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GERMAN, BRITISH AND POLISH REGULATIONS FOR THE USE OF GEOSYNTHETICS IN ROAD AND RAIL WAYS STRUCTURES AS SEPARATION & FILTRATION AND AS REINFORCEMENT LAYERS

Abstract

Introduction. The use of geosynthetic materials in road and railway construction has become widespread in Europe due to their ability to perform separation, filtration, and reinforcement functions in soil and structural systems. A crucial task is the comparison and systematization of regulatory frameworks from different countries to ensure the reliability and durability of transport structures.

Problem Statement. Despite extensive practical experience, challenges remain in unifying requirements for geosynthetic properties, selection criteria depending on soil type, load and installation conditions, as well as in evaluating long-term durability under various environmental influences.

Purpose. The main objective of this study is to analyze and summarize German, British, and Polish regulations on the application of geosynthetics in road and railway construction, and to demonstrate approaches to the selection and calculation of their characteristics.

Materials and Methods. The research is based on a review and comparison of key regulatory documents (EBGEO:2010, BS 8006:2010, ITB 429/2007, RStO 12, RIL 836:2022), analysis of the Geotextile Robustness Classification (GRC**)** system, and examples of methods for determining foundation bearing capacity, considering creep, durability, and resistance of geosynthetics to mechanical and chemical impacts.

Results. It is shown that the German GRC system effectively combines soil properties and installation conditions for the correct choice of geotextile. The paper characterizes design rules for reinforced embankments, retaining walls, and working platforms according to current standards. The application of geosynthetics ensures compliance with deformation modulus requirements (Ev2 ≥ 45 MN/m²) for road and railway structures, reduces the thickness of load-bearing layers, and increases structural reliability.

Conclusions. Geosynthetic systems have proven their effectiveness in transport construction and have become an integral part of modern engineering solutions. Their use enhances the durability and safety of structures, while the analysis of regulations confirms the need for harmonization of requirements across European practice to support further technological development

Keywords: geosynthetic materials, geotextile, geogrid, road and railway structures, soil separation, filtration, reinforcement, durability, EBGEO, BS 8006, RIL 836, Geotextile Robustness Classification (GRC).

Legislative basis of the German Regulation System used in the design of geotextile improved / modified soils or structures

The legislative basis for contracts in road constructions is the «Verdingungsordnung für Bauleistungen, VOB/A, :2019 VOB/B, :2016 VOB/C:2016», a framework of German Standards (DIN) for contract provisions for all kind of building and construction. There are 3documents for earth works in the road construction including the use of geosynthetics, which are supplementing each other:

— ZTVE StB 2017, Additional provisions for technical contracts and guidelines for earthwork in road construction;

— TL Geok E-StB 2019, Technical terms of delivery of geotextiles and geogrids in earthwork in road construction;

— M Geok E 2016, Leaflet on the use of geotextiles and geogrids in earthwork in road construction.

For the use of geosynthetic in railways structures RIL 836 [8] was revised and published in 2022.

The elaboration of regulations for road construction was the task of special working groups of the «Research Association for Roads and Transports (Forschungsgesellschaft für das Straßen-und-Verkehrswesen FGSV)» with members from administrations, contractors, consultants, producers and universities. The regulations are recognised by the Minister of Transport of Germany and of the German Federal States (Bundesländer) as obligatory for all relevant parties.

Geosynthetics in earth works, Merkblatt M Geok E 2016

The «Leaflet on the use of geosynthetics in earthwork in road construction 2016», Merkblatt für die Anwendung von Geokunststoffen im Erdbau des Straßenbaus 2016) have following parts:

(1) general remarks;

(2) terms and their definitions;

(3) technical properties of products (geotextiles, geogrids, geocomposites and geosynthetic barriers);

(4) fields of applications:

— separation of different kind of soils, to prevent the penetration of fine particles into coarse grained soils under load but to allow the move of pore water;

— filter to allow the passage of water and protect the soil structure subjected to hydrodynamic forces;

— drainage by collecting and transporting of water in the plain of the drainage layer;

— reinforcement of embankments, slopes and retaining structures against failures;

— protection of surfaces against erosion;

— protection of geosynthetic and natural barriers against damage;

— barrier function: the control of migration of liquid or gas;

(5) basic conditions for dimensioning of filters and reinforcements;

(6) test procedures;

(7) proposals for the selection of products for a given use;

(8) recommendations for contract design.

Geosynthetics in pavements

In addition, two groups of the FGSV are engaged to work out «Notes on the use of geotextiles under concrete pavements» and «Notes of the use of geosynthetics in asphalt — interlayers».

The use of nonwovens between a cement — or an asphalt bounded base and a concrete pavement plate is now a regular construction principle, after more than 20 years practice experience with test sites on heavy trafficked German Highways. The nonwoven has the function of separator between pavement concrete plate and base, a drainage function to discharge water which seeped through joints to the sides and a bedding function to cushion and absorb dynamic traffic load.

Product specification- selection of geotextiles

Functions and related properties of geosynthetics

To find the product, which fits best in a special application, the designer must define the properties, which the product must have and the technical requirements, which it must be fulfilled. Calculations will be performed where calculations are possible and will be omitted, if there is no calculate basis or where calculations does not fit **Table 1**.

Table 1

Functions and related properties of geosynthetics, [2]

Properties	Separation	Filtration	Drainage	Reinforcement	Protection of soil	Protection of barriers	Barrier function
Mass per unit area	GRC	GRC	-	-	*	class	class
Thickness	-	*	calc	-	*	class	class
Resisting tensile force	GRC	GRC	-	calc	*	calc	class
Elongation	GRC	GRC	*	calc	*	class	class
Creep, creep rupture	*	*	-	calc	-	-	class
Robustness to installation damage	GRC	GRC	GRC	rf/st	***	class	prot
Friction	-	-	-	calc	*	calc	calc ***
Characteristic opening size	class	calc	calc **	-	-	-	-
Water permeability	class	calc	calc	-	-	-	-

End of the table 1

Properties	Separation	Filtration	Drainage	Reinforcement	Protection of soil	Protection of barriers	Barrier function
Resistance to weathering	class	class	class	class	class	class	class
Resistance to chemical ageing	class	class	class	class/rf	class	class	Class
Calc: calculation; class: classification; GRC: Geotextile-Robustness-Classes; rf: reduction factor; st: site test; prot: to be protected; * influence not to quantify; ** filter only; *** installation procedure according to product properties; **** on inclined plains only; not needed.							

Mass per unit area and thickness

Mass per unit area is used for product identification and for definition of minimum values for protection layers. Mass per unit area can be used as index value for a comparison with other products or for the estimation of material efficiency of used polymers.

Thickness under load including compressive creep is important for drains, for protection layers and for barriers. Thickness should be tested at load: 2, 20, 200 kN/m^2 or project specified.

Geotextile-Robustness-Classification

The German Dr. Eng. W. Wilmers [2] changed the Nordic Classification in 1994 into 5 classes. It was based on push-through-force for nonwovens (EN ISO 12236) and on the tensile strength and elongation of wovens tested, (EN ISO 10319). It was decided In Germany to continue with the Geotextile — Robustness — Classification.

Classification of fill material

To find out the necessary GRC for a given site, the fill material should be assigned in one of the 5 levels, on the base of the diameter and the coarseness/sharpness of aggregates, s. **Table 2**.

Table 2

Classification of cover – material: classes AS1 to AS5, [2]

Classes	Type of cover material
AS 1	without influence of selection
AS 2	round shaped coarse grained or mixed material without stones
AS 3	AS 2 with 5 % ≤ 40 % stones
AS 4	AS 2 with ≥ 40 % stones
AS 5	AS 4 with sharp edged aggregates

Stones— have a diameter d ≤ 63 mm

When using a fill of sharp edged, crushed aggregates, take the next higher class of cover: AS 3 of rounded aggregates becomes AS 4 with sharp edged aggregates.

When the subsoil is a compacted coarse-grained soil, the class has to be elevated 1 step: than a fill with coarse-grained sharp-edged aggregates on a subbase of a very stiff clay becomes AS 5.

A fill of stones on coarse grained subbase does not need a separation layer. If ever a fill with more than 40 % sharp edged stones as to be placed on a very stiff clay, site tests are proposed.

Classification of impact load during installation, GRK

The load or impact resulting from installation and the art of construction works is divided in 4 impact levels. AB, s. **Table 3**.

Table 3

Classification of impact load during installation, [2]

Classes	Type of impact load on geosynthetic
AB 1	Manual installation and covering no significant stresses resulting from compaction
AB 2	Mechanical installation and compaction without significant stresses resulting from construction vehicles

End of the table 3

Classes	Type of impact load on geosynthetic
AB 3	Mechanical installation and compaction and increasing stress resulting from permitted rutting with depths from 5 to 15 cm
AB 4	Mechanical installation and extreme stresses resulting from permitted rutting with depths of more than 15 cm

Combination of fill and impact load to GRK

The necessary Geotextile-Robustness-Class (GRK) for a given site is the result of a combination of the class of fill material (AS) and of load impact (AB), see **Table 4**.

Table 4

Determination of the Geotextile-Robustness-Class, [2]

Fill Classes AS	Loading Classes AB				
	AB1	AB2	AB3	AB4	AB 5
AS 1	GRK 3				
AS 2	GRK 3	GRK 3	GRK 3	GRK 4	GRK 5
AS 3	GRK 3	GRK 3	GRK4	GRK 5	(1)
AS 4	GRK 4	GRK 4	GRK 5	(1)	(1)
AS 5	GRK 5	GRK 5	(1)	(1)	(1)

(1) field tests necessary or increasing thickness of the cover layer required

Table 5

Geotextile Robustness Classes for non-woven, [2]

Geotextile Robustness classes GRK (-)	CBR - test puncture resistance req. $FP_{,5\%}$	Mass pro unit area Req. $m_{A,5\%}$
3	≥ 1,5 kN	≥ 150 g/m^2
4	≥ 2,5 kN	≥ 250 g/m^2
5	≥ 3,5 kN	≥ 300 g/m^2

Table 6

Geotextile Robustness Classes for Products: woven and knitted (foil strips and splice yarns, mostly PP or PEHD), [2]

Geotextile Robustness classes GRK (-)	Maximal tensile force req. $T_{max, 5\%}$	Mass pro unit area Req. $m_{A,5\%}$
3	≥ 35 kN	≥ 180 g/m^2
4	≥ 45 kN	≥ 220 g/m^2
5	≥ 50 kN	≥ 250 g/m^2

Table 7

Geotextile Robustness Classes for Products from multifilament yarns, [2]

Geotextile Robustness Classes GRK (-)	Maximal tensile force req. $T_{max, 5\%}$	Mass pro unit area Req. $m_{A,5\%}$
3	≥ 150 kN/m	≥ 320 g/m^2
4	≥ 180 kN/m	≥ 400 g/m^2
5	≥ 250 kN/m	≥ 550 g/m^2

This table is valid for products with tensile strength tested longitudinal (MD) and tensile strength 50 kN/m crosswise machine direction (CMD). For the use of products with another tensile strengths field tests will be recommended.

With this classification can be covered by the design the load impact on products by installation procedure and type of fill soils. It means, that the most possible site condition can be reflected. On sites, where the stresses are higher, a field test will be proposed. The simplest way to reduce rutting is to enlarge the thickness of the fill cover layer. In other cases, it can be interesting to combine a geosynthetic reinforcement with the separation layer.

Reinforcement combined with separation fill layer

Sometimes a combination: non-woven & geogrids or simply a high tensile strength woven will be combined with cover soil on the very soft base. In such case the thickness of bearing layer and the required tensile strength of reinforcement should be estimated by the use of static calculations. The soft soil could be tested on 3 ways:

— static loaded plate test in situ with the results: E_{v2} and E_{v1}, $E_{v2}//E_{v1}$;
— vane test in situ, with c_u undrained shear strength;
— CBR field or laboratory tests with % of basic value.

These parameters can be correlated, in many publications some of this correlation are presented in the **Fig. 1**.

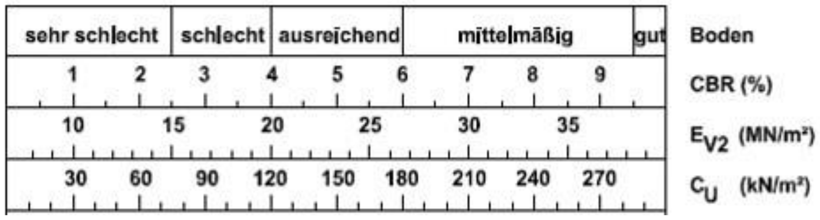


Figure 1 **—** Correlation of CBR, E_{v2}, c_u, [HUESKER Collected data]

In Germany all classes paved roads [RStO 12] and all railways classes [RIL 836] should be constructed only, if on the top of the base, foundation level (Planum) $E_{v2} \geq 45$ MN/m^2. This requirement could be solved by soil exchange & geosynthetic reinforcement. In the first step designer can try to achieve the $Ev_2 \geq 45$ MN/m^2 only by soil exchange using the nomogram, s. **Fig. 2** without reinforcement.

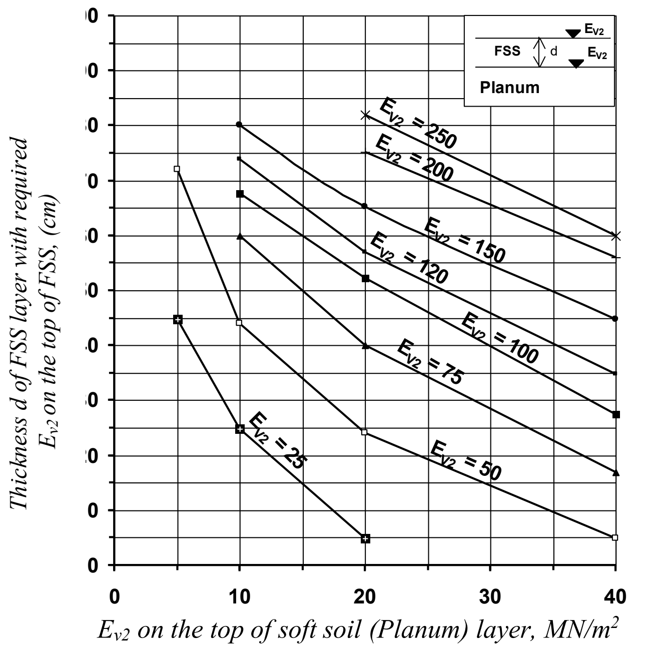


Figure 2 — Thickness of frost and bearing layer (FSS) depend on E_{v2} on the top of soft soil layer (Planum) and the required value E_{v2} on the top of FSS layer (FSS-Frostschutzschicht), Technical University of Munich

The thickness of required cover soil layer could be reduced by the use of reinforcement. For such solution there are many nomograms or software programs published by geosynthetic producers and academic institutes, for example Huesker Synthetic, **Fig. 3**.

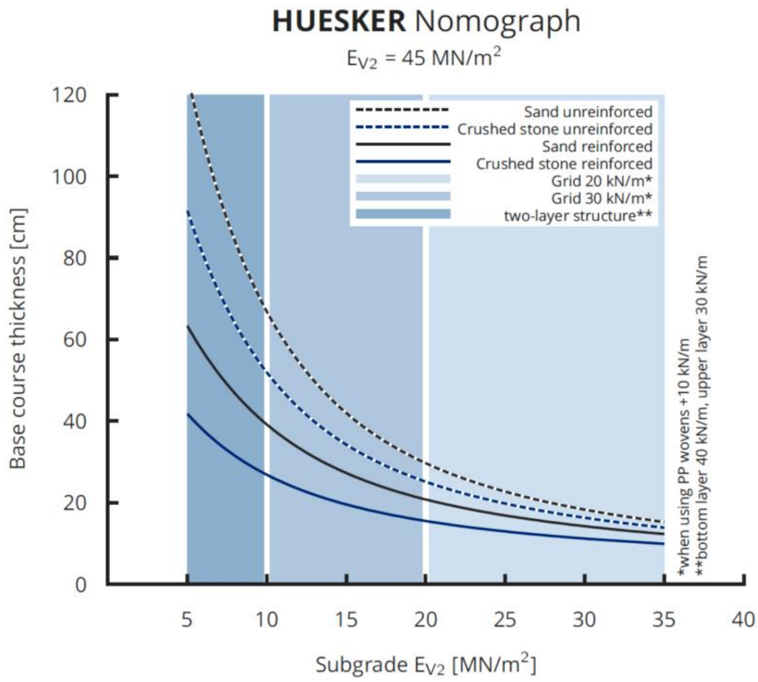
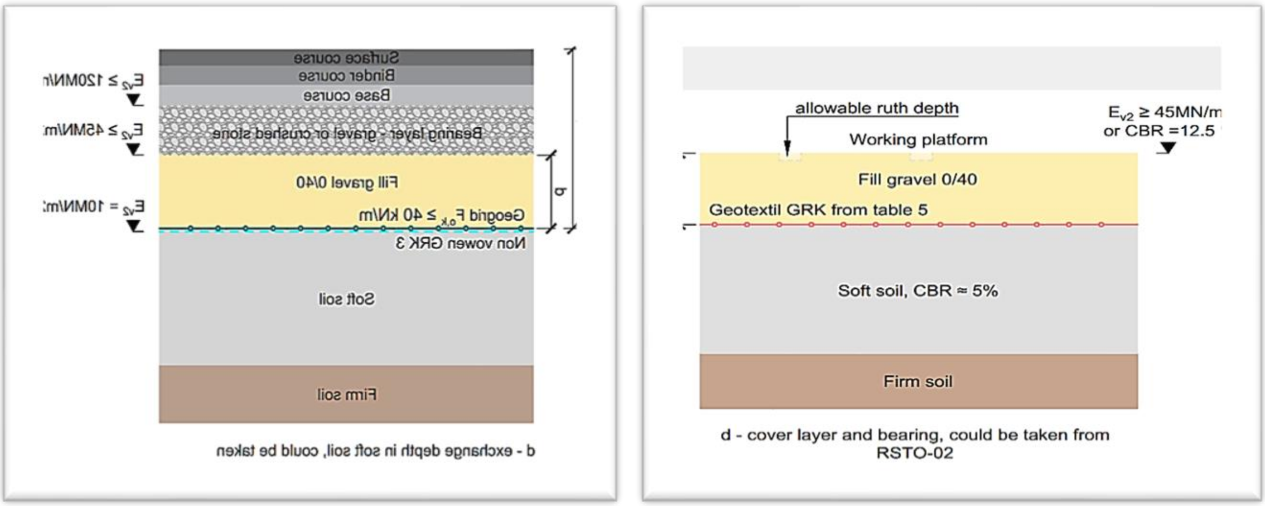


Figure 3 — Huesker design nomogram for estimation of thickness of base course layer d and the ultimate tensile strength of geosynthetic reinforcement for the required E_{v2} ≥ MN/m² on the top of the beaaring layer



a) b)

a) paved road structure according to RStO 12, [7];
b) working platform with geotextile GRK.

Figure 4 — Example of application a. paved and b. unpaved road or working platform 3. Strength, elongation and creep: ULS ultimate limit state, determination of the design value of the long-term ultimate tensile strength, F_d

Strength and elongation for the most functions is covered by geotextile-robustness-classes GRC, only for reinforcement there is a calculation, based on data from tensile and creep tests.

In the limit state method, the design value of the long-term tensile strength of geosynthetics for ULS (refers to the point of rupture of the geosynthetic after a given service life t_E) is determined as follows, EBGEO:2010, [6] with designations from ITB /2007 [4]:

$$F_d = \frac{F_{0,k}}{A_1 \cdot A_2 \cdot A_3 \cdot A_4 \cdot A_5 \cdot \gamma_F}, \tag{1}$$

where $F_{0,k}$ — characteristic value of short-term tensile strength, (UTS – Ultimate Tensile Strength), estimated according to DIN EN ISO 10 319 on 5 min. samples with the width 20 cm tensioned with the standard velocity of 20 % min. It presents the declared value for the confidence level of 95 %;

A_i — material reduction factors;

A_1 — creep;

A_2 — mechanical damage, installation damage for separation, filtration and drainage is covered by GRC. But in case of reinforcements we demand reduction factors based on performance-tests and on-site tests, where the product is tested under the real condition of the given site, concerning fill material and method of installation and compaction;

A_3 — connection or attachment;

A_4 — influence of chemical or biological aggression;

A_5 — influence of cyclic or dynamic loads (ITB 429/2007 [4] omitted this aspect);

γ_F — partial safety factor for material safety depend on load case.

In the form (1) the polish notation of all forces and coefficients was used, s. ITB:2007, [4].

Attention: the above presented reduction factor are not safety factors, they present a reduction of tensile strength depend on the given influent.

Tensile creep and creep rupture of reinforcements is investigated by long-term tests. A short-term index creep test (EN ISO13 431) gives the chance to find out the basic creep properties of a product and to compare the creep-properties with those of a long-term tested products. Compressive creep and creep collapse of drain elements is tested by a short-term index test (EN ISO 13432).

Strength, elongation and creep: SLS Serviceability limit state, determination of the characteristic values of the long-term tensile strength of the reinforcement

In SLS in addition to the conventional requirements such as permissible settlements, permissible deformations in reinforced structures a condition for permissible elongation of the reinforcement is imposed. The values for the permissible elongation of the reinforcement, established through experience, are intended to protect the structure in question from excessive deformation. Depending on tradition and the degree of experience, the permissible elongation values are defined somewhat differently in different countries. In Instruction 429/2007 [4], the ITB relied mainly on the British recommendations of that time, as most of the values postulated there are in line with the withdrawn BS 8006:1995. **Table 8** gives the permissible elongation values for geosynthetic reinforcement as contained in the ITB Instruction 429/2007 [4].

Table 8

Permissible elongations of geosynthetic reinforcement for SLS due to Instruction ITB 429/2007 [4]

Type of structure	Allowable elongation of reinforcement ε_{gr} (%)
Retaining walls with a rigid facing without load from another structures	6,0
Embankments and reinforced walls on public roads	5,0
Embankments and reinforced walls on railways	2,0
Bridge abutments t_0-t_E	2,0
Allowable $\Delta\varepsilon$ during exploitation rom t_B to t_E	0,5

From the summary in **Table 8**, it is apparent that according to the ITB Instruction [4] the polish designer generally has one condition to check for elongation and that is the total elongation of the geosynthetic, ε_{gr}. Only in the case of bridge abutments or supports additionally should be taken into account Δε elongation from the completion of construction t_B to the end of the service life t_E, it does not exceed the value of 0.5 %. However, BS 8006:2010, [5], changes the requirements for SLS postulating only Δε as follow:

— retaining walls with no permanent loads on the ground: Δε ≤ 1,0 %;
— retaining walls with permanent heavy loads and abutments: Δε ≤ 0,5 %.

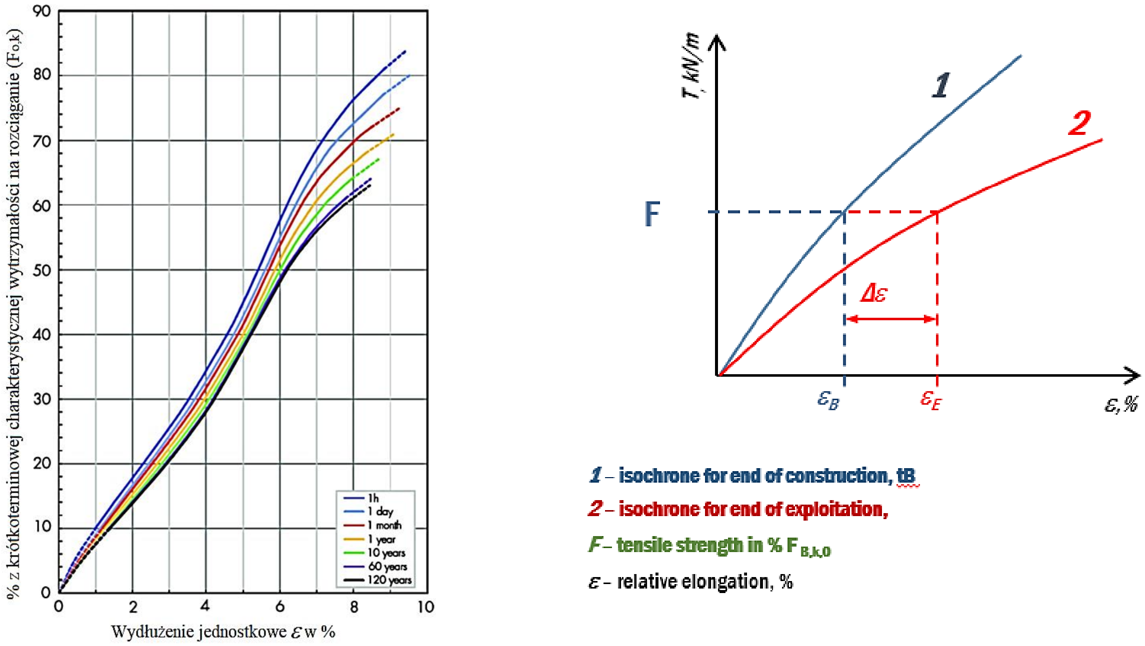


Figure 5 — Isochrones of polyester (PET) geotextiles, Huesker collected data

In order to check this SLS condition, it is necessary to use isochrones for the estimation of the elongation at the time t_B and elongation at the end of service time t_E. For example, **Fig. 5** gives isochrones for polyester (PET) geotextiles. Without isochrones, it is not possible to determine correctly the characteristic long-term strength values for SLS or to prove the suitability of the given product for the requirements specified in the design. Unfortunately, it is very rare that elongation conditions appear in the technical specifications, which means that the given design was reduced only to ULS.

According to ITB Instruction 429/2007 [4] for SLS the characteristic value of the tensile strength is to be determined from the condition of permissible total elongation ε_{gr}:

$$F_k(\varepsilon) = \frac{F_{0,k} \cdot \beta_\varepsilon}{A_2 \cdot A_3 \cdot A_4 \cdot A_5}, \quad (2)$$

where β_ε — permissible load ratio for a given permissible reinforcement elongation ε_{gr} and a given structure lifetime (t_E). Here the author has extended formula (2) to include the influences from A_2, A_3, A_4 and A_5, which are not included in ITB Instruction 429/2007 [20]. The point is that the actual strength in the ground, i.e. after the possible action of all influences, must be taken into account. The value βε is determined based on the isochrones for the given product. In the case of abutments or bridge supports according to the ITB Instruction, the characteristic value of the strength of the reinforcement for the condition of not exceeding Δε is additionally determined:

$$F_k(\Delta\varepsilon) = \frac{F_{0,k} \cdot \beta_{\Delta\varepsilon}}{A_2 \cdot A_3 \cdot A_4 \cdot A_5}, \quad (3)$$

where $\beta_{\Delta\varepsilon}$ — the permissible load ratio of reinforcement loading for a given permissible increment of reinforcement elongation $\Delta\varepsilon$ from the time of construction completion t_B to the end of the service life of the structure t_E, for abutments and walls with significant permanent loading on the crown $\Delta\varepsilon \leq 0.5$ %, otherwise e.g. according to BS 8006:2010 $\Delta\varepsilon \leq 1.0$ %.

Anchorage and bond coefficient of the reinforcement in soil

Friction is necessary for slope protection and for reinforcements. Slopes are simulated by an inclined plane test (EN ISO 12957-2); for reinforcements the results of direct shear tests or pull-out tests are used (EN ISO 12957-1). A reinforcement should be able to overtake the anticipated tensile force, it must be sufficiently anchored in the soil, this is basically analogous to reinforced concrete, so that a lack of anchorage excludes the respective insert from tensile work. As part of the static calculations of a reinforced soil structure, the condition of its anchorage must be checked as the anchorage strength is not always greater than the tensile strength of the reinforcement itself. When carrying out stability calculations, the various possible failure patterns of the structure are checked, which are defined by slip lines or curves. As soon as the slip line or curve crosses the reinforcement, it is assumed that a tensile force can be mobilized in the reinforcement. The maximum value of the force that can be carried by a given insert at a given point of intersection of the slip line with the reinforcement is determined by taking into account:

— tensile strength: F_d in ULS the minimum value from [$F_{\varepsilon,k}$ or $F_{\Delta\varepsilon,k}$] in SLS;

— the anchorage capacity of the reinforcement remaining to the left and right the sliding curve, the design value T_d for ULS and the characteristic value T_k for SLS.

In each case, the minimum value of the above three values is authoritative and entered into the balance of forces or moments in equilibrium for ULS and SLS respectively. Thus, without determining the anchorage capacity of the individual inserts, stability calculations cannot be carried out. It is therefore apparent how important it is to specify the reinforcement-to-ground interlocking ratio assumed in the stability analyses and the specification. In practice, the values of the reinforcement-to-soil ratio are determined based on tests in box apparatus with dimensions of at least 30 x 30 cm, **Fig. 6**. It can be seen, that two cases should be tested:

— sliding of the soil over the product, shear test with one slip surface;

— pull-out modus with 2 slip planes, because friction exits on both sides of reinforcements.

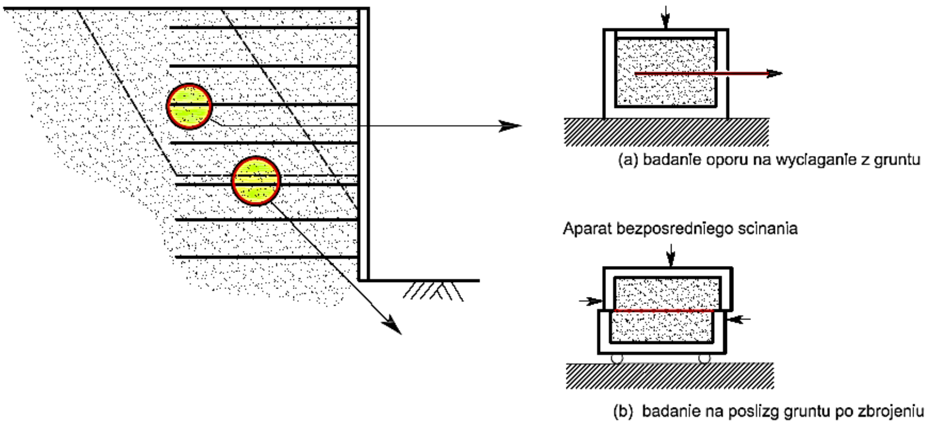


Figure 6 — Testing of interlocking of reinforcement in soil, Huesker collected data

As a result of these tests, the respective values of bond coefficients $\mu_{\varphi,k}$ and $\mu_{c,k}$ for sliding and pull-out could be determined for cohesive «c» and not cohesive soils (φ). This test could be performed in undrained conditions, too. In such case the value of $\mu_{cu,k}$ will be estimated.

Certainly, better interlocking is influenced by the selection of an appropriate geogrid mesh size due to the grain size of the soil. As mentioned above, opinions are divided here, as it is in difficult to determine diameter of the grain that determines the best interlocking. Regarding the optimum mesh size of a geogrid, two recommendations are known:

— Koerner (USA) [1]:

$$a \geq 3.5 \cdot d_{50}\ , \tag{4}$$

— EBGEO:1997:

$$0.6 \cdot a \geq d_{80}\ , \tag{5}$$

where d_{50} and d_{80} — the equivalent diameter of the grains in mm which, together with the smaller fractions, account for 50 % and 80 % of the dry mass of the soil, respectively. In this case, it is the grain size of the soil in contact with the geosynthetic. By using both criteria at the same time, it can be expected that a correct interlocking of the soil with the reinforcement will be achieved. However, for larger structures, the authors recommend determining the interlocking indices by performing tests in large-scale box apparatus or in the field conditions.

According to Instruction 429/2007 [4], the anchorage capacity for pull-out is determined as follows:

$$\text{for ULS:} \qquad T_d = 2 \cdot \sigma_k \cdot L_B \cdot \mu_k \cdot \frac{\tan(\varphi_k)}{\gamma_{\varphi'}}\ , \tag{6}$$

$$\text{for SLS} \qquad T_k = 2 \cdot \sigma_k \cdot L_B \cdot \mu_k \cdot \tan(\varphi_k)\ , \tag{7}$$

where σ_k — characteristic value of the stress normal to the reinforcement;
L_B — anchor length of the insert;
μ_k — characteristic value of bond coefficient in friction soil;
$\gamma_{\varphi'}$ — partial safety factor for internal soil friction in ULS.

The above formulae are valid for non-cohesive soils (because there is no component for adhesion) and for pull-out of the reinforcement from the non-cohesive soil, because the number 2 indicates the number of slip surfaces that resist the pull-out of the insert.

Filter design

Mechanic filter criteria to prevent blocking and clogging: the hydraulic conditions and the soils are investigated and 3 cases are distinguished (Characteristic opening size measured by EN ISO 12956):

Case 1: water quantity low, hydraulic gradient low, water flow only from one side:

0,06 mm ≤ O_{90} ≤ 0,16 mm.

Case 2: high water flow from one side, or changing direction of water flow:

Cohesive soils: 0,06 mm ≤ O_{90} ≤ 0,16 mm;

Non cohesive silt: 0,06 mm ≤ O_{90} ≤ 0,08 mm;

Running sand: 0,06 mm ≤ O_{90} ≤ 0,10 mm;

Sand coarse grained: 0,10 mm ≤O_{90} ≤ 0,60 mm.

The water permeability of the filter is assumed to be sufficient, when O_{90} is chosen in the upper field of the possible range and when $v_{50} \geq 1{,}0 \cdot 10^{-4}$ m/s (EN ISO 11058).

Case 3: high hydraulic impact or/and soils unstable against inner erosion or suffusion: the situation must be investigated by a specialist. The dimensioning of the filter can be made by a calculations or by performance tests.

Durability of geosynthetics

Durability is necessary for design life:

— separator for a support during construction works 1/2 to 1 year;
— separator with a permanent importance 80 – 120 years;
— filter in a drainage easy reparable: 10 to 25 years;
— filter in a drainage under a structure: 80 – 120 years;

— reinforcement under an embankment against failure: time for consolidation, typically 1 to 5 years but in special cases for example foundation on piles 80 – 120 years;

— reinforcement of steep slopes or retaining structures for long-term: 80 – 120 years.

Resistance to weathering of geosynthetics

Resistance to weathering is classified by the results of weathering tests in the Global-UV-tester (UV-rays and eventually washing out of protective inhibitors) (ENV 12224). Annex B of EN 13249 gives limits for the maximum exposure time from placing the product to covering. There is a difference made between application where a long-term strength is a significant parameter. German regulation requires higher level for all cases.

Table 9

Classification of weather resistance (ENV 12224) and maximum exposure time (EN 13249)

Remaining tensile strength	For all applications max. exposure time during installation
< 60 %	1 day
60 – 80 %	2 weeks
> 80 %	1 – 4 moths

Resistance to chemical ageing of geosynthetics

Resistance to chemical ageing: follow EN 13249 Annex B (normative) durability aspects:

— for PA, PE and PP the oxidative,

— for PA and PET the hydrolytic resistance has to be observed and in case of permanent applications to be improved, when the product is decisive for the life of the structure.

In long-term constructions PET must not be used in contact with soils with pH ≥ 9,5. In all cases PET is not to be used in direct contact to cement or concrete and to soils, mixed with cement or lime. The investigation of existing long-time installations is a very good way to characterize the long-term stability of a product. For constructions, where the fabric is crucial for safety, it is recommended to install test specimen under realistic conditions and test them periodically after several years, to see if there is a change with time and to have the opportunity to act early, if ever a lack of safety will be developed.

Geosynthetics in road and railway structures

For unpaved road the Method of Jaecklin&Floss [1], will be often used, this method is an empirical approach based on 88 French roads and has a solid experimental basis. The main parameters used in input are as follows:

— R, allowable rut depth (assumed by designer: 3 cm, 5 cm, 10 cm or 15 cm);

— CBR of subgrade;

— V, traffic coefficient for number of lorries passages with the mass up to 40 t (4 axles) during use time of the unpaved road, up to 100.000 t during use time;

— K, quality of bearing layer covering reinforcement layer (trafficked layer);

— D, thickness of bearing layer;

— G, coefficient connected to the tensile strength and elongation of geosynthetics.

As results of the analysed case: r — tensile strength at break and ε_f elongation at break point of geosynthetic. Based on calculated data the type of reinforcement can be finally assumed.

Working platforms trafficked on soft subgrade with undrained strength, $c_u \geq 20$ kN/m^2 can be designed by the use of guide Working platform published by BRE in 2004, [3]. The input parameter are:

— undrained shear strength of subgrade, $c_{u,k}$;

— angel of internal friction of platform, ϕ'_k;

— unit weight of subgrade and platform, Υ'_k, Υ'_p;

— dimensions of tracks, W-width, L-length;

— tensile strength of reinforcement, $T_d = F_{o,k}/2$ or tensile force at 5 % elongation;

— load on the track, q1d, q2d depend of load case 1 or 2, in kNm$_2$.

The resisting force R_d (reaction from soft soil and reinforced platform) will be calculated taking into account: the puncture resistance of platform material, the bearing force of soft soil and the tensile strength $2 \cdot T_d$. It should be proven, than both (q_{1d} or/and q_{2d}) $\leq R_d$. Additionally, some check should be made concerning the thickness of working platform and the bearing capacity only of working platform material.

In RIL 836, 2022 [8] similar applications of geotextiles in the bearing structure of railway tracks could be found. Especially the improvement of foundation layer up to $E_{v2} \geq 45MN/m^2$ is one of the most practical cases.

Summary

A world without geosynthetics is no longer conceivable today. In the last 50 years the industry has successfully developed many products, many regulations and design method were invented for practically each main application. Geosynthetic systems have proven themselves and today they are not to replace from daily earth works. Reinforced retaining walls, reinforced foundation system in railway and road structures, reinforced embankments on piles and columns, erosion protection systems and much more applications implemented in practice confirm the effectivity of geosynthetics in earth structures.

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НІМЕЦЬКІ, БРИТАНСЬКІ ТА ПОЛЬСЬКІ НОРМИ ЩОДО ЗАСТОСУВАННЯ ГЕОСИНТЕТИКІВ У ДОРОЖНІХ ТА ЗАЛІЗНИЧНИХ СПОРУДАХ ЯК РОЗДІЛЮВАЛЬНИХ І ФІЛЬТРУВАЛЬНИХ ШАРІВ, А ТАКОЖ ШАРІВ АРМУВАННЯ

Анотація

Вступ. Використання геосинтетичних матеріалів у дорожньому та залізничному будівництві набуло широкого поширення в країнах Європи завдяки їх здатності виконувати функції розділення, фільтрації та армування основ і конструкцій. Важливим є порівняння та систематизація нормативної бази різних держав для забезпечення надійності та довговічності транспортних споруд.

Проблематика. Попри значний практичний досвід, залишаються актуальними питання уніфікації вимог до властивостей геосинтетиків, критеріїв їх добору залежно від типу ґрунтів, навантаження та умов монтажу, а також оцінки довговічності матеріалів у різних середовищах.

Мета. Основною метою роботи є аналіз та узагальнення німецьких, британських і польських нормативів щодо застосування геосинтетичних матеріалів у дорожньому та залізничному будівництві, а також демонстрація підходів до вибору та розрахунку їхніх характеристик.

Матеріали й методи. У дослідженні використано огляд та порівняння ключових нормативних документів (EBGEO:2010, BS 8006:2010, ITB 429/2007, RStO 12, RIL 836:2022), аналіз системи Geotextile Robustness Classification (GRC), а також приклади методик визначення несучої здатності основи з урахуванням повзучості, довговічності та стійкості геосинтетиків до механічних і хімічних впливів.

Результати. Показано, що німецька система GRC дозволяє поєднати властивості ґрунтів та умови монтажу для коректного вибору геотекстилю. Охарактеризовано правила розрахунку армування насипів, підпірних стін і робочих платформ відповідно до сучасних норм. Зазначено, що застосування геосинтетиків забезпечує досягнення вимог щодо модулів деформації ($Ev2 \geq 45$ МН/м²) для дорожніх та залізничних конструкцій, скорочує товщину несучих шарів та підвищує надійність споруд.

Висновки. Геосинтетичні системи довели свою ефективність у транспортному будівництві й стали невід'ємним елементом сучасних інженерних рішень. Їх застосування дозволяє підвищити довговічність і безпеку споруд, а аналіз нормативної бази підтверджує необхідність гармонізації вимог у європейській практиці для подальшого розвитку технологій.

***Ключові слова*:** геосинтетичні матеріали; геотекстиль; георешітка; дорожні та залізничні конструкції; розділення ґрунтів; фільтрація; армування; довговічність; EBGEO; BS 8006; RIL 836; класифікація міцності GRC.