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Analysis of Changes in Strength Characteristics of Geosynthetics During Its Operation

Statement of the problem. In the article the authors have been given the task to learn how the strength characteristics of geosynthetics vary with time under load in earth structures using geosynthetic reinforcements and how to take into account the fact of deterioration when designing these structures.

Results. The tests were conducted to study the strength characteristics (tensile strength) of geosynthetic material that had been operated for a long time as a part of earth structure using geosynthetic reinforcements. At the same time similar tests were conducted with samples of new geosynthetic material. According to the test results change of tensile strength – operating time dependence was obtained.

Conclusions. The test results confirm the theoretical approaches of Recommendations for Design and Analysis of Earth Structures using Geosynthetic Reinforcements (EBGEO) with a due account taken of geosynthetics deterioration and allow one to draw a conclusion about the reasonability of the experimental dependences when designing earth structures with geosynthetics in geological conditions in this country.

Keywords: geosynthetics, breaking load, stress reduction, creep, material utilization, material use coefficient, «aging» of materials.

Introduction

Geosynthetics are now commonly used construction materials along with steel, concrete and wood. There is significant worldwide experience of the applications of geosynthetics [3—4, 6—9]. In Perm region constructions using geosynthetics first appeared in the mid-1980s, 30 years ago. Since then there has been huge experience of applications of these materials [1, 2], which still serve their construction purposes.
One of the largest reinforced soil structures to be built in Perm was a retaining wall in Elkin Street constructed in 1986.

Due to no previous experience of designing retaining walls of reinforced soil at the time, there were certain mistakes made at the construction stage that resulted in defects and deformations during their service (Fig. 1).

Identifying changes in the strength characteristics of geosynthetics over time is crucial, since the way how the characteristics of geosynthetics, which are components of reinforced soils, change in the long-term has not been properly investigated yet. Besides, the existing strength (creep) tests of geosynthetics are not totally certain to be consistent with the factual behavior of a geosynthetics in a retaining structure.

As a result, in 2013 the retaining wall was dismantled and a new one was constructed. During the dismantling of the reinforced soil retaining wall an opportunity emerged to select polyester (geogrid) reinforcement layer which lasted for 27 years and was examined for possible change of the strength characteristics of this type of material (Fig. 2) considering the time factor.
1. Experiments to determine the strength characteristics of geosynthetics

It was originally found that the retrieved geogrid is an analogue of geogrid ОС N 8 manufactured on “Krasnokamsk Plant of Metal Fibers”. The research to identify the strength characteristics of geosynthetics was conducted in a laboratory at the Department of Construction Production and Geotechnics” of Perm National Research Polytechnic University in collaboration with the Department of Central Plant Laboratory Ltd. “Krasnokamsk Plant of Metal Fibers”. The research took place in two stages. The first one involved a study of tearing characteristics of the geogrid samples retrieved from the retaining wall after 27 years of service life and the second stage entailed a study of tensile characteristics of the samples of the analogous new geogrids.

In order to conduct the research, a sample tensile machine MT-136 was used (Fig. 3). The machine operates on the transformation of tension by a strain gauge applied to the sample in the analogous electric signal changing proportionally to the tensile strength of the sample. The lower clamp was in operation, while the upper one remained motionless. The machine was
computer operated. The software specified the speed of the operating clamp, recorded elongation of the sample, the effort applied. As a result of the study, loading was plotted against the elongation (Fig. 4) with the x-coordinate specifying the absolute elongation, mm, the y-coordinate depicts the effort, kgf [5, 8].

![Tensile machine MT-136](image)

**Fig. 3.** Tensile machine MT-136: 1 is a geogrid sample; 2 is a strain gauge; 3 are clamps

![Example of “loading-elongation” diagram of the operating software of the tensile machine MT-136](image)

**Fig. 4.** Example of “loading-elongation” diagram of the operating software of the tensile machine MT-136

The tests were performed in compliance with the methods described in [5, 8]. In order to do tests, the samples free of damage and defect were selected from the geogrid. There were the total of five tests along and five tests across, the tests of the new geogrid were performed in the same fashion. The results of the tests are summarized in Table.
In order to study the state of geogrids after 27 years of service life, the 100-fold increase photos were taken (Fig. 5); this picture shows that disintegration of the material occurs on the transverse fiber of the grid followed by failure.

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Fig. 5. The used grid OC N 8: 1 are areas of the material disintegration

2. Analysis of the experimental data

Changes in geosynthetics can be identified by comparing tensile loads of the new grid and the used geogrid as some coefficient.
This is a coefficient $A_1$ as suggested by the European recommendations for design and analysis of earth structures using geosynthetic reinforcements (EBGEO). The coefficient $A_1$ is reducing one which is used in the calculation of reinforced soil structures since it represents the dependence of short-term and long-term strength of a geosynthetic.

Short-term strength is determined by means of tensile tests of geosynthetics. The initial parameters were the speed of the clamps where a geosynthetic is placed.

Long-term strength (creep) is determined by means of tensile tests of geosynthetics. The initial parameter was the loading applied over a certain amount of time.

Therefore, the coefficient $A_1$ allows the evaluation of changes in the strength of a geosynthetic over a long service life and the consideration of it in the construction of reinforced soil structures:

$$A_1 = 1/\beta,$$  \hspace{1cm} (1)

where $\beta$ is the coefficient of use of the material:

$$\beta = F / R_{B,ko};$$  \hspace{1cm} (2)

$F$ is the yield tensile strength in the creep tests; $R_{B,ko}$ is the yield tensile strength in the short-term tests.

Using the results of the tests of the geogrid OC N 8 (see Table) where $F = 108.4$ kN/m, $R_{B,ko} = 120.2$ kN/m the coefficients $A_1$ and $\beta$ were found to be 1.11 and 0.902 respectively for new and in service material.

Therefore, it can be stated that after the service life of 27 years of the geogrid OC N 8, the coefficient of use of material $\beta$ was down by 0.098. However, given extrapolation, it can be assumed that the coefficient $\beta$ for 100 years of service life is 0.623. Similarly, using the formula (1), the coefficient $A_1$ for 100 years of service life is 1.61, which is indicative of almost a double reduction in the strength characteristics of the geogrid.

**Conclusions**

1. The experimental study confirmed that geosynthetics are susceptible to aging and wear. Strength losses for the polyester geogrid OC N 8 were 17.3 % along the fibers (along
the current loading), 9.8 % across the fibers after 27 years of service life.

2. A 100-fold magnification of the used grid OC N 8 suggests that the material disintegrates across the fibers followed by failure.

3. According to EBGEO for polyester materials the coefficient $A_1$ ranges from 1.5 to 2.5. Based on extrapolation of the obtained experimental data, the reducing coefficient $A_1$ can be assumed to be 1.61, which indicates almost a double reduction in the strength characteristics of the geogrid.

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