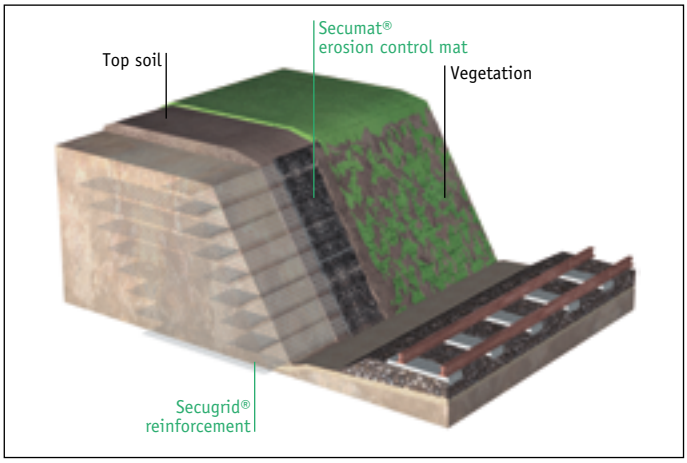


Bild 61 Secugrid® reinforced slope with 70° inclination, using enveloping method and spray-on vegetation

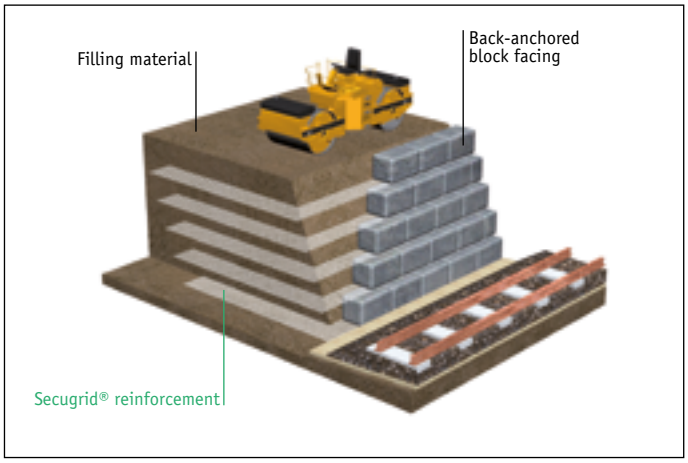


Bild 62 Secugrid® reinforced retaining wall with 87° inclination and back-anchored block facing

Geosynthetics for drainage of structures

Figure 63
Secudrain® basement drainage and protection layer to waterproofing membrane

To avoid damage caused by the build-up of hydraulic pressure in retaining walls, bridge foundations, basement walls and other subterranean structures, an effective drainage system is often necessary.

Drainage

Secudrain® is used for the drainage of areas or structures which are in contact with soil, including excavation backfill. It will discharge percolation water, thereby reducing the hydrostatic pressure on the structure and its sealing system.

Figure 64
Drainage of a retaining wall with Secudrain®

Secudrain® geosynthetic drainage systems consist of a statically stable three-dimensional, wave-structured drainage core, manufactured from polypropylene (PP) monofilaments combined with at least one filter-stable Secutex® nonwoven geotextile.

Due to the high void ratio of the drainage core (at least 95%), Secudrain® has a high water discharge capacity in all directions.

The relationship between the water discharge capacity and confining stress has been examined in laboratory tests and is documented in pressure-creep-curves. Secudrain® flow capacities are determined based upon the thickness expected under the specific confining stress, which can be correlated to long-term laboratory test results. Therefore, no special reduction factors are required in the drainage calculations (see chapter "Drainage with geotextiles").

Figure 65
Backfilling against Secudrain® system

Filtration

The PP Secutex® nonwoven geotextiles in Secudrain® should be selected in accordance with the filtration guidelines (see chapter "Filtration with geotextiles"). With proper selection, the geotextile component will prevent clogging of the three-dimensional drainage core by fine particles while also providing filter stability to the surrounding soil. The physical structure of the three-dimensional, labyrinth-like core, in combination with the Secutex® filter nonwoven maintains the water discharge capacity.

Protection

To protect sealing systems when using coarse-grained drainage soil, mechanically bonded Secutex® nonwoven geotextiles with a mass per unit area of 1,200g/m² should be installed. For filter

Design Cross sections Details

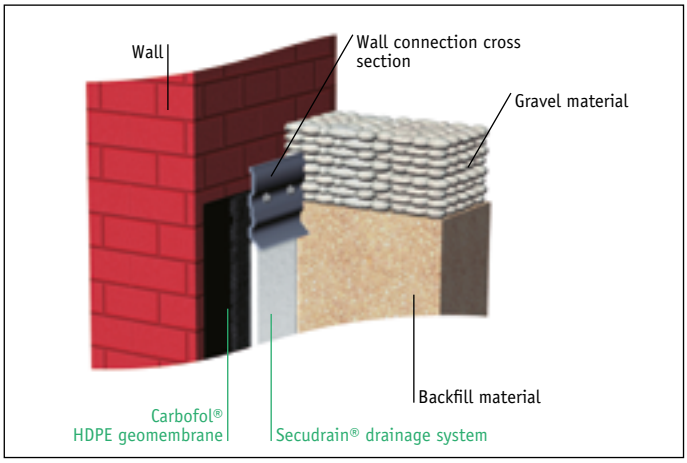


Figure 66 Drainage of the structure (wall connection detail)

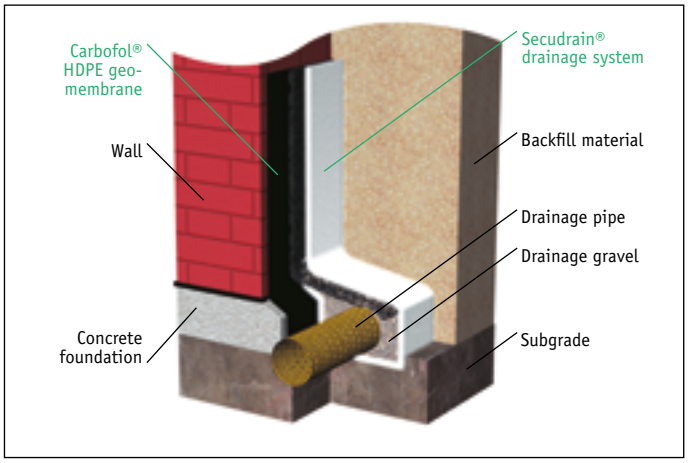


Figure 67 Drainage of the structure (drainage connection detail)

stability between drainage soils and fine grained backfill, a filter-stable Secutex® nonwoven geotextile should also be used. When used in conjunction with geosynthetic sealing systems, Secudrain® offers an efficient replacement to mineral drainage layers and filter stabilising geotextiles, whilst also providing protection to the sealing system.

Figure 68 **Secudrain® as precipitation and groundwater collector on a tunnel (Pustertal, Italy)**

Resistance

Secudrain® and Secutex® products are used for the drainage and filtration of subterranean structures. Carbofol® geomembranes and Bentofix® geosynthetic clay liners are commonly used for the sealing of these structures. All of these products are non-rotting and resistant to typical soil chemicals.

Installation

Secudrain® is quick and easy to fix and install to structures. The flexible, multi-functional drainage material can accommodate corners, edges and complicated geometric structures, without impacting the performance characteristics.
The pre-manufactured overlap configuration of Secudrain® provides a simple and quick junction of the panels in the longitudinal direction. This structure ensures the continuous discharge of water within the drainage core. In the transverse direction, the panels are installed with a simple overlap.

Figure 70 **Installed Secudrain® on a bridge structure (Grossen-Marpe, Germany)**

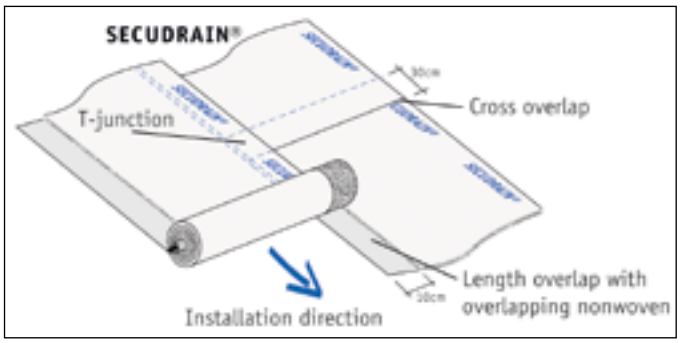
The standard roll dimension of 0.70m in diameter (width of 2.0m and length of 35m) makes Secudrain® rolls simple to handle and easy to install. For special projects, Secudrain® can be manufactured to a width of 6m.

Conclusion

Using Secudrain® drainage systems ensures the long-term controlled discharge of percolation water from subterranean structures. Secudrain® drainage systems minimise hydrostatic pressure on sealing systems reducing seepage. When using Carbofol® geomembranes or Bentofix® geosynthetic clay liners, Secudrain® also acts as a protection layer, preventing mechanical damage of the sealing system caused by the backfill material.

Even in complicated structures, the use of Secudrain® drainage systems ensures a simple, fast and economical installation.

Figure 69 **Longitudinal and cross overlapping of the Secudrain® drainage system**



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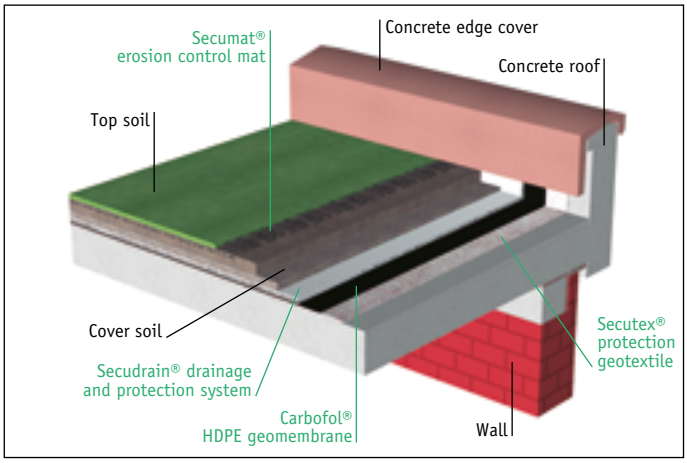


Figure 71 Geosynthetics for flat roofs

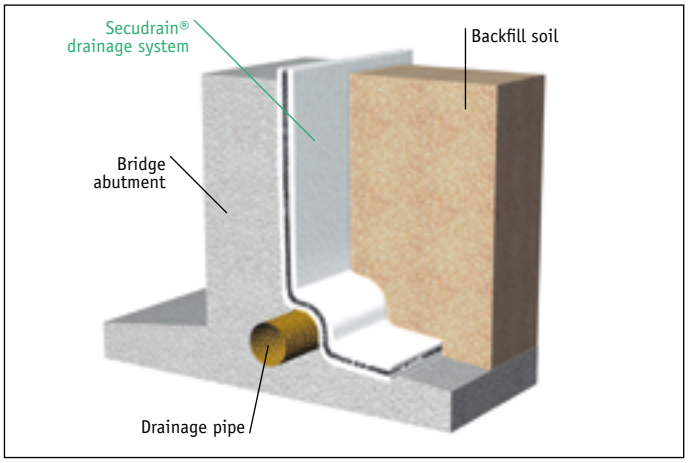


Figure 72 Drainage of a bridge abutment

Geosynthetics for building over soft subsoils

Figure 73
Placing of cover soil over the Combigrid® and Secugrid® reinforced structure (Nordenham, Germany)

Geosynthetics can be used in a variety of ways for capping, covering, sealing and reinforcement of soft soils. They offer an economic, lightweight solution to different environmental conditions.

Reinforcement

When reinforcing large areas of very soft subsoils, one of the most challenging engineering aspects is to make the area suitable for traffic or construction. Combigrid® can be placed directly on soft subsoils to immediately improve soil bearing capacity (ask for the ***Secugrid® calculation tool***). Combigrid® offers the advantages of two materials with the simplicity of installing a single product, as it is a composite product combining the reinforcing properties of Secugrid® geogrids with the separation and filtration properties of Secutex® nonwoven geotextiles.

Figure 74
Soil placement over Combigrid® and an extreme weak soft soil (Germany)

When used in conjunction with a nonwoven geotextile, the robust monolithic flat bars of the Secugrid® geogrids distribute point loading homogeneously through the grid to a larger surface area. This load distribution results in a reduction in local deformation and improves the bearing capacity of the soft subsoil.

The load distribution characteristic (snow shoe) of Combigrid®, enables placement of a mineral soil cover layer, while at the same time the separation properties of the integrated Secutex® geotextile ensure that two differing soil types do not intermix.

Sealing

In sludge lagoon capping applications where highly contaminated substances must be controlled, geosynthetic solutions by Naue GmbH & Co. KG will ensure their long-term containment.

Figure 75
Welded Carbofol® geomembrane (Allmannsweier, Germany)

Similar in concept to soft soil applications, Combigrid® products offer load-distributing characteristics, enabling lightweight equipment to traffic the liquid surface.

High density polyethylene (HDPE) Carbofol® geomembranes provide a virtually impermeable seal to water and gases. They are inert to the aggressive chemicals that are most often present and can be securely welded to form a uniform barrier to the intrusion of rainwater or the escape of gases.

To protect Carbofol® geomembranes from excessive deformation as well as the possibility of puncture by sharp edged

Design Cross sections Details

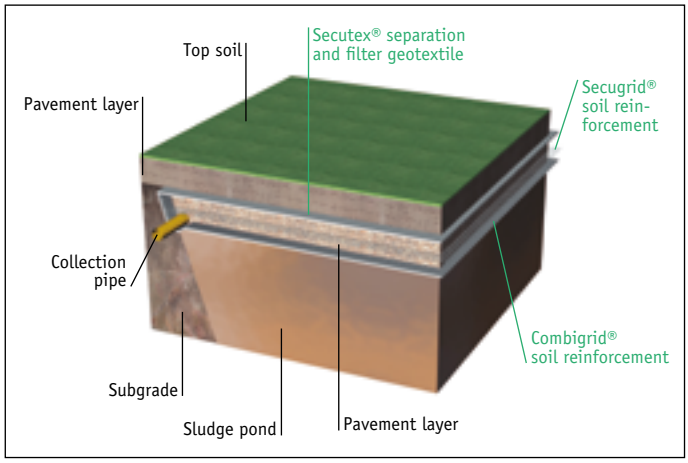


Figure 76 **Construction over a sludge pond (systematical drawing)**

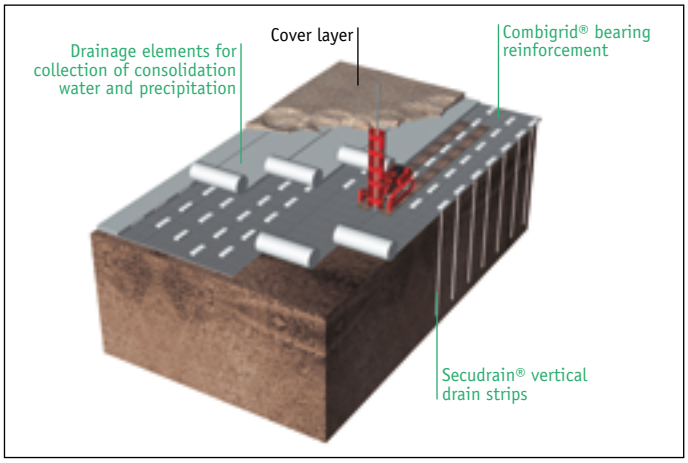


Figure 77 **Bearing reinforcement and improvement of consolidation with geosynthetics**

Figure 78
Welding of the gas barrier Carbofol® on a sludge pond (Rositz, Germany)

stones present in the mineral cover soil/drainage layer, a heavy weight mechanically bonded nonwoven cushion geotextile (1,200g/m² or above) can be installed directly over the geomembrane.

Bentofix® geosynthetic clay liners are well suited to sealing subsoils that are susceptible to large settlement. Bentofix® uses high quality, natural sodium bentonite encapsulated between two geotextiles. Once hydrated, the high swelling bentonite creates a seal against liquid and gas flow.

Using high elongation, mechanically bonded cover and carrier nonwoven geotextiles, the uniform needle-punched structure of the Bentofix® can endure deformation of over 30%.

The installation of Bentofix® in a rain-lap orientation will ensure that the seal is not compromised, even after consolidation induced settlement.

Vertical drains

Consolidation is a slow process where excess pore water is released in relationship to an applied stress. However, as the pore water must have a path to escape, Secudrain® vertical drains are commonly installed into the consolidating soil. Secudrain® vertical drains are approximately 100mm wide and are made from a coarse-fibre nonwoven geotextile drainage core encapsulated between two nonwovens. With this flexible composite structure, Secudrain® vertical drains have long-term filter stability (see chapter "Filtration with geotextiles"), and are especially suitable for use in soft subsoils that may be susceptible to settlement. With installation equipment termed "stitchers", Secudrain® vertical drains are rapidly positioned and "stitched" into the saturated soil. Secudrain® vertical drains substantially reduce the consolidation time of soft, relatively impermeable soils.

Gases beneath the sealing system can also be collected and discharged with a cost-efficient Secudrain® drainage system. Secudrain® is effortlessly unrolled by one man and can be covered with Carbofol® or Bentofix® liner. When used above the Carbofol® or Bentofix®, Secudrain® is also a cost-efficient alternative, offering protection, separation, filtration and drainage - all in one product.

Conclusion

With their superior soil reinforcement characteristics, Secugrid® and Combigrid® products improve soil bearing capacity, permitting traffic and construction to occur over soft subsoils. Secutex® nonwoven geotextiles offer excellent protection for Carbofol® geomembranes. Where differential settlement is expected, the more flexible, Bentofix® geosynthetic clay liners can be used in place of Carbofol® geomembranes.

Figure 79
Two layers of Secugrid® reinforcement as base course reinforcement of a federal road (Loxstedt, Germany)

To accelerate consolidation, filter-stable, flexible Secudrain® vertical drains can be "stitched" into the soil. Gas as well as rainwater can be discharged by Secudrain® synthetic drainage systems depending on where it is deployed.

Geosynthetic solutions are often the only option for the rapid capping and sealing of soft subsoils. Naue is the ideal choice when geosynthetic solutions are required.

Design Cross sections Details

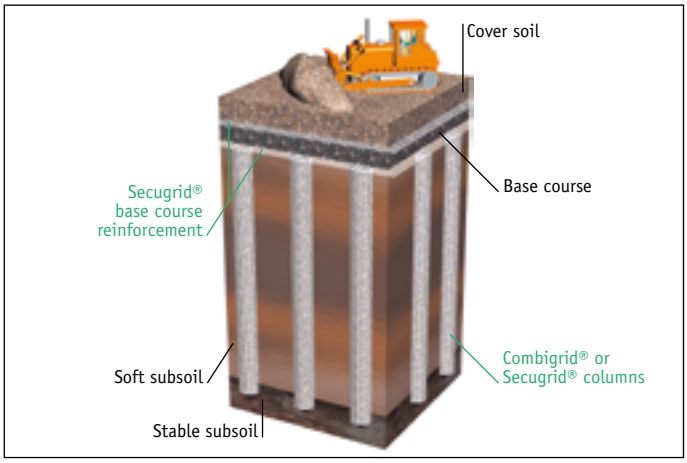


Figure 80 Base course reinforcement in areas with soft subsoils

Figure 81 Secugrid® reinforcement over weak and/or collapsing subsoils

Geosynthetics in pipeline construction

Figure 82
Protection wrapping of a pipeline with Secutex® (Arnstorf, Germany)

During pipeline construction, geosynthetics such as Secutex® protection nonwovens and robust Secugrid® geogrids can be used in several ways to prevent damage to the system at all stages of the project.

Protection

In the construction of pipelines, protection sand has become a substantial cost factor due to the volume of material required and associated transportation and installation costs. Secutex® protection nonwovens are a cost-effective alternative to this conventional construction method. Depending on the grain size distribution and the existing confining stress, various Secutex® protection nonwoven geotextiles can be used.

For soils with a maximum grain size of 8mm, a 4.5mm thick Secutex® protection nonwoven would be suitable, whereas for more gravelly cover materials, a 20mm thick protection nonwoven may be necessary. As a reference value to aid in the selection of the correct geotextile, the achieved elongation of the geomembrane (as determined in the plate load bearing test) with a minimum confining stress of 2.5 times higher than the on-site final confining stress after 100 hours can be assumed. The actual permissible elongation depends on the requirements of the pipe and can lie between 0.25% and 1%.

Secutex® is resistant to all naturally occurring soil chemicals as well as microbiological deterioration. It also has high thermal resistance, which can be particularly important for heating lines etc. Wrapping pipes with Secutex® also provides a barrier that prevents intimate contact between the pipe and the soil, helping to reduce electrolytic corrosion. Upon request, Secutex® protection nonwoven geotextiles can also be supplied in various pre-cut widths. The finished product is easy to handle and quick to install, allowing pipes to be wrapped prior to placement in the pipeline trench.

The stability of a pipeline against flotation in soils that are subject to alternating groundwater conditions should also be considered. Where this is the case, concrete U-channels are often placed over the pipes to provide greater resistance to the uplifting forces. To protect the pipes from the rough surface of the concrete U-channel, as well as high point loading, Secutex® polypropylene (PP) nonwoven protection geotextiles with a mass per unit area of > 1,700g/m² are used to line the U-channels, providing a cushion effect even under high pressure. The PP raw material has a high long-term chemical resistance, even to the alkaline concrete, and it can be bonded to the concrete with suitable adhesives.

Figure 83
Increasing the soil bearing capacity in a pipe ditch with Combigrid® (Briesen, Germany)

Sub-base reinforcement

When constructing pipelines over soft or unstable soils, where differential settlement is expected, soil stabilisation measures will be required to ensure a homogeneous load distribution. Traditionally, soil stabilisation has been achieved by replacing soft soil layers with higher strength soils (often up to 1m), or by the construction of reinforced concrete pads.

Design Cross sections Details

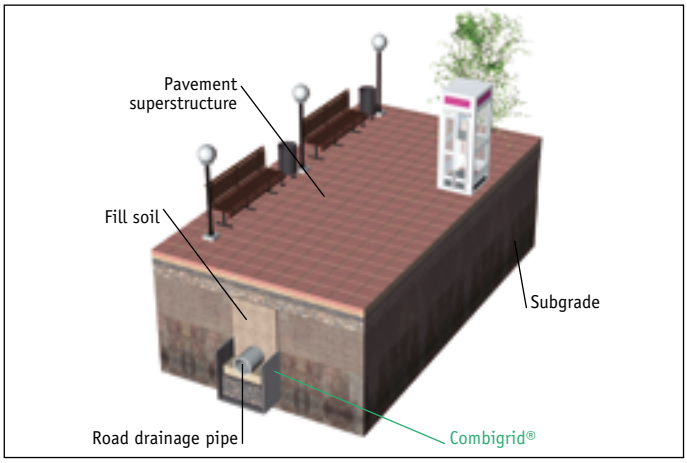


Figure 84 Pipe trench reinforcement (constructed at the side)

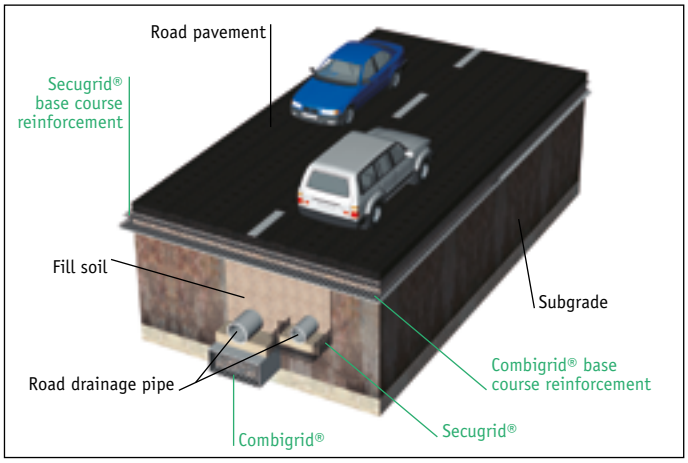


Figure 85 Pipe trench reinforcement

Figure 86
Installation of Combigrid® to increase the pipe foundation (Wismar, Germany)

Alternative economic solutions for soil stabilisation can be achieved using Combigrid®, a bonded composite product produced with Secugrid® high strength low elongation geogrids and with the excellent separation and filtration properties of Secutex® GRK rated geotextiles. The Secugrid® portion of the Combigrid® product evenly distributes the pipeline loading over a much larger base area resulting in a lower soil bearing capacity requirement.

The physical interlocking between Secugrid® and the coarse-grained fill material absorbs horizontal forces while the Secutex® component of the composite functions as a membrane, separating the finer grained subsoil from the coarse-grained fill soil. This membrane allows the passage of groundwater without the build-up of hydraulic pressures that may damage the pipeline (see chapter "Filtration with geotextiles").

Figure 87
Concrete U-channels with Secutex® protection nonwovens to avoid uplifting

Secugrid® is a monolithic laid geogrid of extruded flat bars that is welded at the crossing points. It makes differential settlement in the soil more homogeneous through its high force absorption at low elongation. The interlocking of Secugrid® with coarse-grained base course material provides optimum horizontal force absorption. This eliminates the need for additional soil replacement, such that the necessary E_{V2}-value of the bearing capacity can be economically achieved with little soil material.

Depending on the subsoil and the loads, various construction variations are possible. A structure with either one or two layers may be necessary. Where small or uniform settlement is expected, single or double layers of Combigrid® or Secugrid® may be placed along the base of the trench to provide planar reinforcement. If the settlement stability requirements are particularly high or in case of very soft subsoils, the U-shaped concrete forms with Secutex® protection are preferred over the planar construction method. The vertical layers of Secugrid® with their "disc-effect", substantially augments the bearing capacity of the pipe trench and creates a kind of rigid beam of crushed stone. At the same time, a connection between the backfill soil and trench wall is created, further reducing settlement.

Figure 88
Secutex® protection nonwovens for pipelines (Arnstorf, Germany)

The long-term performance of the base course can only be ensured if the fine particles of the fine-grained subsoil do not intermingle with the coarse-grained layer. As Secutex® filter nonwoven geotextiles are manufactured from long-term resistant PP, filter stability is assured (see chapter "Filtration with geotextiles") when the geotextile has a robustness of class 3 (see chapter "Separation with geotextiles").

Conclusion

Secutex® nonwoven geotextiles provide protection to pipeline systems against mechanical puncture and abrasion damage. Settlement that can occur in soft subsoil conditions can be controlled using either Secugrid® geogrids or Combigrid® composites. Secugrid® geogrids and Combigrid® also enables installation over soft subsoils possible, making expensive soil replacement unnecessary.

Design Cross sections Details

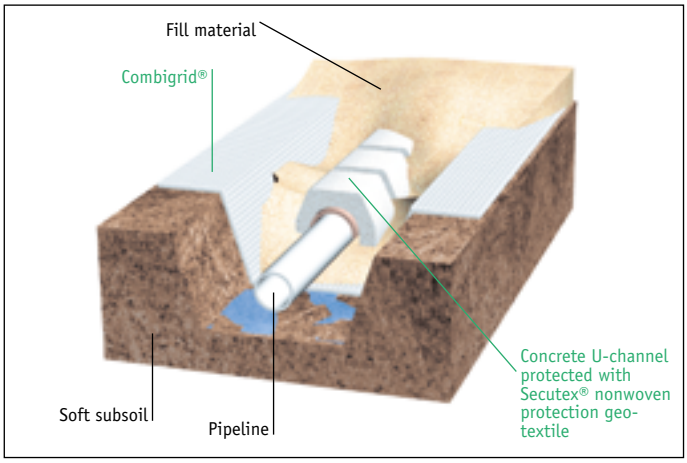


Figure 89 Protection against pipe floatation

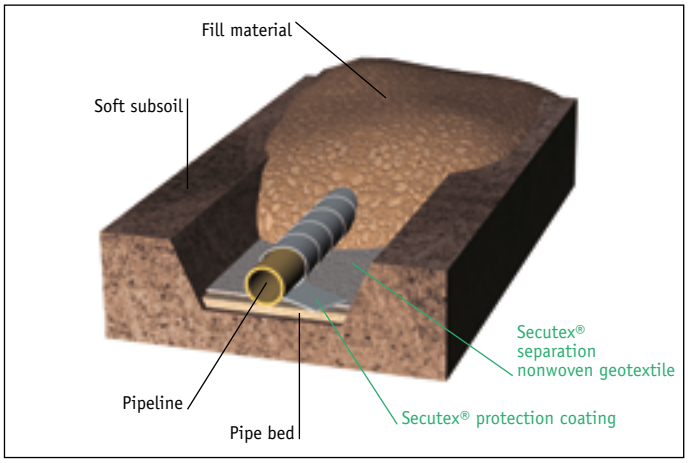


Figure 90 Pipe protection with a geotextile wrap

Quality assurance and control

...the continuous monitoring of raw materials, components, production and products

All incoming raw materials, fibres or components, needed for the production of our geosynthetics, are subject to a strict material analysis. Acceptance test certificates, submitted by base material suppliers, are reviewed and qualified in accordance with our product-specific protocols.

During production of all geosynthetics, additional quality assurance measures are performed. To ensure personnel effectiveness, the quality assurance staff is assigned to a separate and autonomous division from the production division.

After all quality assurance measures have been performed as defined in the quality assurance plan, an acceptance test certificate will be issued according to ISO 10204 when requested. Material will only be released once it has passed all quality reviews, checks and has all supporting documentation completed.

These quality assurance measures are conducted for all of our products according to the current standards and guidelines in effect at that time. This continuous manufacturing quality control guarantees product performance characteristics and enables complete documentation from the raw material to the final product.

Naue geosynthetics also undergo third party quality process checks that are typically performed twice a year. Independent experts obtain test specimens from the different Naue production facilities as well as from the various product inventories. The properties of the geosynthetic products are tested and documented in detail, including the notation of production processes, the type and extent of the manufacturing quality control and any other relevant observations.

Project-specific product properties

In special cases, independent experts are retained to test project-specific product properties and to certify the test results. This testing is in addition to and completes the manufacturing quality control carried out on the raw materials as well as the finished products.

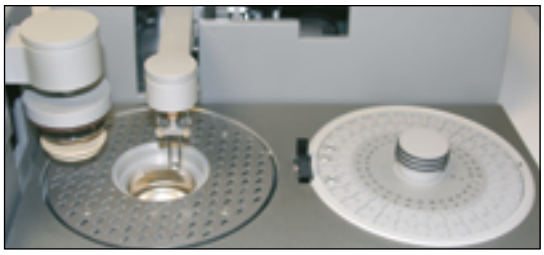
Quality management according to ISO 9001

Since December 1994, the geosynthetics development, production, sales and geotechnical engineering divisions of Naue GmbH & Co. KG have been certified according to ISO 9001. This certification is regularly validated by scheduled audits.

With the aid of this integrated quality management system, the requirements of the customer and/or the projects are understood and fulfilled. While we continually strive to improve the quality level of our existing products and services, a high quality foundation is guaranteed by our ISO 9001 standards.

Compulsory CE-marking

From 1st October 2002, CE-marking for geosynthetics was made compulsory (except for erosion control mats). The CE-marking certifies that a product corresponds to the product-specific European guidelines for specific applications and functions (separation, filtration, reinforcement, sealing, protection and drainage). Naue has taken all necessary steps to put into effect the compulsory CE-marking.



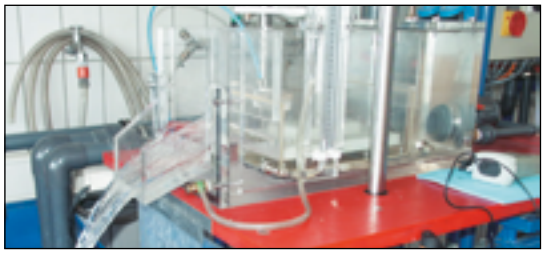
Raw material identification according to the DSC method (EN ISO 11357)

Determination of the strength and elongation properties of single fibres (EN ISO 5079)

Static puncture test according to (EN ISO 12236)

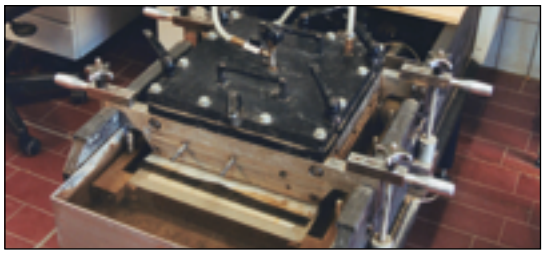
Tensile strength test of Secugrid® geogrids (EN ISO 10319)

Tensile test on Carbofol® geomembranes (EN ISO 527)



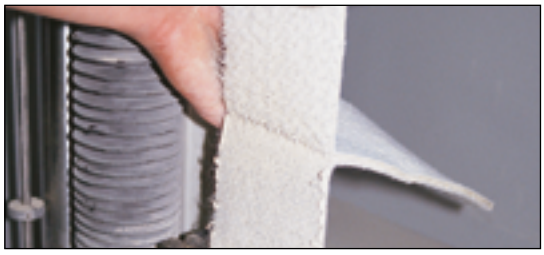
Determination of water flow capacity in their plane (EN ISO 12958)

Load plate-bearing test for the qualification of geotextile protection layers (EN 13719)



Direct shear device for the determination of friction coefficients (ISO 12957-1)

Determination of the montmorillonite content of bentonite via the methylene-blue-adsorption (titration) method (VDG P69)

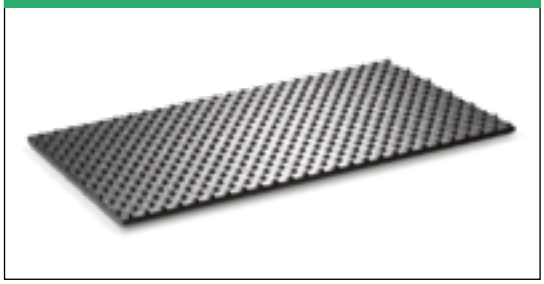


Determination of the bonded peel strength of Bentofix® geosynthetic clay liners (ASTM 6496)

Products

The innovations of Naue are leading the geosynthetic industry into the future. We offer project-specific product development, geotechnical engineering support, and provide solutions to complicated challenges, simplifying your project.

Carbofol®



Carbofol® geomembranes are made with high density polyethylene (HDPE). They are available in different thicknesses as well as with different surfaces for all of your sealing tasks.

Bentofix®

Bentofix® is a needle-punched reinforced geosynthetic clay liner (GCL) that uses two geotextile layers to encapsulate a layer of natural sodium bentonite. The needle-punched fibres transmit shear forces through the bentonite core. It is used as a sealing barrier against liquids and gases in various civil and environmental applications.

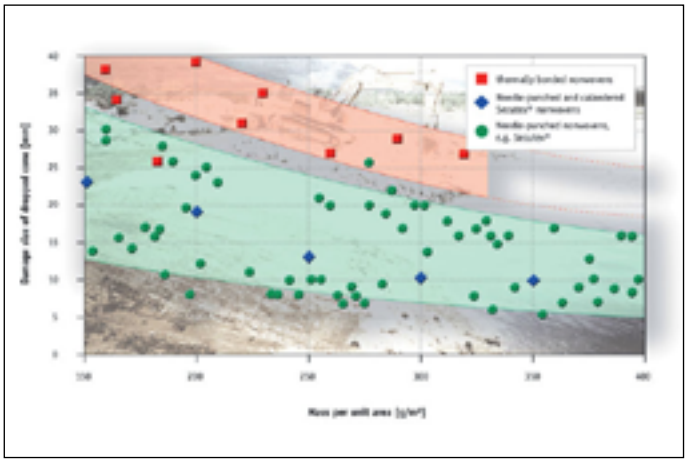
Secutex®

Secutex® is a needle-punched staple fibre nonwoven geotextile (some types are additionally calendered) used for separation, filtration, protection and drainage. Secutex® can be used in many civil engineering applications such as hydraulic engineering, landfill engineering, road construction as well as tunneling.

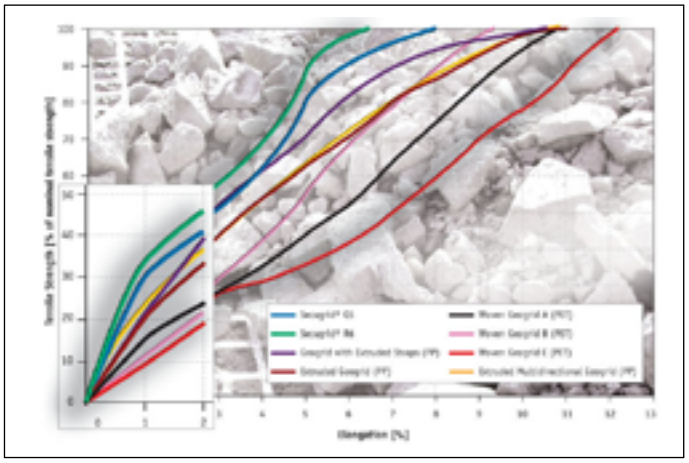
Secudrain® WD

Secudrain® is a three-dimensional drainage system designed to discharge liquids and gases. It consists of a drainage core and one or more filter layers on the outer surfaces to protect the drainage core from clogging. All layers are uniformly bonded together to ensure high internal shear strength.

Data Facts Figures



Cone drop behaviour (according to EN 918) of thermally bonded and needle-punched nonwovens



Typical stress/strain curves for geogrids during tensile strength tests according to ISO 10319 and ASTM 6637

Naue has decades of experience in the development and production of high quality geosynthetics, offering complete geosynthetic solutions.

Secumat®

Secumat® is a three-dimensional erosion control mat consisting of a UV-stabilised labyrinth-like polymer core. Secumat® controls surface erosion by ensuring rapid vegetation growth on slopes while preventing soil erosion during heavy rains and water flows.

Combigrid®

Combigrid® is a firmly bonded composite of a high strength, low elongation Secugrid® and a needle-punched Secutex® nonwoven geotextile for soil stabilisation and filtration applications.

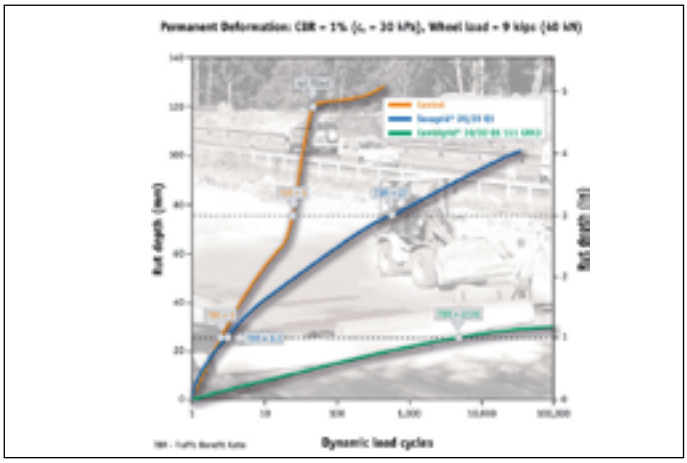
Secugrid® R

Secugrid® R geogrids have rectangular-shaped grid openings. As a rule, machine and cross machine strength are not the same. The numbers in each of the product names e. g. 200/40 for Secugrid® 200/40 R6 define machine and cross machine ultimate strength values [kN/m]. Typical applications of use are reinforced walls and slope stabilisation.

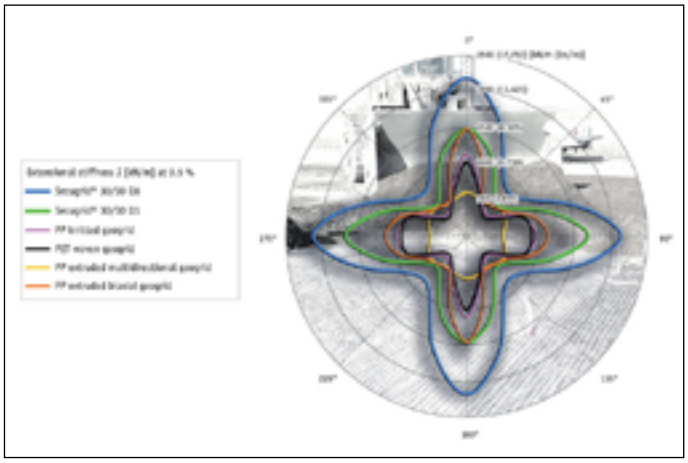
Secugrid® Q

Secugrid® Q geogrids are biaxial geogrids with uniform, square shaped grid openings. With these geogrids the machine and cross direction extruded polypropylene straps exhibit uniform strengths in each direction. The numbers in each of the product names e. g. 30/30 for Secugrid® 30/30 Q1 define machine and cross machine direction ultimate strength values [kN/m]. A typical application of use is base reinforcement.

Data Facts Figures



Combigrid® and Secugrid® traffic benefit ratio over a very weak subsoil, compared to an unreinforced design



Radial secant stiffness of geogrids at 0.5% elongation

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