Theme lecture: Use of geosynthetics and geotextiles in geotechnical engineering

Exposé sur le thème: Utilisation des géosynthétiques et des géotextiles en géotechnique

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ABSTRACT: The elected subjects of the Report are divided up in two parts, the first one with reference to the Papers of the Discussion Session 5.2, the second part gives some news on the recent German research, especially on prestressed geosynthetic reinforcements for soil-bearing layers and on the behaviour of geosynthetic reinforced slopes. Concerning the Session Papers there were registered 16 reports alltogether, 14 papers in English, 2 in French. The themes of these papers can be devided up into the items:Testing and performance of geotextile filters, design and performance of drains and preloading, bearing capacity of geosynthetic reinforced systems, steep slope and embankment stability, special testing on reinforcing effects, case history studies. The following presentation summarizes some indications and remarks showing the progress in research and development.

Part I: News on Research and Development with reference to the Session Papers

(1) The influence on the thickness and the filter characteristic values (opening size, water permeability behaviour and the behaviour in the turbulence test) caused by stretching of geotextiles in contact with soil was determined. A proposal for a criteria and for the classification of the flexibility (F_K) of streched geotextiles is based on results of the plunger puncter test and the maximum stretching in the biaxial tensile test. A basically different behaviour between the different bonded geotextiles was founded in these tests. (F. Saathoff, Germany)

(2) Mud pumping can be simulated by a new filtration-test. This test is mainly based on the soil-retaining requirements of the filter. The weight of the subgrade soil passing the filter caused by the repetitive loading is measured and hence a Soil Contamination Value (SCV) is calculated. The SCV correlates systematically to the Effective Opening Size (EOS) of the geotextile in dependence on the soil. (S. V. Ramaswamy, India)

(3) Research work is done on the speeding up consolidation by vertical band-shaped drains and the vacuum preloading. In the comparison of the consolidation surcharge and underpressure-suction there are significantly differences in the total and effective stress state and accordingly in the consolidation rate. In both soil improvement methods stress decreases with depth, but in the case of surcharge the rate is significantly slowlier. The vacuum consolidation doesn't cause consolidation below and outside the vertically drained area. The pumping time is almost some times shorter than the traditional surcharging time. (P. Vepsäläinen / N. Punmalainen, Finland)

(4) A case study deals with a particular application of Geotextile French Drains (GFD), in which the geotextiles have a satisfactory performance used to intercept the groundwater flow in order to dewatering and avoid a piping problem. (V. Trueba, Mexico)

(5) The practical analysis of preloading and vertical drain effects on the consolidation of soft clay is connected with several uncertainties. From the data of full - scale field tests it is concluded that the course of settlement agrees better with the consolidation equation based on non-Darcian flow than with the conventional Darcian flow theory. This fact has been confirmed in previous studies. Another possible explanation may be a gradual decrease in the coefficient of consolidation during the course of settlement. (S. Hansbo, Sweden)

(6) The main applicated test method for the investigation of bearing capacity and deformation of multilayered systems are large scale laboratory or field loading tests compared to calculation results made by FEM. The simplest and therefore often used way for field loading is the application of plate bearing tests, but it has to be considered that these tests are not suitable to verify the changes of normal and shear stresses at the interface of the soft soil layer and the reinforcement. Up-to-now the results and the conclusions of such comparisons are not consistent. The causes may be on the one side the different test conditions and the difficulties in the determination of the reinforcement and soil parameters in the FEM-calculations, on the other side the differences of interfacing the reinforcement between or inside the layers and the differences in the stiffness of the reinforcing geosynthetics.

(7) Research work at Helsinki University of Techno-logy by laboratory model testing has the conclusion that a reinforcement between a soft subgrade and a sand layer does not significantly decrease settlements or increase the bearing capacity in the range of small displacements (< 40 mm). The best benefit of reinforcement is reached for large displacements and when using two reinforcements. In this case the reinforcement decreases the shear stresses at the top of the soft layer. Another result is that the density of the compacted super structure has larger effect on the bearing capacity than the stiffness of the reinforcement. (A. Aalto / P. Friberg / E. Slunga, Finland)

(8) For the examination of the effect of horizontal geosynthetic layers for reinforcing soft soils beneath foundations, a reduce scale-model was placed in a centrifuge. The results show that the bearing capacity of the soil can increase if it is reinforced by one or two geosynthetic layers. But it has to consider, that the deformation of the soil increases as well. (T. Dubreucq / P. Delmas, France)

(9) Large scale laboratory investigations by plate bearing tests supported by FE analysis have verified that the use of woven and non woven geotextiles in granular bearing layers can improve the bearing capacity. But the beneficial effects of the woven reinforcing geotextiles is only essential at large deformations. The two layer solution with a woven geotextile in the bottom and a geogrid in the granular masses increases the bearing layer stiffness and results in significant improvement of the deformation characteristics both for static and cyclic leading. (A. Watn et. al, Norway)

(10) The results of two natural scale tests are presented in which a steep sand embankment reinforced with two different geotextiles (woven and nonwoven) were loaded up to the break point. A different failure mechanism in the embankment occurred, depending on the used geotextile. Due to the correlation between deformation and load, it is possible to specify a critical load. In this connection the nonwovens have shown more efficient behaviour than the wovens. (E. Baraize et al., France)

(11) On the basis of centrifuge modeling it was verified, that marginally insitu slopes can be stabilized by high strength non-woven geotextile strips. The strips perform the dual functions of reinforcement and drainage. On account of their survivality it is possible to drive them into existing slopes in a similar manner as to driving wick drains into the ground, thus requiring little or no excavation. But more study is necessary on the driving mechanism and on minimizing the disturbance to the slope during installation of the strips. (Th. F. Zimmie / M. B. Mahmud, USA)

(12) In Germany more experience and knowledge could gathered of piled and reinforced embankments in areas of soft ground.

In the case of a track railway line an embankment was founded on driven piles with concrete pile caps and reinforced by three layers of high tenacity polyester geogrids. The measurements reveal a satisfactory performance of this structure which was choosen instead of conventional deep replacement of the soft peaty soils. (E. Gartung et. al, Germany).

In another case a road embankment was founded on soft peaty ground by sand columns (diameter 0,6 m, distance 1,25 m) reinforced by a geotextile coating instead of soil replacement. The coating of the columns was composed of a reinforcing sewn geotextile of polyester threads and a geotextile filter. This geotextile composite is subjected to ring tension forces, gives a radial supporting of the sand columns in connection with the surrounding soil and guarantees the filter effect. The installation of the columns need a pre-filling for working and was carried out by several vibration driving of casings. (H.-G. Kempfert et. al, Germany).

Part II: News on German Research Results (examples 1996 / 97)

At the Institute of Foundation Engineering, Soil and Rock Mechanics of the Technische Universität München the load and deformation behaviour of prestressed geosynthetic reinforcement for soil-bearing layers and non-prestressed reinforcement for steep slopes were themes of extensive research in 1996 / 97.

1. Research on prestressed geosynthetic reinforcements for soil-bearing layers

The idea to prestress the reinforcement on a defined level before loading arises from the requirement that only very low system deformations are allowable for bearing layers with special usability.

First of all a technology for prestressing of geosynthetics was developed and performed for the foundation of sport grounds on soft subgrade. Lit.: Floss, R.; Gold, G., Prestressed Geosynthetic Reinforcements for soil-bearing Systems. Proceedings Geosynthetics 97 Conference Long Beach, California, USA, March 10 - 13, 1997.

Furthermore the influence of different degrees of prestressing of the reinforcement was analyzed using the Finite Element Method (FEM). By prestressing the reinforcement the stress state of the granular bearing layer is modified. The prestressing operates mainly in horizontal direction and so the horizontal stresses are increased. When the loading in vertical direction is brought on the layer, there is an increase in vertical stresses. So several load steps can be brought up, until a stress state comparable to the hydrostatic stress state is achieved. The increase of the second invariant of the stress deviator, which is important for the yielding of the system, happens on higher load level. The results are:

- The deformations of the granular bearing layer itself are reduced, because plastic deformations are only reached on a higher load level.

- Because of the higher load level in the granular bearing layer, there is given an essentially improved load spreading and stiffer load reaction of this layer. Therefore bigger areas of the subsoil are claimed and smaller deformations result for the whole system. This is the essential effect for the reduction of the system deformations, because the main part of these deformations result from the soft subsoil.

- The most significant reduction of the vertical deformation was calculated by the system with the thickest granular layer (0,5 m). But the prestressing generally shows better effects for systems with lower stiffness of the reinforcement. The reason for this is, that a high stiffness of the reinforcement has a good performance even without prestressing.

2. Research on load and deformation behaviour of geosynthetic reinforced steep slopes

2.1 The main topic of the research on reinforced steep slopes was the influence of the bond between soil and geosynthetic reinforcement on the deformation behaviour of the composite system. Reinforced shear tests and in-soil tensile tests were carried out with a number of nonwovens and wovens. The tests with the nonwovens show an increase of the tensile strength and stiffness of the system, a decrease of the creep deformation and the deformation rate according to the soil surcharge. But the comparison between the wovens in soil and without soil show no clear difference in the deformation creep behaviour.

The results show clearly the increase of tensile strength and stiffness according to the soil surcharge and have to be transformed into a material law for using in FE-calculations, analytical approaches and practical designs. The results of that material law show a good agreement with the test results for the range of usual working loads.

Calculations of load-settlement characteristics and deformation behaviour of reinforced steep slopes with the Finite Element Method show the necessity of in-soil tensile tests with nonwovens. The investigations and comparisons with full scale tests demonstrate that soil reinforcing with nonwovens can be effective. (Doctoral-thesis of A. Bauer, Germany)

2.2 In another research and thesis work a large biaxial test device was developed to investigate the load-deformation behaviour and interaction of multilayered geosynthetic reinforcements in sand: .

Tests under plane strain conditions according to the real situation in site were carried out (maximum load 1000 kN/m²) with three layers of geosynthetics (geogrids, wovens and nonwovens) in sand and also for sand without reinforcement. The size of the test device was sufficient for a nearly full scale test. The different stress-deformation-behaviours were compared. On the basis of these tests the composit behaviour was described approachingly with a mechanical model.

The reinforcement by nonwovens results from an increase of the shear force intensity, but with unchanged stress-/strain behaviour of the reinforced soil. Deformations necessary to achieve reinforcement effects are smaller with geogrids than with wovens. The analytical approach can be used to predict the deformations of steep slopes, even with nonwovens. (Doctoral-thesis of M. Nimmesgern, Germany)

Summary (Part I and II)

(1) The performance of geotextile seperators and drains is confirmed by research and experience, so in generally the application can be recommended for highway and railway engineering. But the assumption must be a careful designing on the basis of representative investigations on the ground and hydrological conditions. Attention is necessary on the distinct behaviour between different bonded geotextiles caused by stretching under load.

(2) In the case of preloaded and vertical drained soft clay more research should be useful on the gradual decrease of the coefficient of consolidation during the course of settlements.

(3) An essential requirement for the durability of geotextiles and geogrids must be the resistance against abrasion and other damages by covering, compaction and traffic loading.

(4) The knowledge on the chemical durability and on the creep behaviour of geosynthetics need more research and practical experience. The situation is on this field the same as before.

(5) The main applicated test method for the investigation of bearing capacity and deformation of multilayered systems are large scale laboratory or field loading tests compared to calculation results made by FEM. The simplest and therefore often used way for field loading is the application of plate bearing tests, but it has to be considered that these tests are not so suitable to verify the changes of normal and shear stresses at the interface of the soft soil layer and the reinforcement.

(6) According to the present state the best effect of reinforcing bearing layers seems to be reached by using two reinforcements, but the efficiency is complex influenced by both the quantity of displacement and stiffness of the reinforcement as well as the density of the super structure. These complex influences have to be seen seperated for static and dynamic loading. Also the efficiency of prestressing the reinforcement could be an essential step for further development of geosynthetic structures.

(7) Calculations of the load-deformation behaviour of reinforced steep slopes with the Finite Element Method show the necessity of in-soil tensile tests with nonwovens. The investigations and comparisons with full scale tests demonstrate that soil reinforcing with nonwovens can be effective. The reinforcement by nonwovens results from an increase of the shear force intensity.