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EBGEO – German recommendation for reinforcement with geosynthetics

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ABSTRACT: In Europe the fundamental design principle for geotechnical works has changed from a global safety concept to a partial safety concept. The according standard is EC 7 - EN 1997-1 which will be obligatory starting from 2010. Meanwhile national standards have to adopt the principles and make the regulations applicable. In Germany the regulations for reinforced earth works are on the way (DIN 1054:2005, EBGEO). Besides the ultimate limit state, considerations about the serviceability are incorporated for standard constructions (e.g. embankmenst on weak soil, steep slopes) as well as for new techniques for the use of geosynthetics (e.g. embankments on column, overbridging of sinkholes).

1 INTRODUCTION

The German Geotechnical Society (DGGT) had published the first edition of "EBGEO – Recommendation for Reinforcement with Geosynthetics" in 1997, which was prepared by its working group AK 5.2. Meanwhile a lot of new experience with reinforcement applications of geosynthetics are available that will be involved in the new edition that is planned to be published in 2006.

2 HISTORY AND MEMBERSHIP OF WORKING GROUP

The work for the EBGEO started in the early 1990s under the leadership of Dr. Ing. B. Thamm and led to the publication of the booklet EBGEO - "Recommendation for Reinforcement with Geosynthetics" in 1997. The working group AK 5.2 of the German Society for Geotechnical Engineering (DGGT) is now under the chairmanship of G. Bräu with his co-chair A. Herold.

The members of the working group come from university, governmental departments, consult-ants, manufacturers and contractors, which form a wide spread and experienced group to look at the specific problems from different points of view. Meanwhile there are 29 members (1997: 19 members) within the group and additionally about 15 guests in different subgroups for the discussion of special topics.

The work of the group is organized within several subgroups dealing with the different chapters of the recommendations, the construction and materials. Actually the following subgroups are under work:

5. General recommendations
6.1 Design principles
6.2 Embankment over weak subsoil
6.4 Layers for improved bearing capacity in road constructions
6.5 Reinforced foundation cushions
6.6 Steep slopes
6.8 Waste disposals
6.9 Reinforced embankments on pile-similar elements (punctual/linetype)
6.10 Geosynthetic covered columns
6.11 Dynamic loadings
6.12 Overbridging systems in areas prone to subsidence

3 ACTUAL STATE OF DISCUSSION

3.1 *Design principles*

In Germany the fundamental standard for all soil mechanics work is DIN 1054. This standard was published in 1976 and is based on a global safety concept. In the 1990s the first drafts of a new DIN 1054 ("part 100") were discussed, which were based on the partial safety concept. When the EBGEO were published in 1997, these drafts were taken as basis for the design concepts. Unfortunately the "part 100"-

series were not finalized, leading to an uncertain status of EBGEO with the need to calculate each problem with the global and the partial safety concept regularly.

Meanwhile the DIN 1054 is published with its edition January 2005, which has been officially acknowledged in several states of Germany during the year 2005. In this edition the partial safety concept is fixed and also the necessary partial factors for permanent and variable actions as well as for resistance are given. Also the principles for the design calculation are shown mostly in accordance with EN 1997, the so called Eurocode EC 7.

The actual drafts and working papers for the new edition of EBGEO are based on this new concept of DIN 1054-2005 and will use those specifications. This means a simplification and harmonization of the design work and a better attraction for the geosynthetic way of reinforcement in Germany (Floss 2004).

There are two fundamental approaches in design: Calculations with the ultimate limit state (GZ 1) ensure the construction against failure and the serviceability limit state (GZ 2) leads to suitable and usable constructions. Within GZ 1 there are mainly used the limit states GZ 1B, where the failures of the components of the construction are looked at, whereas GZ 1C is responsible for the overall stability of the structure. Problems occure, because the assignment of failure mechanism, where geosynthetics are involved, touched or cut, to GZ 1B and/or GZ 1C is not clarified within DIN 1054 and is still under discussion in EBGEO. Finally it will be fixed in EBGEO to ensure safe, easy and certain use by the designer.

Within GZ 1B the calculation uses characteristic values for the determination of characteristic actions E_k and resistance R_k. Finally the characteristic actions E_k are multiplied by the partial factors for actions to receive the design values for the actions E_d. The same is done for the resistance by dividing the characteristic values by the appropriate partial factors to receive the design value R_d. The limit state is fulfilled with the equation $E_d < R_d$.

The calculation of GZ 1C applies the partial factors to the parameters of the soil strength and takes these design values of the soil strength to calculate the limit state conditions.

Figure 1 shows the several limit states realised in DIN 1054 and the actual associated failure mechanisms (Thurwell et. al. 2004).

For the calculation of the design strength of the geosynthetics the meanwhile widely accepted procedure is used. The short term strength $R_{Bi,k0}$ retrieved by tests with DIN EN ISO 10319 is divided by several reduction factors (A_1 to A_5) to get the characteristic value of the long term strength $R_{Bi,k}$. The design strength $R_{Bi,d}$ results by dividing $R_{Bi,k}$ by the partial factor of safety γ_M.

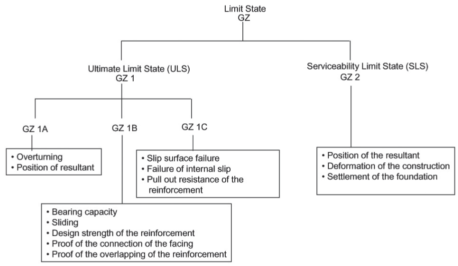

Figure 1. Limit states according DIN 1054/EC7.

$$R_{Bi,d} = \frac{R_{Bi,k0}}{A_1 \cdot A_2 \cdot A_3 \cdot A_4 \cdot A_5} \cdot \frac{1}{\gamma_M}$$

The partial safety factor for the geosynthetic materials is actually fixed to γ_M = 1,4/1,3/1,2 for the three load cases LF1 (permanent)/LF2 (transient)/LF3 (extraordinary).

The reduction factors (not: factors of safety!) are dealing with the following topics:

A1 long term behaviour
A2 installation damage, compaction
A3 connection and overlapping
A4 environment
A5 dynamic influence

Within EBGEO the reduction factors shall be certified by laboratory or field tests otherwise certain fixed minimum values have to be used for the calculation. The following table gives an overview showing the actual state of discussion.

Table 1. Reduction factors without special investigations.

A_1	long term behaviour for permanent structures	PP/PE PES/PA	5,0 2,5
A_2	installation damage, compaction	mixed/coarse round material	2,0
		fine grained round material	1,5
A_4	environmental conditions (permanent structures with lifetime < 100 years)	DIN EN 13249 ff annex B4 only new polymers proved by tests for 25 years	
		PES/PVA:	2,0
		AR/PP/PE:	3,3

The discussion about reduction factor A_5 has to be to continued. Several laboratory and field tests are under evaluation indicating minor problems than expected.

For the calculation the shear parameters have to be considered. If there are no test results, the interaction parameters have to be reduced as follows:

geosynthetic/soil $f_{sg,d} = 0.50 \tan \varphi'_d$

geosynthetic/geosynthetic $f_{gg,d} = 0.20$

This restrictive approach in EBGEO urges the parties to do tests with the real soil and geosynthetic for the site, which is the only way to get realistic values for the design. Results from index testing are not worthwhile.

All the applications, tests and recommendation for the geosynthetic products are in strict coordination with the other German regulations for geosynthetics in earthworks (M Geok 2005, TL Geok E-StB 2005).

3.2 *Embankment over weak subsoil*

The EBGEO 1997 already presented a design method for embankments over weak subsoil that was proofed in several sites equipped with measuring devices Blume et. al. (2004). For the new edition some additional aspects will be considered. It was found, that the reinforcing effect of the geosynthetics at the toe of the slope (anchorage) could be taken into account.

On the other hand the squeezing out of the subsoil beneath the embankment is a potential failure mechanism which should be incorporated according to BS 8006.

3.3 *Steep slopes*

The calculation method for steep slopes is shown in EBGEO 1997 with a clear distinction between “internal” and “external” stability. This division of the calculations led to problems, as not all possible failure mechanisms were found and makes no longer sense as the way of the calculation is the same for both. The designer has to think about all mechanisms with failures of the whole structure, failure mechanisms crossing the reinforced structure or not and sliding mechanisms along the geosynthetics at each layers. This led to the actual state for the new edition of EBGEO to urge the calculation for all mechanisms without distinction in “internal/external”.

The calculation will be done using the limit state GZ 1C mainly. A comparison of different design methods (DIN, BS, CUR) is given in Thurwell et. al. (2004).

For the serviceability (GZ 2) of those structures there will be hints for calculations. These procedures are still under discussion and will cover the possibility of the observational method and learned experience from former sites. The parameters of in-soil-tests will be taken into account, as it is possible to reinforce structures also with non-wovens using these parameters Bauer & Bräu (1996), instead of high strength, low strain materials only. The possible deformations that should be calculated are shown in Figure 2.

3.4 *Reinforced embankments on pile-similar elements*

For the construction of embankments over weak subsoil sometimes the standard procedure shown in Par. 3.2 is not sufficient to get a low deformable earthwork with high bearing capacity. To solve this problem, in the recent years reinforced embankments with a pile-similar support were developed. The system consists of pile-similar elements in a regular distance in the weak subsoil. Over these elements at least one reinforcement layer is placed, followed by the rest of the embankment Figure 3.

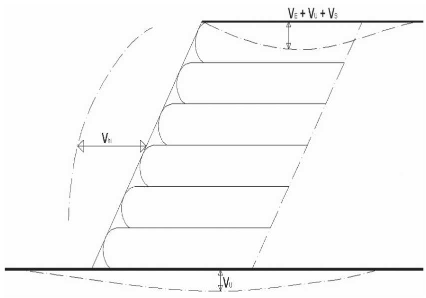

Figure 2. Calculation of possible deformations (GZ 2).

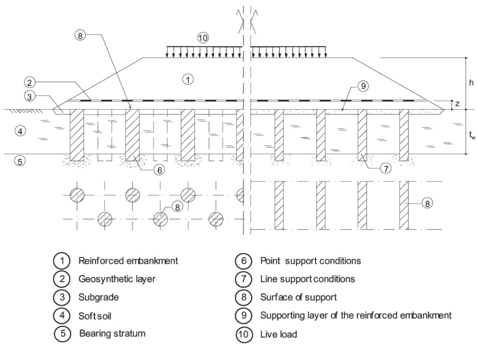

Figure 3. Geosynthetic-reinforced pile-supported embankment.

Meanwhile several applications, especially for highway and railroad embankments showed the practicability and performed well regarding both bearing capacity and serviceability.

The design method is based on the arching effect in the reinforced embankment over the pile heads and a membrane effect of the geosynthetic reinforcement, taking into account also the support of the soft soil between the pile-similar elements.

A more detailed description of the design method and the field tests and investigations is given in Kempfert et. al. (2004) and Zaeske & Kempfert (2002). The draft of this chapter from EBGEO is presented since 2004 to the public on the website of the “Special section Geosynthetics” of DGGT.

3.5 *Columns coated with geosynthetics*

Sand or stone columns are used to improve the bearing capacity of soft soil. Without a geosynthetic coating the material of the columns and the surrounding soil will mix and a regular behaviour is not possible.

There are several types of coated columns which are different in the construction procedure and the kind of improvement of the soil. Systems with small diameters (d < 30 cm) are used to accelerate the consolidation of the soft soil by giving an open structure for the reduction of pore water pressure (Geuder et. al. 1997). The reinforcing effect of these columns usually is neglected.

Systems with greater diameters (d > 80 cm) besides the drainage effect are installed due to their reinforcing effect (Kempfert & Wallis 1997). They can be built by excavating the soil protected by a piling equipment or by repressing the soil with an additional compaction effect for the subsoil.

For the above mentioned types usually woven geotextiles are used. In the recent years also systems with geogrids were developed that are able to give sufficient support for embankments even if the support of the subsoil is very low (i.e. organic soils) (Paul & Ponomarjow 2004, Trunk et. al. 2004).

For the several types of application of geosynthetic coated columns design methods are developed and will be presented in the new edition of EBGEO.

3.6 *Overbridging systems in areas prone to subsidence*

Another new topic in EBGEO will be the design of overbridging systems with geosynthetics in areas prone to subsidence and sinkholes. The systems are used to secure highways, motorways and railway constructions at least for a short period until the rehabilitation could take place.

Actually the national and international experience is studied and the design methods for EBGEO prepared due to the different needs of full and partly secured systems, with isotropic and anisotropic reinforcement. Actual considerations are shown in Paul (2004).

4 PERSPECTIVE

The 1997 edition of EBGEO is no longer available, the final version of the new EBGEO is planned to be published as draft for public discussion in late 2006. Besides the recommendations there will be typical calculations for all samples.

To give information about actual design considerations and bring the practical experience back to EBGEO during its development, the working group decided to present drafts in the internet:http://www.gb.bv.tum.de/fachsektion/b_ak/ak52.htm.

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