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# GEOTEXTILE REINFORCEMENT OF A RAILROAD STRUCTURE
# TRAGFÄHIGKEITSERHÖHUNG DURCH GEOTEXTILIEN IM EISENBAHNUNTERBAU
# RENFORCEMENT D'UNE STRUCTURE DE VOIE FERREE PAR UNE NAPPE TEXTILE

Geotextiles placed in the layer system of the substructure of the track are supposed to help to decrease the tensions and deformations which result from operational loads and to improve or preserve the strength properties of the gravel sand placed in the substructure. The analysis of the field tests made in the years from 1977 to 1984 revealed that the load carrying capacity of a layer system with incorporated non-woven fabrics is higher in terms of long-time behaviour than that of systems without non-woven fabrics and that non-woven fabrics gain increased importance in cases of sub-grades with a lower load carrying capacity. Given this there was developed a model according to which the effect of non-woven fabrics was adjoined to the gravel sand layer lying upon it.

## 1. Introduction

Railway traffic and weather exert static and dynamic pressure on the road bed. Along many line sections railway subgrade is no longer able to cope with the stress; there occur deformations in the soil substructure and the load carrying capacity is impaired.

The underlying reasons are increased traffic load, new types of permanent way and the condition of drainage systems.

In order to maintain or restore the stability of the track position, it is necessary to build drainage systems and, if this does not suffice, to imporve the railway subgrade.

Such work involves high building expenditure and disturbe railway traffic. In addition, the technical solutions applied so far have not sufficiently stood the test with regard to discharge stability and the gravel sands available do not always meet demands.

Given the structure and properties of geotextiles, they may make a contricution to the

- separation and filtering of unconsolidated rock,
- drainage and stabilization of unconsolidated rock,
- carrying capacity of layer systems.

The Deutsche Reichsbahn (DR) has therefore tested and used geotextiles since 1974 to rationalize building processes and enhance the functionability and life of track installations. tions.

Road bed drainage systems admit insertion of various textiles and non-woven fabrics with guideline (1) 1980. Geotextiles may consequently, in case of non-existent discharge stability, be built into the contact zone between the adjacent unconsolidated rock and the gravel sands in the shape of a ditch filter and in the contact zone between the gravel sand and the tube perforation in the form of a tube filter. Their opening size (pore characteristic $O_{90}$) is calculated in dependence on the adjacent unconsolidated rock. Long-terms tests (2), covering a period of observation ranging between five and nine years, prove that filters in drainage systems built with geotextiles function reliably and need little maintenance. Permeability is ensured, detrimental solid particle shifts (erosion and colmation) are excluded and an initial contact suffosion is rendered possible. Negative influence through ageing has not been observed. We propose a new diagram for designing the opening size based on an analysis of previous tests (2), under which the ratic $O_{90}/D_{50}$ can be selected in dependence on the non-uniformity between the boundary lines for erosion and colmation.

Non-woven fabrics with the guideline (3) 1981 were admitted as an element of the subgrade layer system. Under it, non-woven fabrics can be built in on the soil substructure between the adjacent unconsolidated rock and the protective layer and/or ballast material. They serve as a separating and filtering element to prevent detrimental solid particle shifts and interpenetration. Being reinforcing elements, they prevent deformations in the superior layer, absorb tractive forces and share in the load carrying capacity of the layer system. Long-term tests over a period of observation of five to eight years have shown that non-woven fabrics are suited as a component of the subgrade layer system. This is true of cases with direct ballast addition in the context of intermediate and preventive action and of insertion in connection with protective layers composed of gravel sand.

We will report on some selected results, particularly on those relating to an increase in the load carrying capacity of layer systems with non-woven fabrics.

## 2. Foundations of the load carrying capacity of the layer system

In the road bed load carrying system every element (rail, sleeper, ballast bedding, protective layer) has its own particular share in decreasing the load resulting from railway traffic. The tensions that occur must be absorbed by the given strengths, beth for the carrying system as a whole and for anyone of the elements. The deformation of the carrying system must not exceed the permissible limits. The determination of the dimensions depends on the observation of the permissible rail stress. The load carrying capacity of the layer system required (adjacent unconsolidated rock - protective layer - bedding) is composed of the load carrying shares of the layers. The lower the load carrying capacity of the adjacent unconsolidated rock, the higher the load carrying share of the layers to be built in mus be. The specific deformation modulus of the material to be built in and the depth of the layer are decisive for it. The share of the bedding is considered as constant in case of the grain size of the ballast according to rule and a corresponding depth of the layer below the lower sleeper edge, as well as medium degree of imputity. According to current regulations, the gravel and stone sand of the protective layer is based on a constant specific deformation modulus $E_{ps}$.

The regulations maintain as variable dimensions and dimensions subject to influence the depth of the protective layer and the carrying capacity of the adjacent unconsolidated rock. Under TGL 24756/09, it is therefore possible to calculate the depth of the protective layer of gravel sand in dependence on the minimum load carrying capacity of the soil substructure and with due regard to a stabilization of the adjacent unconsolidated rock through lime.

Elements which are newly to be built into the layer system must adapt to these principles. Their job is to reduce tensions and deformations as well as improve and maintain in the long run the strength properties of the materials used.

Geotextiles (especially non-woven fabrics) are relatively thin, flexible, elastic, even and stable broad-sized materials. Due to their specific physical and geohydraulic parameters, they may have the following effects on the carrying behaviour of layer systems:

- Separating and filtering effect

  The geotextile prevents solid particles rising up from the adjacent unconsolidated rock into the protective layer and/or the bedding. The materials thus remain clean, keep their shear strength and consequently their carrying capacity. There will be no drop in the specific deformation modulus owing to impurities from below; the load carrying capacity is retained.

- Separating effect

  The geotextile prevents a mixing (interpenetration) of the gravel sand with the adjacent unconsolidated rock and maintains a clear layer structure; the effective layer depth and the load carrying capacity are thereby maintained.

- Reinforcing effect

  Inserted in the layer system, the geotextile acts as a reinforcing element of the superior layer. It prevents the deformation of the layer, absorbs tractive forces and increases the load carrying capacity of the layer.

These influences on the carrying behaviour do not occur separately. They are generally expressed in an enhanced deformation modulus at the upper edge of the superior layer and in a greater long-time stability of the layer system.

## 3. Results of the field tests

### 3.1. Scope of the test

In the period 1976 - 1980 the Deutsche Reichsbahn established a total of 10 test sites with a protective layer of gravel sand and non-woven fabrics. Some 10,300 $m^2$ of non-woven fabrics were built in over 2,250 m of track.

Special measurements were made during three tests conducted in 1976 and in 1977. The load carrying out at a test site of the Deutsche Reichsbahn at Theißen (4) rendered results which are particularly capable of generalization given the uniform geological and hydrological conditions. It will therefore be given major attention. The other tests will only be referred to to complement the results.

### 3.2. Field test at Theißen

#### 3.2.1. Characteristics

Insertion of a non-woven fabric in connection with a protective layer of gravel sand

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| Extension: | 530 m, of which<br>480 m with non-woven fabric and<br>50 m without (zero section) |
| Test fields: | 25 m each |

Adjacent unconsolidated rock: loess loam (UT), spread evenly

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| | over the whole test site<br>$w_L$ = 0.29 ... 0.37,<br>$w_p$ = 0.14 ... 0.19<br>$I_p$ = 0.1 ... 0.2 |
| Drainage: | Ditch on left side of railway partly grown over and contaminated |
| Protective layer: | Gravel sand<br>- Depth of layer according to TGL 24756/08 and 09: for the unconsolidated rock UT and the hydrological case 2 ($I_c$ = 0.75 ... 1.0) the calculation modulus is $E_H$ = 15.0 MPa<br>Depth h = 25 cm<br>existing depth h = 28 cm<br>- Filtering stability according to TGL 24756/09<br>$w_L = 0.302 \rightarrow d_{17}$; perm. = 0.19 mm<br>$d_{17}$, exist. = 0.46/1.3 mm > 0.19 mm = $d_{17}$, perm.<br>The gravel sand is not safe from contact erosion from the |

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| | adjacent loess loam. A non-woven fabric must be built in as a filtering element. |
| Non-woven fabric: | building fabric from Wurzen<br>WT 2 - 450 g/m$^2$, $0_{90}$ = 0.10 mm<br>WT 3 - 600 g/m$^2$, $0_{90}$ = 0.10 mm<br>WT 5 - 450 g/m$^2$, $0_{90}$ = 0.12 mm |
| Track load: | 54,000 gross Mg/24 h<br>From the date service started on 24 October 1977 to the date of measurement on 30 March 1984 about 125 million gross t. |

3.2.2. Evaluation:

The track installation is stable. There are no inadmissible deviations with regard to longitudinal and transversal height or torsion. The ballast is normally or heavily contaminated as a result of trickling loss. The depth of the bedding is between 40 and 50 cm. A mixed zone of some 3 cm has formed between the ballast and the gravel sand.

The non-woven fabric constitutes a clear separating layer between the loess loam and the gravel sand, its prevents mixing and ensures filtering stability.

In contrast to it, a mixed zone of loess loam-gravel sand of 6 ... 10 cm formed in the zero section without non-woven fabric until March 1984.

The fabric shows no damage and has taken on a yellowish colouring. It sticks firmly to the loess loam; when it is being detached, soil particles are torne out too. The fabric samples are relatively rigid and firm and form a stable plate after drying. On the surface of the non-woven fabric, gravel sand particles have deposited. The random-laid structure of the fabric is penetrated by loess loam.

This finds expression in an increase in the surface mass of the colmated samples taken of 450 g/m$^2$ to ~2,875 g/m$^2$. In the random-laid structure of the fabric ~2,425 g/m$^2$ of fines have consequently been deposited. This colmation leads to a decrease in the opening size $0_{90}$, from $0_{90}$ = 0.10 mm/0.12 mm to $0_{90}$ ~0.06 mm. Despite these appearances of colmation, the permeability k of the non-woven fabric has changed only slightly. The laboratory tests produced the following results:

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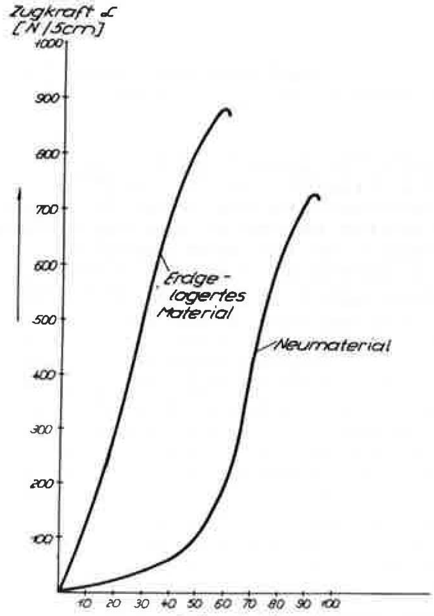
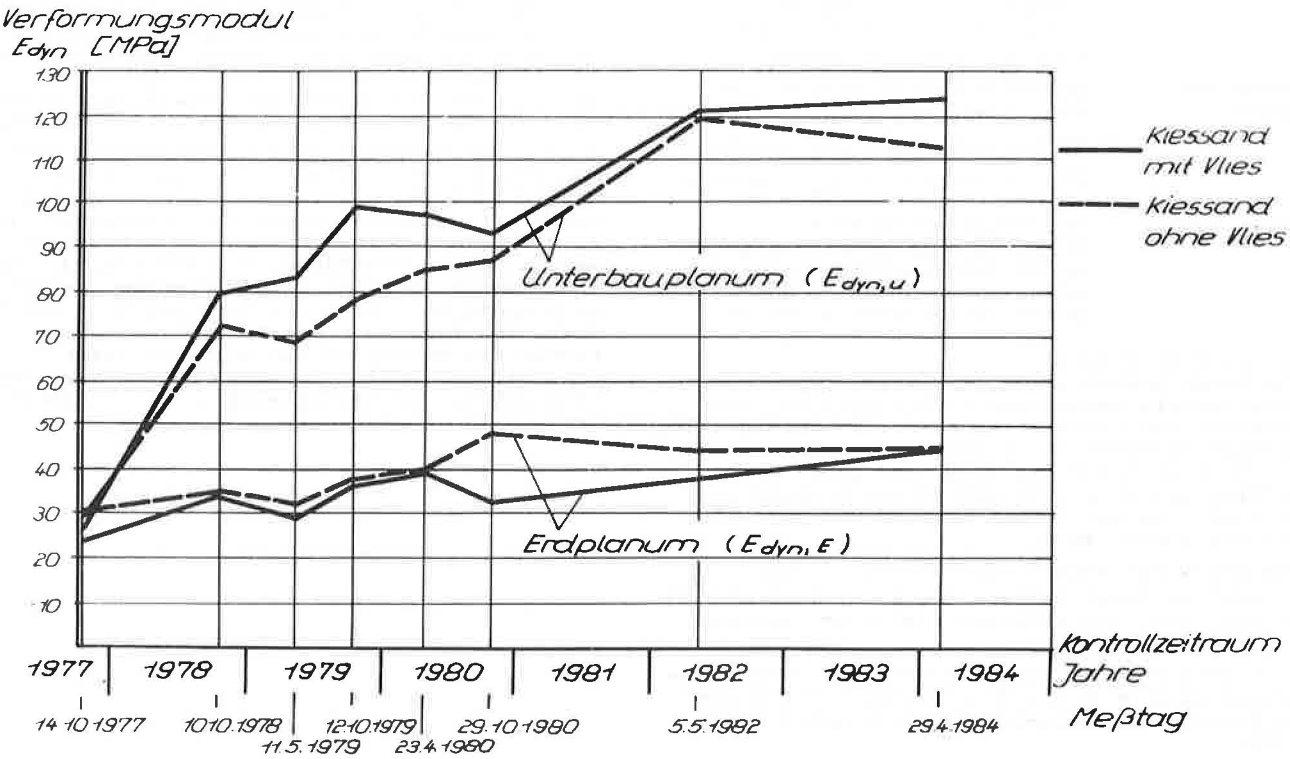
| WT 5 new | 1977 | k = 8.52 · $10^{-3}$ m/s |
| WT 5 soil-attached | 1979 | k = 5.54 · $10^{-3}$ m/s |
| WT 5 soil-attached | Oct. 1984 | k = 1.7 · $10^{-3}$ m/s |

The water from the adjacent loess loam (k = $10^{-6}$... $10^{-7}$ m/s) thus can run through without being dammed up. In order to express the changes in the stability of the non-woven fabric in terms of measurements, tensile tests were carried out according to TGL 0-53857 on textile strips which were 5 cm wide, with new and soil-attached samplex (graph 1). The higher stability of the soil-attached non-woven fabric expresses itself in a greater breaking strength, in lower breaking elongation and, above all, in a changed curve behaviour. Soil-attached samples do not avoid so much load, but absorb tensile forces even in cases of low elongation The soil substructure is solid, even and sloped transversally; deformations have not occured. The deterioration of the hydrological conditions at the ditch grown over expresses itself in a lower increase in the natural water content $w_n$ and in a lower decrease in the consistency index $I_c$. The takings of samples at the test points showed that the cohesiveness of loess loam differs from sector to sector (plasticity index $I_p$ = 0.11 and 0.18). Despite an almost identical natural water content $w_n$ = 0.178 ± 0.03, there thus appeur sections with differing consistency index $I_c$ = 0.71 ... 1.13 and $I_c$ = 0.91... 1.23. The four test points with non-woven fabric are mainly in the range of stiff consistency, while the zero section with two test points was established in the range of semi-solid consistency.




Graph 1 - Tensile force - elongation behaviour (parallel)

As a result, we always measured a lower load carrying capacity of the soil substructure at the test points with non-woven fabric. The results of the load carrying capacity




Graph 2 - Results of load carrying capacity measurements ($E_{dyn}$), Theißen site

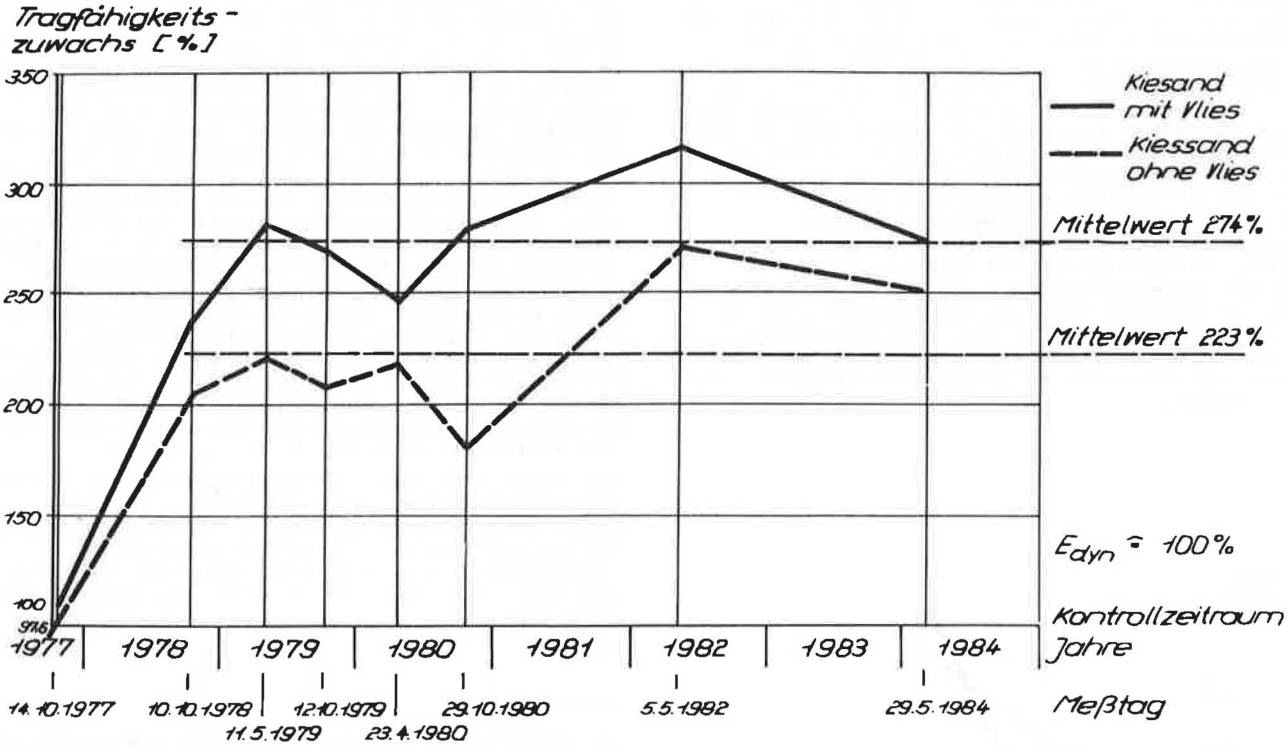
measurements with the dynamic plate $E_{dyn}$ according to TGL 11461/10 on the soil and road bed substructure are shown in graph 2, featuring the medium values of the measurements and the development of the load carrying capacity over a period of some seven years. The layer system, which in October 1977 did not have the carrying capacities required, was consolidated by October 1978, attaining normal values. The carrying capacity of the soft softer soil substructure at the test points w with non-woven fabric is lower throughout. Nevertheless, we always measured higher load carrying capacities on the road bed substructure, with the exception of the initial measurement. This can also be seen in graph 3, which shows the increase in the load carrying capacity through the protective layer with and without non-woven fabric and its development over the time.

The layer of gravel sand with non-woven fabric produces a higher increment than without non-woven fabric; the factor of improvement $v = \frac{E_{dyn,u}}{E_{dyn,E}}$ is for the protective layer of gravel sand v = 2.23 and for the protective layer of gravel sand with non-woven fabric V = 2.74. The higher load carrying capacity of the protective layer with non-woven fabric and the dependence of the effect produced by the non-woven fabric on the carrying capacity of the soil substructure is clearly shown by the regression lines of all the values measured in graph 4. The influence of the non-woven fabric is greatest in the case of soft soil substructure and it decreases as the carrying capacity of the soil substructure rises.

No difference have been found between the qualities of non-woven fabrics used as regards filtering stability and influence on the load carrying capacity.

Conclusions regarding the effect of the non-woven fabric.

Laboratory and field texts indicate that geotextiles influence positively the load carry-




Graph 3 - Load carrying capacity increment, Theißen site

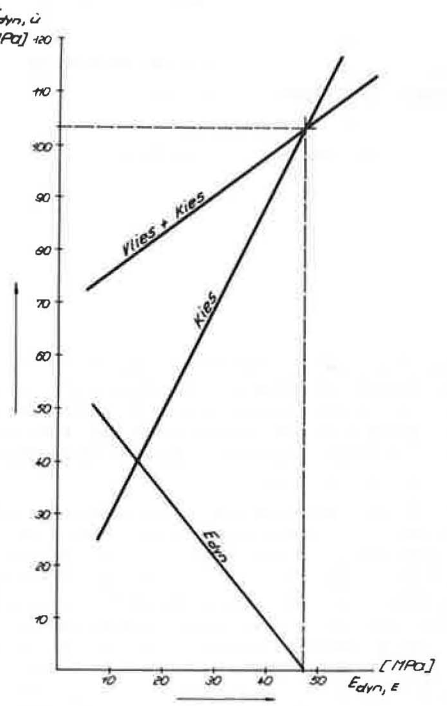
ing capacity of the layer system. The load carrying capacity of a layer system with non-woven fabric is in the long run higher than without non-woven fabric, and as the carrying capacity of the soil substructure drops, the influence of the non-woven fabric rises.

The non-woven fabric has proved its effectiveness as a separating and filtering element. The strength properties of the superior protective layer are maintained in the long run.

A protective layer with non-woven fabric is capable of coping with locally limited spots and phases where there is lower load carrying capacity without critical deformations and with clear separation between the layers.

A lower deformation has been measured on the protective layer with non-woven fabric (depression of the plate). The non-woven fabric consequently prevents the deformation of the superior protective layer. It acts as a tractive element and absorbs part of the vertical forces resulting from the operational load on the level of the non-woven fabric in the form of tractive force ($P = R + Z \cdot \sin \beta$). This reinforcing effect increases as the soil substructure becomes softer, since deformations ($\sin \beta$) become greater.

The effect of the non-woven fabric as an element of increasing load carrying capacity, does not, however, occur immediately after insertion, but only in a phase when the layer system stabilizes. This must partly be attributed to the gravel sand, the compactness of which increases under conditions of operational load and whose compactness of deposition becomes higher. The non-woven fabric, however, and the interaction between the non-woven fabric, however, and the interaction between the non-woven fabric and the adjacent unconsolidated rock accounts for most of the effect. Solid particles from the surrounding unconsolidated rock have deposited in the random laid structure of the fabric, resulting in a stabilized fibre structure through soil particles. Existing cavities in the random laid structure are filled, a displacement of the fibres is impaired or prevented and thereby a deformation of the non-woven fabric, both on its own level and vertically to its level. The solid particles transmit pressures; the fibres absorb tractive forces. The tensile test on soil-attached samplex (see graph 1) indicates much lower breaking elongations (between 30 and 57 %) and a changed behaviour. Low elongations are also capable of absorbing forces. In case of direct insertion in the adjacent unconsolidated rock and under conditions of biaxial tension, the capacity of the non-woven fabric and of the soil-non-woven fabric system will be even lower, so that forces can be absorbed while deformations are still minor.




Graph 4 - Comparison of load carrying capacities of gravel sand with and without non-woven fabric

## 4. Measurement for the layer system

The layer system is measured according to the multi-layer theory. Given its low thickness, the non-woven fabric as a separate layer does not produce an increase in the load carrying capacity. The reinforcing effect comes, as has been shown by measurements, from the superior layer. In the case of the protective layer with non-woven fabric, with the carrying capacity of the soil substructure and layer depth being equal, we measured higher load carrying capacities of the road bed substructure. The protective layer with non-woven fabric must therefore produce a higher specific deformation modulus. The specific deformation modulus under the multi-layer theory was established at $E_{ps}$ = 150 ... 200 MPa on the basis of the measuring results obtained (graph 4). For the protective layer with non-woven fabric there was a dependence of the specific deformation module on the load carrying capacity of the soil substructure of $E_{ps'}$ = 240 ...1,000 MPa. The deformation module calculated is highest for soft soil substructure, since the non-woven fabric as a tractive element absorbs the highest proportion of the vertical forces. With a diminished specific deformation modulus of $E_{ps'}$ = 250 ... 500 MPa, a new measurement curve can be established for the layer system with non-woven fabric. A comparison between the measurement curves for protective layers with and without non-woven-fabric shows that the protective layer with non-woven fabric will find its application in calculation modulus $E_H \leqq 15$ ... 20 MPa.

For these low load carrying capacities of the soil substructure, the advantages of the non-woven fabric as an element of separation, filtering and reinforcement are especially conspicuous. Both the load carrying capacity and the long-time behaviour of the layer system will improve.

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