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# Investigation of the interaction of geosynthetics with ground on the example of shear test and pull-out test

## Enqête sur les geosynthetics de liens avec terrain sur l'exemple de essai sur cisaillement et essai sur gigogne

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ABSTRACT Nowadays it is difficult to imagine any construction site without the presence of geosynthetics on it. However practice shows this type of materials are used in Russia, as a rule, thoughtlessly, or alternatively are used to a limited extent. This is due to the lack of a competent regulatory framework, and as a consequence of the lack of any quality control of these materials. Russian scientists geotechnics at the moment currently lead a comprehensive study of all types of geosynthetic materials. But, in spite of this there are a large number of the issues are raised, among them - the study of the interaction of geosynthetics with the ground. This interaction may be evaluated by testing the shear and pull-out tests on geosynthetic material. These parameters are necessary for a competent design of reinforced soils. This is the main aim of our research, which were conducted jointly - Building faculty Hochschule Magdeburg-Stendal (Germany) and the Department "Building manufacturing and geotechnics" Perm national research polytechnic university (Russia).When tested woven geosynthetic material used Geospan TN-50 ("Hexa-nonwovens materials" Ltd., Russia), which is a linearly independent orthogonally twisted monofilament . Monofilament represent a flat tape thickness of 0,1 mm and a width of 2-3 mm. Application of thin filaments gives certain advantages: low flexural stiffness (workability), good permeability, good mechanical properties and the ability to use as separation layers.

RÉSUMÉ Aujourd'hui, il est difficile d'imaginer un chantier de construction sans la présence des géosynthétiques sur elle. Cependant la pratique montre ce type de matériaux sont utilisés en Russie, en règle générale, sans réfléchir, ou bien sont utilisés dans une mesure limitée. Cela est dû à l'absence d'un cadre de réglementation compétentes, et en conséquence de l'absence de contrôle de la qualité de ces matériaux. Scientifiques russes géotechnique pour le moment actuellement de mener une étude approfondie de tous les types de matériaux géosynthétiques. Mais, en dépit de cela, il ya un grand nombre de questions se posent, parmi eux - l'étude de l'interaction des géosynthétiques avec le sol. Cette interaction peut être évaluée par des essais de cisaillement et des tests d'arrachement de la matière géosynthétique. Ces paramètres sont nécessaires pour une conception compétente de sols renforcés. Tel est l'objectif principal de nos recherches, qui ont été menées conjointement - faculté bâtiment Hochschule Magdeburg-Stendal (Allemagne) et le ministère "de la fabrication et de la géotechnique bâtiment" Perm national de recherche universitaire polytechnique (Russie). Lors d'un essai matériau géosynthétique tissé utilisé Geospan TN-50 ("Hexa-nontissés matériaux», Russie), qui est un monofilament perpendiculairement tordu linéairement indépendants. Monofilament représente une épaisseur de la bande plate de 0,1 mm et une largeur de 2-3 mm. Application de minces filaments donne certains avantages: faible rigidité à la flexion (de maniabilité), une bonne perméabilité, de bonnes propriétés mécaniques et la capacité à utiliser comme couches de séparation.

## 1 INTRODUCTION

Currently in the construction practice there has been strengthened focus to a permanent increase in load on the foundation soil. The reason for this is the increase in the number of levels and as a consequence the increase of stress. According to (Ponomarev et al 2013), the cost of foundations construction of various buildings and structures can be up to 30% of the total cost of construction, and in some plants (supports high-voltage lines and other high-rise buildings) the cost of foundations reach half of the total cost. Therefore reducing the cost of construction is an actual task. Particularly acute issue of reducing the cost of installation of foundations on soft ground, the question arose in connection with the sealing buildings of urban settlements and territories that were previously considered unsuitable for construction now turned into the territory of modern construction sites.

Among many existing technologies installation of foundations on soft soils the most simple and rational use of groundwater are the pillows. In traditional performance design of such bases involves replacement of the soft soil layer on the stability of the material (crushed rock, gravel, sand). Main disadvantages of this method are: relatively high consumption of materials, large volumes of excavation, as well as the imperfection of existing calculation methods for frequent giving exaggerated characteristics of these structures. Significantly reduce the financial costs allows using in such constructions of reinforcement effect.

Reinforcement is one of the most common ways to increase the bearing capacity and reduce sediment base where reinforcing materials were used for the purpose of wide application of geosynthetics. Characteristics of soil may be significantly improved through using reinforced elements.

Significant economic impact in the construction of foundations on reinforced foundation pads are produced by reducing the cost of shipping materials, a substantial reduction in the volume of work. Another important factor is to increase the safety of operation of structures on reinforced foundations.

At present in our country there are no regulations for the design of reinforced foundation pads. Therefore it is necessary to create a methodology for calculating the bearing capacity and settlement of foundation on reinforced pads. In addition, this methodology should consider changes of the strength and deformation properties of soils, in terms of joint deformation of the reinforcing elements and the soil for the geotechnical conditions of the Perm region.

According to a significant effect on the bearing capacity of foundation pads have a reinforced mechanical properties of reinforcement materials (geosynthetics). There are many articles dedicated to the calculation of the influence of strength and elongation of geosynthetics. But in our country the assessment of the impact interaction characteristics of geosynthetics with the ground on the bearing capacity of reinforced foundation pillows is not investigated (Bartolomey et al 1999; Melo & Santos 2014)

This interaction may be assessed by testing the shear and pull-out tests on geosynthetic material from the ground. (Tatiannikov & Kleveko 2014; Ponomaryov, & Zolotozubov 2014) Similar experiments were not considered in our country due to lack of equipment required. Therefore the authors set out to conduct these studies in order to determine the necessary parameters of the interaction of geosynthetics with Grunhow. These parameters are necessary for the study of the bearing capacity of reinforced foundation pillows in the geotechnical conditions of the Perm region. The determination of these parameters will allow us to design the foundation pillow on the basis of reinforced soil

Our studies were conducted jointly - Faculty of Civil Engineering Hochschule Magdeburg-Stendal (Germany) and the Department "Building Construction and Geotechnics" PNRPU (Russia).

## 2 RESEARCH

### *2.1 Machinery and equipment*

All experiments were performed on the Building Faculty Hochschule Magdeburg-Stendal (Germany). The experimental equipment used special shear installation (Figure 1).

This apparatus is made in accordance with the requirements of DIN EN ISO 12957-1 and DIN 60009. The main part of the machine consists of a managed clamping device and a two-part box sizes 500×500×200 mm. Geosynthetic material is located between filled with sand, the upper and lower portions of the box and is secured in the clamping device. Vertical load is created using pneumocompressor, horizontal displacement geosynthetics used with the clamping device equipped with a stepper motor. The process of testing is fully automated, all input data are given in a special program on the PC.

As a primer there was used sand with physical and mechanical characteristics, which are listed in Table. 1.

Two types of geosynthetics were used in tests: geogrid Secugrid (NAUE GmbH & Co) and woven geotextiles Geospan (Hexa) (see. Figure. 2 and Table 2).

**Figure 1.** Apparatus for direct shear.

**Table 1**. Physical and mechanical properties of sand.

| Soil characteristics | Designation | Values characteristics |
|---|---|---|
| Solid particles of soil | $\rho_s$, kg / m$^3$ | 1944 |
| Soil density | $\rho$, kg / m$^3$ | 1483 |
| Unit weight | $\gamma$, kN / m$^3$ | 14,53 |
| Void ratio | $e$ | 0,32 |

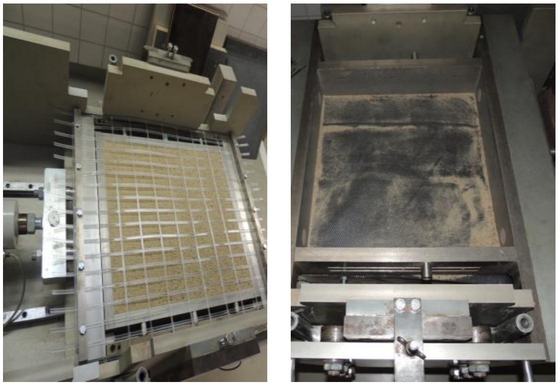

**Figure 2.** Geosynthetics: a - geogrid, b - woven geotextiles.

**Table 2.** Physical and mechanical properties of geosynthetic materials.

| Property | geogrid | geotextile |
|---|---|---|
| The surface density | 415 g / m$^2$ | 275 g / m$^2$ |
| The maximum tensile, kN/m along / across | 400 / 400 | 50 /50 |
| Elongation at maximum load, % along / across | 9 /9 | 17 / 15 |

*2.2Methods*

Methodology for shear and pull-out tests is adopted according to the German regulations DIN EN ISO 12957-1 and DIN 60009. The scheme of experimental works for the shear tests and pull-out tests are presented in Table 3.

**Table 3.** Test configuration.

| Normal stress | Shear test (system) | | | Pull-out test | |
|---|---|---|---|---|---|
| | sand – sand | sand – geogrid | sand – geotextile | sand – geogrid | sand – geotextil |
| 20 | - | - | - | + | + |
| 30 | - | - | - | - | + |
| 40 | - | - | - | + | + |
| 50 | + | + | + | - | + |
| 60 | - | - | - | + | - |
| 100 | + | + | + | + | - |
| 200 | + | + | + | - | - |

*2.3 Processing test results*

One of the main experimental research problems was to establish the patterns of development of shear stress duo to the displacement of the material for different types of systems.

The results of the experiments are shown in Figures 3 to 7. This data forms a source for studying the interaction between soil and geosynthetics.

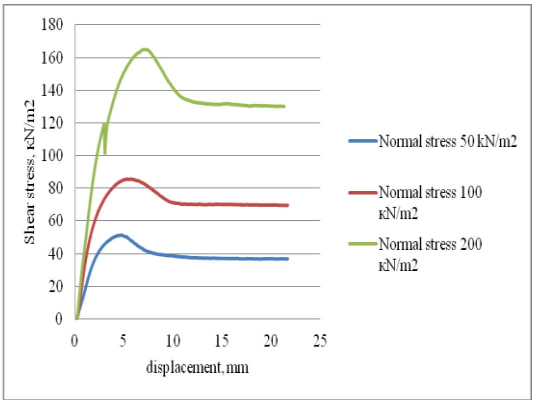


**Figure 3.** The system sand – sand shear test results.

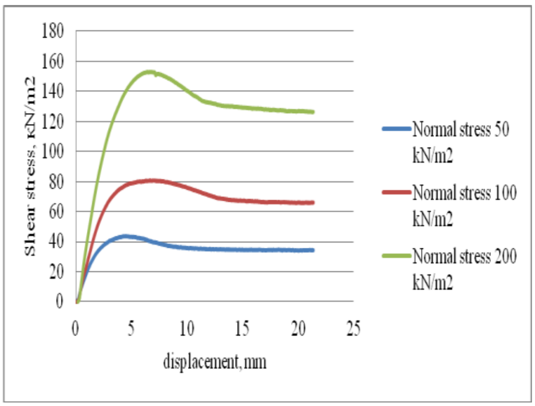


**Figure 4.** The system sand – geogrid shear test results.

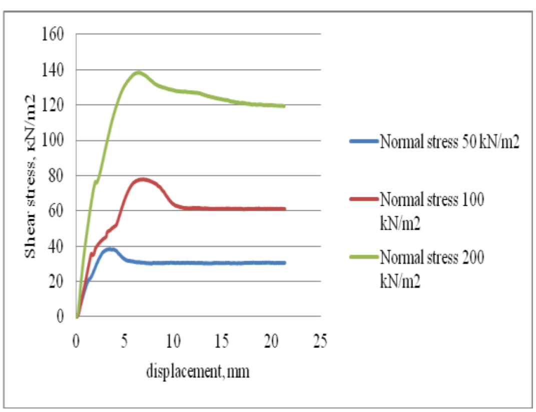


**Figure 5.** The system sand – geotextiles shear test results.

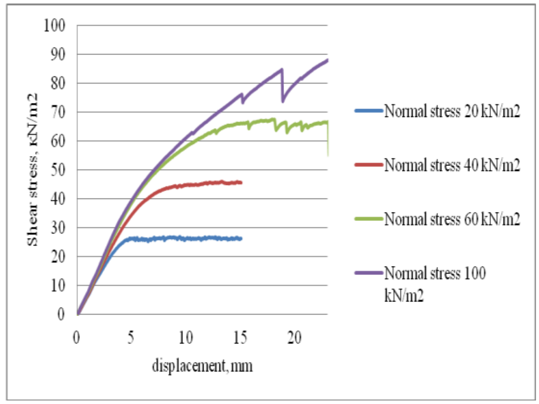


**Figure 6.** The system sand – geogrid pull-out test results.

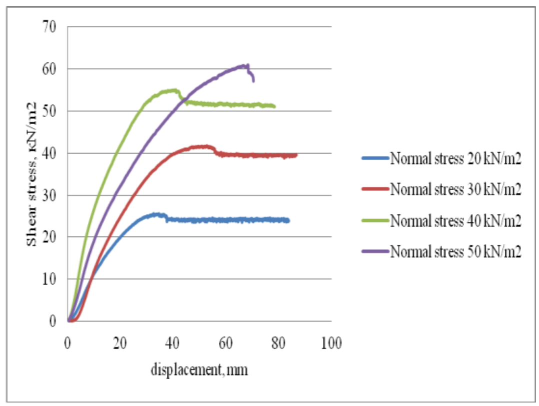


**Figure 7.** The system sand – geotextile pull-out test results.

As a result of the shear tests in geosynthetic materials permanent deformation are not detected.

Tensile forces are transmitted to the geosynthetic material due to friction between the soil and geosynthetics. Therefore, the friction coefficient is introduced to evaluate the interaction between soil and geosynthetics (Tatiannikov et al 2014), which is defined according to claim 9 DIN EN ISO 12957-1. Without knowledge of this ratio it is impossible to assess the bearing capacity of the foundation pads on reinforced soils. The obtained values of the friction coefficient are shown in Table 4.

**Table 4.** Values of the coefficients of friction.

| Type of system | Normal stress, kPa | Friction coefficient |
|---|---|---|
| Sand – geogrid | 50 | 0,846 |
| | 100 | 0,939 |
| | 200 | 0,927 |
| Sand – geotextile | 50 | 0,745 |
| | 100 | 0,907 |
| | 200 | 0,841 |

The coefficient of friction between soils and geosynthetics can be determined by calculation according to formulas EBGEO, but in this case it's value will be very low.

According to Alfaro et al (1995) and Koerner. (1999), we can determine the strength characteristics (angle of internal friction and cohesion) due to the Mohr-Coulomb law for the following types of systems: "sand-sand" and "sand-geosynthetic material". For comparison of these characteristics with the two systems there were introduced the following efficiency factors. The obtained results are summarized in Table 5.

**Table 5**. Shear Test Results.

| Type of system | comparing of the angle of internal friction | | comparing of the cohesion | |
|---|---|---|---|---|
| | value of the angle internal friction | coefficient efficiency of friction, % | value of cohesion, kPa | coefficient efficiency of cohesion, % |
| Sand – sand | 32,1 | 100 | 5,85 | 100 |
| Sand – geogrid | 31,7 | 98,7 | 3,5 | 60 |
| Sand – geotextile | 30 | 93 | 2,87 | 49,5 |

Some irreversible deformation was observed while conducting of pull-out test for vertical stress greater than 60 kPa in the geotextile, which led to its rupture, but in the case of geogrid this phenomenon was not observed.

The main parameter of the interaction between geosynthetic material and soil for pull-out test is the maximum value of pull-out resistance (Tatiannikov & Kleveko 2014), which is determined in accordance with claim 8 DIN 60009. This parameter makes it possible to evaluate the stability, shear strength of constructions, as well as the ability of reinforced soil to expand.

The obtained values of pull-out resistance are summarized in Table 6.

**Table 6**. Pull-out resistance values for different types of systems.

| Type of system | Normal stress, kPa | Pull-out resistance, kN / m |
|---|---|---|
| Sand – geogrid | 20 | 54 |
| | 40 | 91,6 |
| | 60 | 135,36 |
| Sand – geotextile | 20 | 51,04 |
| | 40 | 110,32 |
| | 50 | 121,84 |

## 3 CONCLUSIONS

According to the results of tests performed, we can make the following conclusions:

1. Analysis of experimental dependences is presented in Fig. 3-7 showed that the system "sand-sand" perceives larger shear stresses (164.8 kPa) than systems "sand-geogrid" (152.7 kPa) and "sand-geotextile" (138.5 kPa). Thus, this fact should be taken into consideration in the design of the foundation pads.

2. The coefficients of efficiency (Table 4) obtained from studies indicated that the reinforcing elements reduce the strength characteristics of the soil on contact between soil and reinforcing materials.

3. In the constructions that perceive significant shear forces using of geogrids more preferable than using geotextiles. This conclusion is confirmed by the coefficients of friction and efficiency ratios.

4. The value of the coefficient of friction increases with the normal stress to a peak and then it decreases for both types of systems geosynthetic materials, see. Table 4. This dependence must be taken into account in the calculation of the bearing capacity of reinforced foundation pads.

5. The lack of test data on the shear and pull-out strongly underestimates the value of the bearing capacity of reinforced foundation pads, which leads to errors of construction at the design stage.

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