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Geosynthetics – innovative tool in soil reinforcement

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ABSTRACT: About 35 years ago, the first generation of geosynthetics took its place in geotechnical engineering. Initial refusal to accept geosynthetics as a building material has ceased. Today, geosynthetics are classified as an independent building material because of their diversity and specific attributes. Existing as geotextiles, geogrids, geomembranes and related products, they enable technically simple, low-priced and alternative solutions. Many geotechnical applications nowadays cannot be imagined without geosynthetics. This paper concerns itself with approaches for dimensioning and advanced applications of geosynthetics. It reflects the actual national and international awareness of applying a new generation of geosynthetics in contact to the ground to form a composite structure. In this relation, experimental investigations, numerical modelling and dynamic loading will be focussed.

1 INTRODUCTION

For the past couple of decades geosynthetics have come to play a rapidly increasing role in a variety of civil and environmental engineering applications. A wide spectrum of materials characteristics provides a great diversity of geosynthetic functions. These are in most cases a very economic and ecologic alternative to conventional construction materials and methods.

In geotechnical engineering practice recent developments of technology relating to the manufacture of new and enhanced, high-quality geosynthetic materials highlight the use of the reinforcement function of the geosynthetics, such as improvement of soft ground, stabilization of landslides/slopes, construction of road and railway embankments, bridging mining voids and earth subsidence, etc.

However, as with all traditional construction materials, the advantageous application of geosynthetic reinforcement requires a better understanding of the mechanical behaviour of reinforced soil, the use of innovative theoretical and numerical models and the exact determination of all involved representative material properties as well as a good estimation of the risk assessment.

The principal objective of this paper is to present the common state of the art and the state of practice of soil reinforcement techniques, including actual research results, with a special emphasis on traffic induced vibrations to demonstrate the growing significance and innovativeness of geosynthetics in the world of geotechnical construction - herewith the authors reflect the main content of the recently executed international geosynthetics conference which was held on 5 to 8 September 2004 in Schloss Pillnitz, Dresden, Germany (Klapperich, 2005).

Due to the lack of space, only a very brief overview of the topics believed to be more important are presented herein.

2 CHALLENGES

Today the use of geosynthetic construction materials in geotechnical applications is growing day by day and the first application examples in coastal and hydraulic engineering are already date back 50 years. But for many engineers geosynthetics are still “new” materials and they don’t know much about them. In addition, the geosynthetics are somewhat suspicious to them, because of the “poly…” name and e.g. strange time and load-depending behaviour (creep) (Heerten, 2004).

Regarding the Vice-President of the German Society for Geotechnics, Prof. Dr. G. Heerten, these traditional barriers can only be overcome, if the effectiveness of geosynthetic-reinforced soil with top-quality geosynthetic reinforcements is made transparent by systematic research and application, and is documented comprehensibly to enable safe, cost-efficient and environmentally friendly constructions.

The use of geosynthetic reinforcing products can save a lot of money for contractors and owners. From studies all over the world it is known today that geosynthetic reinforced earth structures are money saving champions compared to gravity walls or even metal reinforced earth structures. As a rough estimate, it can be concluded that the costs of geosynthetic reinforced earth structures are less than 50 % of the costs of classical "gravity walls" (Heerten, 2004).

3 CALCULATION AND DIMENSIONING & EBGEO

In Germany, the calculation of the stability of earth bodies with geosynthetic reinforcement layers is controlled by EBGEO (1997) "German Recommendation for Earth Reinforcement with Geosynthetics" (in other countries: e.g. BS 8006, Swiss Geotextile Compendium, GEOGUIDE 6, etc.). An actual comparison of international dimensioning approaches is found in Klapperich (2005), conference session "design approach - numerical models".

The German Geotechnical Society (DGGT) had published the first edition of "EBGEO" 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 planned to be published in 2006 (Bräu, 2004).

Exemplary are the new subject areas "Reinforced embankments on pile-similar elements (punctual/ linetype)", "Geosynthetic covered columns", "Overbridging systems in areas prone to subsidence" as well as "Dynamic loadings". These are presented in detail in the proceedings of the Pillnitz conference and two of them are briefly introduced in the following chapter.

4 NEW APPLICATIONS

4.1 *Reinforced embankments on pile-similar elements*

For the construction of embankments over weak subsoil sometimes the standard procedure with GSY is not sufficient to get a low deformable earthwork with high bearing capacity. To solve this problem, in the recent year's reinforced embankments with a pile-similar support were developed. The system consists of pile-similar elements of regular distance in the weak subsoil. Over these elements at least one reinforcement layer is placed, followed by the rest of the embankment (Fig. 1).

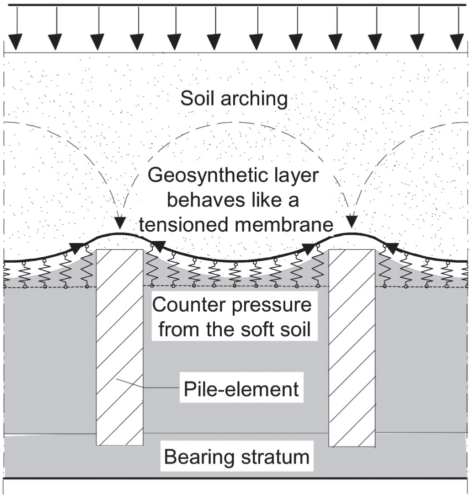

Figure 1. Mechanisms of load transfer of GSY-reinforced pile-supported embankment.

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 Heitz/ Maihold (2004). The draft of this chapter from EBGEO is presented to the public on the website of the "Special section Geosynthetics" of DGGT.

4.2 *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 rehabilitation can take place (Fig. 2).

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

5 INNOVATIVE TECHNICAL EXAMINATION POSSIBILITIES

For the stability analysis of geosynthetic constructions knowledge of the interaction behaviour in the

Figure 2. Sinkhole in a existing highway, caused by dissolving of water-soluble stones (B 180, near Eisleben).

geosynthetic interfaces is essential. For the examination of the main failure mechanisms of a geosynthetic reinforced construction, usually shear- and friction tests, since recently pullout tests as well, are performed.

In Aydogmus/Klapperich (2004) a novel experimental apparatus is presented, which has been developed and constructed depending on the most recent scientific and technical know-how, according to updated testing standards and guidelines (Fig. 3).

In comparison to the known geosynthetic testing practice, the novel testing apparatus offers the special advantage that a wide range of innovative shear and pullout test procedures can be carried out in the same device with negligible influence of test device configurations on friction test results.

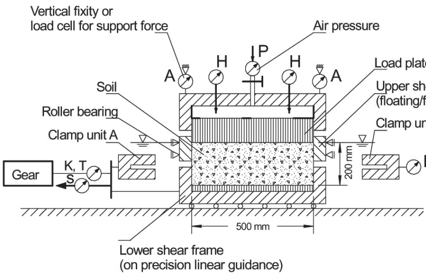

Figure 3. Cross section of the Geosynthetic-Interaction-Testing-Device (GITD) of the Geotechnical Institute of Freiberg University of Mining and Technology.

6 NUMERICAL MODELLING

The stability of reinforced soil is to be proven. Following the limit state principles the two limit states considered in the design are the ultimate limit state and the serviceability limit state. However there is no general method for the design of much innovative geosynthetic reinforced soil structure. The soil and the reinforcement both influence the behaviour of the compound structure, and the equilibrium is too complex to be adequately by the "simple" concept of the limit state principles. Besides other complex and expensive field tests, the numerical methods are an alternative for an effective analysis involving the study of displacement, stress, force and the reinforced soil structure separately and as unit.

Generally, geosynthetic reinforced constructions are made of the following three elements:

- The soil above and below the geosynthetic,
- the geosynthetic itself and
- the interface between the material and the geosynthetic.

Each of these elements has to be characterised with mechanical (e.g. stiffness, strength, ...) and hydraulic (e.g. permeability, porosity, ...) parameters through constitutive laws. Initial and boundary conditions (e.g. initial stress state, ground water level, extra loads, ...) should be specified.

The numerical methods available for a discretisation of the above mentioned elements can be generally divided into continuum mechanical approaches (e.g. Finite Element Method (FEM), Finite Difference Method (FDM), or Boundary Element Method (BEM)) and discontinuum approaches (e.g. Discrete Element Method (DEM) and Particle Methods). A three-dimensional implementation of the soil-geogrid system is depicted in Figure 4 as an example for each of the approaches.

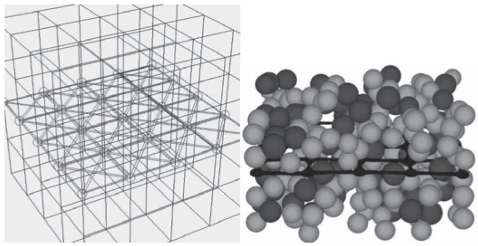

Figure 4. Mechanical continuum (left) and mechanical discontinuum (right) modelling of the soil-geogrid system.

Apart from the soil and geosynthetic attributes, great importance is placed on soil-geosynthetic interface attributes while modelling. While the real geotextile is transmitting the shear stresses along the surface through friction, geogrid reinforcements additionally interlock (interlocking effect).

The mechanism of geogrid-interlocking, although familiar, is a phenomenon still to be investigated. It is a subject of todays scientific research (Konietzky, 2004).

7 DYNAMIC LOADING

The current state of knowledge of geosynthetic reinforced constructions under not predominantly static or dynamic loading is poor in comparison to static loading. On one hand, high load-carrying reserves are known of such constructions, for instance due to the strain of earthquakes and dynamic crash-loads like protective barriers in areas in danger of rockall, on the other hand there is the dimensioning of constructions (if dynamic loads are to be considered) performed with empirical predefinitions and sometimes due to practical experiences. The diversity of factors which should be considered regarding the dynamic impact on the construction stability complicates the task of generalising dimensioning approaches.

Especially in Germany, soil reinforcement with GSY is entering a new dimension. It is no longer used only under static, but also under dynamic loading conditions like in railway embankments or in bridge abutments. Several specific design methods, performance tests and instrumentation programs are developed to satisfy special requirements from engineers and technical authorities (Herold/ Tamaskovics, 2004).

Within the scope of the EBGEO revision (Chap. 3), a recommendation "Dynamic impacts on geosynthetic reinforced systems – not predominantly static loading" will be worked out and added as a new part of EBGEO.

8 CONCLUSION AND PERSPECTIVES

Compared to conventional building materials like wood, concrete and steel with thousands of years experience, geosynthetics are by far the youngest member of the family. With the appearance of synthetic polymers in the sixties and seventies, the basis for the development of geosynthetic products and applications was layed. Modern technology enables the production of a full range of geosynthetics with all kinds of product-specific traits for versatile application.

Cohesive soils are a cost-efficient alternative to purely frictional soils. Often they are found on site and are inexpensive. Recent research has shown that cohesive soils can be improved by adding cement, lime, ash, etc. to improve the interaction and reduce deformation (Aydogmus/Alexiew/Klapperich 2005). Alternatively, electrokinetics can be used to improve the contact zone of the cohesive soil. Numerical calculations are a useful aid concerning parameter studies for optimising already known or new areas of application. The advantages are due to the consideration of numerous factors, especially subsoil and construction parameters (and their range) and the interaction between the soil and the reinforcing element. Parameter studies can be conducted very efficiently – time and money spending laboratory and field experiments can be avoided.

Current research and investigation aim to broaden the use of geosynthetics, to make this method even more cost and time-efficient and to preserve the environment.

The numerous conferences, in addition to publications enable a knowledge exchange and mediation of high standards. A greater concernment of universities for the topic "geosynthetics" will no doubt lead to more open-minded clients and builders.

Today, the geotechnical application of geosynthetics can be seen in context to the philosophy of "constructive engineering" – *soil and geosynthetics replace concrete and steel more and more*.

REFERENCES

Aydogmus, T. and Klapperich, H. (2004). "The Next Generation: Enhanced Shear-Pullout-Testing Device", Proc. IGC-Pillnitz, pp. 395-404, refs. 8.

Aydogmus, T., Alexiew, D. and Klapperich, H. (2005). "Evaluation of Interaction Properties of PVA Geogrids in Stabilized Cohesive Soils: Shear- and Pullout Tests", Proc. 8th International Conference on Geosynthetics, 18.-22. September 2006, Yokohama, Japan, pp. 4.

Bräu, G. (2004). "EBGEO – German Recommendation for Earth Reinforcement with Geosynthetics - Actual State of Discussion", Proc. IGC-Pillnitz, pp. 255-265, refs. 17.

EBGEO (1997). "Empfehlungen für Bewehrungen aus Geokunststoffen", Ernst & Sohn Verlag, Berlin.

Heerten, G. (2004). "Opening Lecture – Conference Goals", Proc. IGC-Pillnitz, pp. 3-10.

Heitz, C. and Maihold, K. (2004). "Reinforced Earth Structures on Point- or Line-shaped Bearing Elements - The New Dimensioning Procedure of Chapter 6.9 EBGEO", Proc. IGC-Pillnitz, pp. 407-416, refs. 7.

Herold, A. and Tamaskovics, N. (2004). "Determination of Dynamic Loading Effects in Geosynthetic Reinforced Soil Constructions with the Cone method", Proc. IGC-Pillnitz, pp. 445-466, refs. 7.

Klapperich, H. (Ed./2005). Proceedings of the International Conference on The Use of Geosynthetics in Soil Reinforcement and Dynamics (IGC-Pillnitz), Schloss Pillnitz, Dresden, Germany, 5.-8. September 2004. Eds.: H. Klapperich, D. Cazzuffi, R.M. Koerner, L. Vollrath. ISBN 3-7739-6003-4, VGE - Essen, 2005.

Konietzky, H. (2004). "Numerical Modelling of Soil – Geosynthetics Systems", Proc. IGC-Pillnitz, pp. 303-312.

Paul, A. and Aydogmus, T. (2004). "Geosynthetic Overbridging Systems in Areas Prone to Subsidence - A State Report of the German Standardization", Proc. IGC-Pillnitz, pp. 325-336, refs. 14.