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The revised german regulations for the use of geosynthetics in road construction

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ABSTRACT: In road construction in Germany geosynthetics are used in all types of earth works. For these applications we have regulations. Their aim is, to find for the user the product, which fits best for his application and to give the producer or deliverer a chance, to go into the market in a fair contest. To define the properties necessary for a given purpose, we calculate where possible and we classify where a calculation method is not available or not practical.

1 REGULATIONS IN GERMANY

1.1 *General remarks*

The basis for contracts in road constructions is the "Verdingungsordnung für Bauleistungen VOB", a framework of german standards (DIN) for contract provisions for all kind of building and construction (VOB 2000).

For earth works in road construction and the use of geosynthetics in it we have three papers, which are supplementing each other:

- Additional provisions for technical contracts and guidelines for earthwork in road construction: ZTVE StB 94
- Technical terms of delivery of geotextiles and geogrids in earthwork in road construction TL Geotex E-StB 95
- Notes on the use of geotextiles and geogrids in earthwork in road construction (Notes 1994) to be replaced by Notes on the use of geosynthetics in earthwork in road construction (Notes 2002)

For testing there are the standards of CEN, ISO and DIN.

The "Technical terms of delivery 95 (TL Geotex E-StB 1995)" and the "notes on the use…1994 (notes 1994)" are now in discussion with the target date for the notes 2002 and for the technical terms of delivery 2003. This will be the forth edition of the notes after 1983, 1987 and 1994.

The European Normalisation by CEN TC 189 Geosynthetics now arrived at a level that not only influences the testing of the products but also the basics of contracts. That is one reason why in Germany the regulations are discussed a new. The other reason is, that since 1995, the year of TL Geotex, some new products are on the market and a lot of research and of experience with new applications is made, which developed the knowledge.

The elaboration of regulations for road construction is the task of special working groups of the "research association for roads and transports (Forschungsgesellschaft für das Straßen- und Verkehrswesen FGSV)" with members of administration, contractors, consultants, producers and universities. The regulations are recognised by the ministries of transport of Germany and of the German Länder as obligatory for all relevant parties.

1.1 geosynthetics in earthworks

The "notes on the use of geosynthetics in earthwork in road construction 2002" (notes 2002: Merkblatt für die Anwendung von Geokunststoffen im Erdbau des Straßenbaus 2002) have following parts:

(1) General remarks
(2) terms and their definitions
(3) technical properties of products (geotextiles, geogrids, geocomposits and geosynthetic barriers)
(4) fields of application (with design principles for 50 examples):
  - Separation of different kind of soils, to hinder the penetration of fine particles into coarse grained soils under load but to allow the trickle of 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 of reinforcements
(6) test procedures
(7) hints for the selection of products for a given use
(8) provisions for contracts: terms of delivery and hints for quality assurance.

1.2 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 on asphalt - interlayers".

The use of nonwovens between a cement- or an asphalt-bound base and a concrete pavement plate is now a regular construction principle, after 15 years practice experience with test sites on heavy trafficked highways. The nonwoven has the function of separator between pavement 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.

There are good experiences with asphalt interlayers as barriers or/and shock absorbing membranes. The reinforcement function is under discussion.

2 PRODUCT SPECIFICATIONS – SELECTION

In the following I concentrate on the selection procedure and on provisions for contracts on geosynthetics in earthworks.

2.1 Functions and related properties

To find the product, which fits best in a special application, we must define the properties, which the product must have and the technical demand, which it must fulfill. We calculate where calculation is possible and classify, where we have no basis to calculate or where calculation does not fit (Table 1).

Table 1: Functions and related properties: calculation or classification

Functions / Properties	Separation	Filter	Drainage	Reinforcement	Protection: soil	Protection barriers	Barrier function
Mass per unit area	grc	grc	---	---	*	clas	clas
Thickness	---	*	calc	---	*	clas	clas
Resistance tensile force	grc	grc	---	calc	*	clas	clas
Elongation	grc	grc	---	calc	---	clas	clas
Creep/ creep rupture	---	---	calc	calc	---	---	clas
Robustness to installation damage	grc	grc	grc **	rf/ st	***	clas	prot
Friction	---	---	---	calc	*	calc ****	calc
Characteristic opening size	clas	calc	calc **	---	---	---	---
Water permeability	clas	calc	calc	---	---	---	---
Resistance to weathering	clas	clas	clas	clas	clas	clas	clas
Resistance to chemical ageing	clas	clas	clas	clas / rf	clas	clas	clas

calc: calculation; clas: 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

2.2 Mass per unit area and thickness

Mass per unit area is used for product identification and for definition of minimum values for protection layers.

Thickness under load including compressive creep is important for drains, for protection layers and for barriers.

2.3 Geotextile-robustness-classification

Since 1980 a geotextile-robustness-classification GRC is successfully used, to classify the robustness of geotextiles against mechanic damage in 4 classes, following a Norwegian proposition (Alfheim & Soerlie 1977, Wilmers 1980), changed 1994 to 5 classes. It was based on push-through-force for nonwovens (EN ISO 12236) and on tensile strength for wovens (EN ISO 10319).

This pragmatic approach is newly in discussion. In the middle of the 80^{ties} we discussed the use of elongation during tensile or static puncture test, the use of a modulus or of the working force as basis for the GRC. In this period we had not enough experience and data. In the last years in different countries and also in Germany a lot of research work has been done about damage during installation and how the resistance to damage can be classified by index tests. Now by the new research we have a better basis for a discussion. The result is: the use of working force or of energy absorption gives not the mean to a clearer distinction of the behaviour of different products on real site condition. So we decided to continue with the Geotextile – Robustness – Classification.

2.4 Classification of installation stress

2.4.1 Classification of fill

To find out the necessary GRC for a given site, we classify the fill material in 5 levels on the bases of the diameter and the coarseness/sharpness of aggregates.

Table 2: Classification of cover – material: classes AS 1 to AS 5

Classes	Type of Cover Material
AS 1	Without influence on selection
AS 2	round shaped coarse grained or mixed grained 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

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 has to be placed on a very stiff clay, site tests are proposed.

2.4.2 classification of load

In addition we classify the load resulting from installation and construction works in 4 levels.

Table 3: Classification of load

Classes	Types of Loading
AB 1	Manual installation and covering and no significant loading on the geotextile resulting from compaction
AB 2	Mechanical installation and compaction without significant stress resulting from construction vehicles
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 stress resulting from permitted rutting with depths of more than 15 cm

2.4.3 Combination of fill and load to GRC

The necessary geotextile-robustness-class for a given site is the result of combination of the classes of fill (AS) and of load (AB) see Table 4.

Table 4: Determination of the geotextile-robustness-class, necessary for a special site

Classes of fill	Loading Classes			
	AB 1	AB 2	AB 3	AB 4
AS 1	grc 1			
AS 2	grc 2	grc 2	grc 3	grc 4
AS 3	grc 3	grc 3	grc 4	grc 5
AS 4	grc 4	grc 4	grc 5	(*)
AS 5	grc 5	grc 5	(*)	(*)

grc: geotextile-robustness-classification

(*) = site test necessary or increasing thickness of the cover layer required

With this classification of stressing the products by installation procedure and material most site conditions can be covered. On sites, where the stresses are higher, site tests are proposed. The simplest way to reduce rutting is to enlarge the thickness of fill layer. In other cases it can be interesting to combine a geosynthetic reinforcement with the separation layer.

2.5 Strength, elongation and creep

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 test.

For reinforcements the possible design strength T_d of a product is calculated by reduction factors for:

- creep (A1),
- damage during installation (A2),
- junctions/ connections (A3),
- durability (A4)
- a general safety factor (γ).

The basis is the characteristic value T_{ch} of the product, defined by the 5%-minimal quantile of the production:

$$T_d = T_{ch}/(A1*A2*A3*A4*\gamma).$$

The general safety factor γ is 1,75 – but when following the partial safety-factor method of eurocode 7 than γ is 1,40.

Tensile creep and creep rupture of reinforcements is investigated by long-term tests. A short-term index creep test (EN ISO 13431) 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 product.

Compressive creep and creep collapse of drain elements is tested by a short-term index test (EN ISO 13432).

2.6 Damage during installation

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.

2.7 Friction

Friction is necessary for slope protection and for reinforcement. Slopes are simulated by an inclined plane test (EN ISO 12957-2); for reinforcements the results of direct shear test are used (EN ISO 12957-1).

2.8 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:

$$0{,}06 \text{ mm} \le O_{90} \le 0{,}16 \text{ mm}$$

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

Cohesive soils:	$0{,}06 \text{ mm} \le O_{90} \le 0{,}16 \text{ mm}$
Non cohesive silt:	$0{,}06 \text{ mm} \le O_{90} \le 0{,}08 \text{ mm}$
Running sand:	$0{,}06 \text{ mm} \le O_{90} \le 0{,}10 \text{ mm}$
Sand coarse grained:	$0{,}10 \text{ mm} \le O_{90} \le 0{,}60 \text{ mm}$

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

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 $v_{50} \ge 1* 10^{-4}$ m/s (EN ISO 11058).

2.9 Durability

Durability is necessary for design life:

- Separator as construction-aid 1/2 to 1 year
- Separator with permanent importance 80 - 100 years
- Filter in a drainage easy reparable: 10 to 25 years
- Filter in a drainage under a construction: 80 - 100 years
- Reinforcement under a dam against slipform-failure: time for consolidation, typically 1 to 5 years
- Reinforcement of steep slopes or retaining structures for long-term: 80 - 100 years.

2.9.1 Resistance to weathering

Resistance to weathering is classified by the results of weathering test 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 and other applications. The german regulation demand the higher level for all cases.

Table 5: 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 months

2.9.2 Resistance to chemical ageing

Resistance to chemical ageing: We 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-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. Dr. Schröder and his colleagues in the BAM/Berlin developed research methods to find molecular changes before they influence the strength (Schröder 2001a and Schröder 2001b).

For constructions, where the fabric is crucial for safety, it is recommended to install test specimen under realistic conditions and to 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 is developing.

3 CONDITIONS FOR CONTRACTS

3.1 Product data sheet and labeling

The CE-marking of products has the chance, to clarify the market. But the list of data which the producer has to give in the CE-accompanying document is not sufficient. This was also the opinion of the specialists who worked out EN 13249. In Germany we demand a data sheet which identifies all relevant data of the product. So it must contain all the data about the construction of the fabric and for all its properties which in EN 13249 Table 1 are indicated as H and A, S only for special cases. In ad-

dition for identification purposes the values of mass per unit area and thickness are necessary.

We demand also the labeling of the single roll/package and the product itself (ENV 30320). This is regulated in Germany since 1987.

3.2 CE – mark not a quality mark

The CE – marking is based on a QS - system for the production and by a factory production control, which is supervised by an approved body (attestation of conformity system 2+). This inspection does not include any product control by the approved body. So the CE – marking is not a quality mark and gives a lower guarantee of product quality, than our actual practice. This makes it necessary, to make an intensive control on site

3.3 Quality Assurance

In Germany since the sixties we have a three step system of quality-assurance-tests for all materials, used in road construction:

- Initial type tests of products by an approved body,
- production control testing by the producer, supervised by an approved body and self control of handling on site by the contractor, supervised by the client. control tests on site and of specimen, taken from the site under the responsibility of the client.

The on site control follows now draft TC 189 WI 70 "on site control", which is good corresponding to our practice. For the control of on site conditions, handling of the products and sampling, draft TC 189 WI 70 "on site control" gives a way to a comprehensive control on site:

On site quality control can consist of :

- the evaluation of compliance of a delivered product with the specification,
- the evaluation of the compliance of site-conditions with specification
- the inspection of handling and conditions of storage
- the inspection of placing the product on site
- taking samples for evaluation of compliance with the specification
- placing and extracting control samples to check damage during installation
- placing of control samples to check the behavior with time.

The number of samples required is a function of:

- the importance of the product for the safety of the work
- the standard of quality assurance applied during manufacture of the product
- the area of product used in the work.

New is: The contractor has to execute an entrance quality control testing of products delivered on site. If the product is certified on basis of a factory production control with continuous inspection, and audit-testing of product by an approved body (equivalent to system 1+) than then entry control is not demanded. The project of European manufacturers, to install a system with product control by an approved body and with a quality – mark on the product may fulfill this reqire.

The specimen for site control are taken by the client together with a representative of the contractor. The result decides the acceptance or rejection of the product. The lot fails, if one ore more specimen fail with one or more test results. Than it has to be rejected. If the products have already been installed, two steps are necessary: a technical evaluation of remaining safety of construction and a contract fine. If the remaining safety is not sufficient, the necessary means must be taken by the contractor and he will demand the producer/deliverer to pay for it. This is a very efficient and very important mean to assure the quality of the products in a high level.

In the german rules the following tests to identify a product in the quality control system are used:

- the mass per unit area
- the thickness for drains, protection layers and barrier layers
- a strength-test: tensile strength for woven and grids, static puncture for nonwovens

Other properties are only controlled, if there is a doubt.

4 FURTHER ACTIONS

To facilitate the use of geosynthetics in a good way, the working group of FGSV has worked out additional papers:

- Hints for specification of products for typical uses
- Checklists for design, project planning, preparation of site and realization on site.

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