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Two-Scale Laboratory Testing of 3D Soil-Stabilizing Mat Tensile Strength

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Abstract: The project MPO FR-TI4 / 330 "Research and development of innovative 3D stabilizing elements for the protection of slopes susceptible to erosion" was focused on the development of 3D slope stabilization mat. The product is protected by a utility pattern CZ 25 861 U1 and its main purpose is to reinforce the slopes threatened by soil erosion. It is designed for very steep rocky-soil slopes, e.g. located along linear structures such as roads or railways. The presented study demonstrates that the strength of the foil is not reduced after 2 years of exposure to UV radiation and weathering.

Key words: Stabilizing Elements; Tensile Strength; Soil; 3D Structure; Railway.

1 Introduction

Embankment soil stabilization is frequently accomplished by means of grouting when the soil is usually strengthened by addition of lime or cementitious admixtures, in some cases even by the materials based on recycled concrete with unhydrated residues [1–3] or polymer solutions [4]. Another approach consists of reinforcement provided by meshes or so called geo-cells. The presented product is formed of endless foil, into which triangular openings are cut. After the mat in-situ unfolding the foil is stretch and the openings are skewed, which results in rotation due to tensile forces in the compact parts of the mat. This results in a mechanism in which the original flat foil (2D) spatial mat, whose surface resembles to that of a kitchen grater.

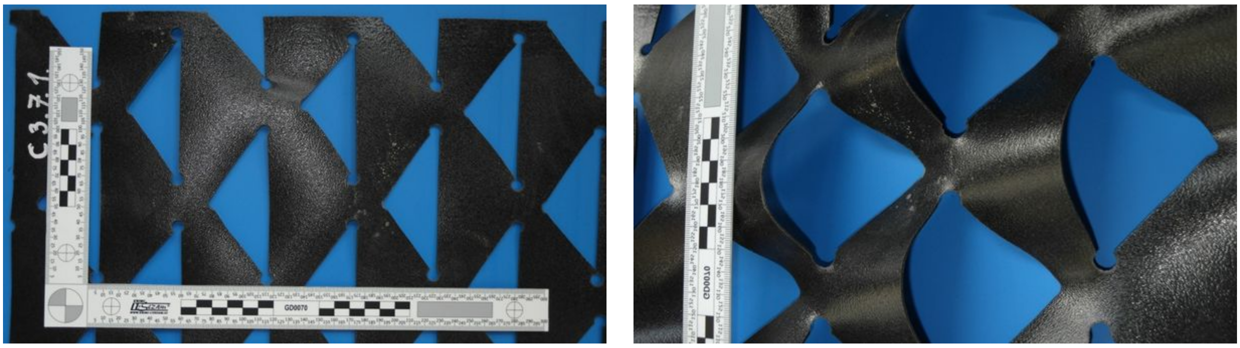
The resulting protrusions and edges naturally resist to the mat movement along the slope, thereby achieving high adhesion. Therefore, with the use of the mats there is a substantial reduction of need for anchoring, especially when compared to the use of geo-cells. Another benefit of the unfolded mats is the formation of pockets allowing for deposition of eroded material. The manipulation and transport of the mats is not demanding since the mat can be, when non-stretched, rolled up as a foil.

2 Tested Samples

Penafol 750, produced by Lithoplast Company, was used for the 3D stabilization foil production, in the thickness equal to 0.6, 0.8 and the best performing 1.0 mm. The thickest foil was produced in 1 mm wide stripes, the thinner ones in the form of stripes 1.4 mm wide. Penafol, based on polyethylene (PE), is commonly used in construction industry as waterproofing or separation layers, but it also finds its use in textile or leather processing industry. The mass density of the bulk material is equal to 750 kg/m^3 and its yield strength exceeds 6 MPa. The high resistance to mechanical loading, waterproofing and radon barrier capabilities, weldability a possibility to shape when heated are among the most important advantages of the material.

To attain the required properties, the mat had to be perforated in the exact pattern of isosceles triangles, 100 mm wide and 40 mm high. The individual perforations are shifted by half with respect to the neighboring ones and placed 30 mm apart. To avoid excessive stress concentrations in the corners, circular holes of 10 mm in diameter were made there, see Fig. 1.

In order to verify the mat behavior experimentally, a slope of the surface mine Nástup Tušimice was chosen for a long-term monitoring. The area belongs to the group of Severočeské doly, who allowed to install several types of mats for the slope stabilization that varied in size and shape of the holes. The stabilizing mats were placed by the principal investigator of the project STRIX Chomutov in 2013, see Fig. 2. The purpose of



(a) unfolded (3D) structure (b) geometry detail of individual perforations

Fig. 1: Mat designed for soil stabilization after unfolding and formation of spatial structure.

installing different types of slope stabilization matting was defining their stabilizing effect on site. Two years after their installation, 2 × 2 mm mat samples were removed from the stabilization matting to be subjected to laboratory investigation and measurements.

The extracted representative samples containing triangular holes (and circular ones located in the corners of the cut triangles) were subjected to laboratory tensile tests in order to determine the peak tensile strength after the exposure of the material to temperature fluctuations, UV radiation and damage associated with assembly and disassembly of the mats. The condition of the mat after 2 years of external application has been documented, based on visual inspection – the assessed damaged area was about 5 percent (from a sample size of 4 m^2) and most of the damage occurred in the corners of the triangular openings.

(a) in-situ unfolded (3D) structure (b) in-situ application

Fig. 2: In-situ application of 3D structure, location – mine Nástup Tušimice (company Severočeské doly).

3 Experimental Methods and Results

The tensile tests were carried out at the same time on the same samples at controlled laboratory environment (temperature about 25 °C and relative humidity equal to 50 %). A secondary aim of the study was to determine optimum tensile force for unfolding of the mat to obtain spatial structure while not exceeding the load-bearing capacity.

The testing was accomplished at two scales: on a material sample without perforations and on a mat segment being a representative element with the perforations. The material mechanical properties were investigated on 140 × 10 mm samples, while the effective tested length after clamping into the testing machine was equal to 100 mm, this testing method is very similar as ones used for thin materials (as foil or nanotextiles) [5, 6]. The MTS loading frame was used for standard testing of 10 representative specimens. Based on results of the measurement, it can be concluded that the material retained its tensile strength after 2 years exposure to the external environment. Maximal tensile strength was 9.5 ± 1 MPa for the reference material and 9.1 ± 1 MPa for applied material, Fig. 3. The average strength was 5 % lower than in the case of a reference material, but the standard deviation was equal to 10 %.

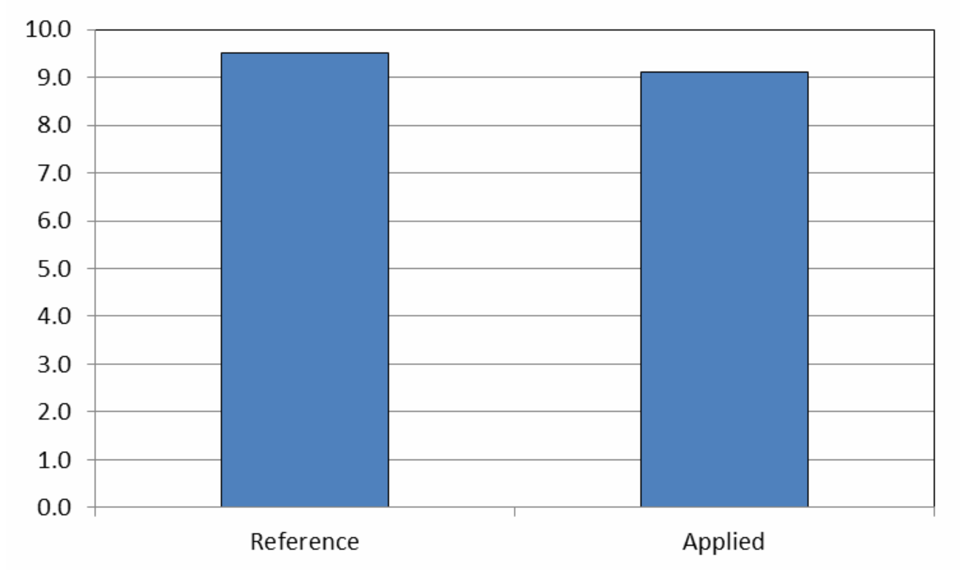


Fig. 3: Comparison between the tensile strength of the tested samples 10 × 100 mm.

Testing at the macro scale was carried on non-damaged 300 × 400 mm mat segments. The effective tested length was equal to 300 mm, 50 mm wide band was reserved at each side to ensure a proper fixation into the clamps of the testing machine. The clamping was accomplished via metal strips placed along the longest edge of the perforated triangle. The loading was displacement controlled at the rate of 0.2 mm/min. Based on the obtained results, it is obvious that the even the average strength of the mat at the macroscopic scale was not reduced by the exposure to the external environment. The standard deviation of the measurement was equal to 20 %, which reflects various failure modes encountered during the testing. The onset of damage took place in the corners of the triangular holes due to stress concentrations. The force required for the mat unfolding (and thus creating 3D structure) was about 23 % of the ultimate tensile strength.

4 Conclusion

3D stabilizing mats offer a cheap alternative of anchored geo-cells or grouting. Their spatial structure can be obtained be stretching of a simple 2D foil with perforations that deform out of plane. The long-term monitoring confirmed offer a long term solution for stabilization of slopes and embankments, since tensile strength of the material was not reduced over two years of exposition to UV radiation and weathering. Based on the findings, the mats can replace some commonly used, yet more expensive, technologies.

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