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Approach to evaluating the change of properties of the geosynthetic material used to stabilize the marine landscape slopes

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Abstract. Changes in the properties of geosynthetic materials (geomats) used in coastal protection structures that protect the high coast from erosion, landslide and talus processes are analyzed. The proposed approach includes the selection of a representative set of sampling points for geomats, which takes into account various exposure conditions, conditions for the extraction of groundwater or in dry places, under the direct influence of the wind or in continuous grass cover, and other local operating features. In the process of cameral work with samples of the geomat, taken at the sampling points, it was proposed to assess the degree of degradation of the geomat, used to keep the slope from breaking, by the value of the breaking load of individual polymer filaments, while assessing the degree of microdamage of the material under study. Objective monitoring of microdamage of filaments is carried out by computed X-ray tomography. Using two geomat sampling as an example, the effectiveness of the approach is shown. Regular monitoring of the properties of geosynthetic material will provide an estimate of the residual life of the shore protection structure, a selection of recommendations for its repair and optimization.

1. Introduction

The beaches of the Kaliningrad region (Russia) are subject to pollution by geosynthetic materials used in coastal protection structures [1, 2]. The complex of engineering measures for strengthening the slopes (CESS) in Svetlogorsk is the largest shore protection structure on the coast of the Kaliningrad Region, the construction of which used geosynthetic material. It was built in 2015-2017 and is currently in operation (Figure 1). The area of the fortified surface is 90 thousand m^2 [3]. CESS performs the function of protecting the promenade from erosion, landslide and talus processes.

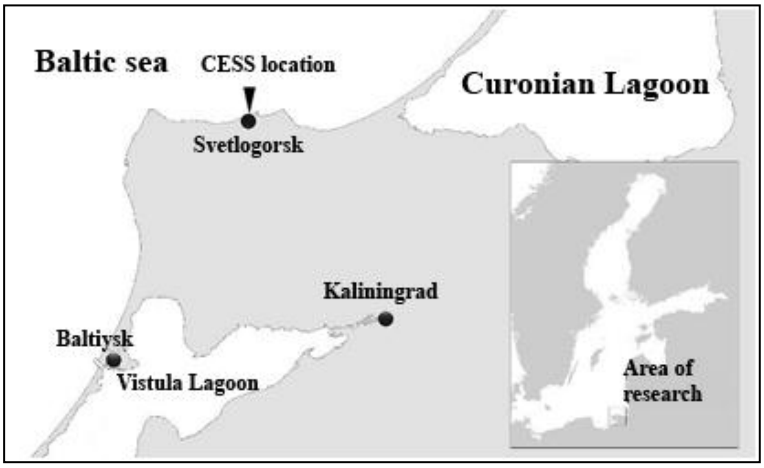


Figure 1. Location of the complex of engineering measures for strengthening the slopes (CESS) in Svetlogorsk

Geomat – a geosynthetic material in contact with air – is the main anti-erosion protection on landslide slopes, where stable slopes have a steepness of 1:1.5-1:2. This material is held by a metal mesh and covers the entire surface of the slope. Slopes with a steepness of more than 1: 1.5 are secured by arranging a reinforced embankment. To protect against erosion in the middle and upper parts of the slope, where the steepness reaches 50°, erosion protection was performed with sowing of perennial grasses, and the slope was retained using self-drilling anchors and a metal mesh.

In general, the slope has a northwestern exposure. For this shore protection structure, various types of geosynthetic materials were used. This is, in fact, the first experiment for the Kaliningrad region, where all artificial (geosynthetic) materials are stacked in such a way that they do not damage, but bypass existing vegetation. Thus, in the process of exploitation and natural environmental conditions, geosynthetic materials are gradually hidden by natural vegetation.

In reality, the geosynthetic material used is in different conditions: under the influence of direct solar radiation; in the shadow; in conditions of draining groundwater or in dry places where even rain moisture is not retained; under the direct influence of the wind or in continuous grass cover.

The aim of the work is to develop an approach to assessing the state of geosynthetic material used in coastal protection structures that protect landslide slopes from erosion, landslide and talus processes.

2. Materials and methods

To determine the degree of degradation of the main material used to hold the landslide slope from destruction – a plastic geomat – in the period 2018-2019, samples were taken of individual parts of the geomat, located in different exposure conditions. Several separate sections of the complex of engineering measures for strengthening the slopes were selected as test sites located east of the main descent to the sea in Svetlogorsk (near the Estrada Theater).

In total, 9 sampling points were determined at which geomaterial samples were taken at different time periods. Five points are located in the upper part of the slope and four points at its foot at heights of approximately 25 and 5 m, respectively (Figure 2).

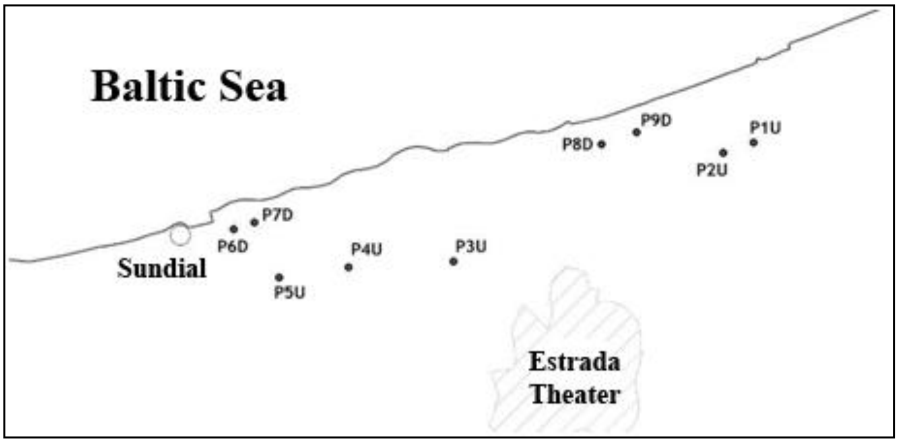


Figure 2. Sampling points for geomats at the complex of engineering measures for strengthening the slopes in Svetlogorsk. For the border of the depicted coastline adopted the outer border of the promenade.

Table 1 provides information on sampling points and operating conditions, including ultraviolet radiation. The point identifier contains a serial number (from 1 to 9), the letter index corresponds to the position of the point (U is the top of the slope, D is the foot of the slope, and the suffix summarizes the operating conditions (Sun - the sample was in an open sunny area, Shd - the sample was in the shady area, Grass - the sample was covered with grass.) Over the entire period of time, 34 samples were taken at all points.

3. Research and experiment

Instron ElectroPuls E1000 is used to conduct studies of the extreme mechanical characteristics of the geomat. A feature of this test machine is the ability to set loading modes in efforts (the value of the load determined by the sensor can control the movements of the actuator so that the specified mode of forces is realized).

Table 1. Sampling points for the geomat used for the complex of engineering measures for strengthening the slopes in Svetlogorsk

Point number	Latitude (degree, N)	Longitude (degree, E)	Description of conditions
P1U_Sun	54.947211	20.161953	The upper part of the slope in the illuminated area, the fragment is not covered with a steel mesh, the sample was taken from the edge, in the sun, not far from the tree, everything is covered with rot
P1U_Sun-Grass	54.947211	20.161953	The upper part of the slope, the fragment is not covered with a steel mesh, the sample was taken from the edge, in the grass, partial shade from the tree
P2U_Sun-Grass	54.947131	20.161564	The upper part of the slope, the fragment is not covered with a steel mesh, the sample was taken at the edge of the slope in the sun
P3U_Shd	54.9463	20.158081	The upper part of the slope, covered with steel mesh, in the shade
P4U_Sun	54.946244	20.156722	The upper part of the slope, the fragment is

			not covered with a steel mesh, the sample was taken from the edge of the slope in the sun
P5U_Shd	54.946162	20.155824	The upper part of the slope, covered with steel mesh, the sample was taken in the shade, with clay and rot.
P6D_Shd	54.946516	20.155227	The lower part of the slope, covered with a steel mesh, the sample was taken in the shade
P7D_Shd	54.946571	20.155495	The lower part of the slope, covered with a steel mesh, the sample was taken in the shade
P8D_Sun	54.947183	20.159987	The lower part of the slope, not covered with a steel mesh, the sample was taken in the sun
P9D_Sun	54.947278	20.160439	The lower part of the slope, covered with a steel mesh, the sample was taken in the sun

Samples were selected and prepared in random order from a geomat taken at two different points of the investigated CESS, characterized by significantly different operating conditions.

Figure 3 shows an example of a geomat sample used before and after the test.

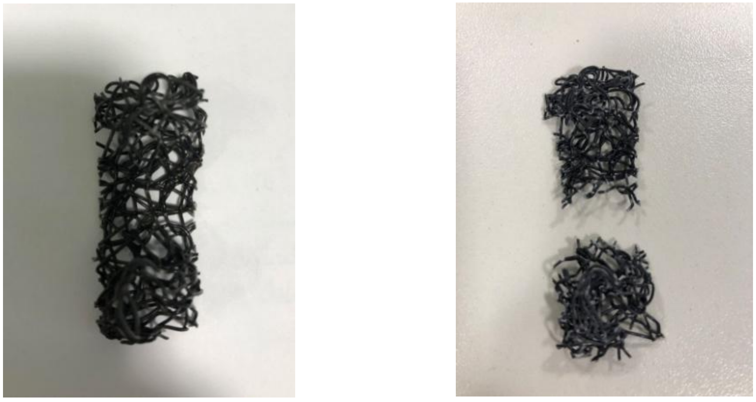


Figure 3. Sample before and after the test.

For each sample, the number of longitudinal filaments, which accounted for the tensile load, was calculated. The tests were carried out until all longitudinal filaments of the test sample were completely broken.

The results showed that the values of the maximum breaking load of the filaments of the considered samples of geomat are significantly different. This indicates a possible difference in the degree of microdamage of the filaments. Objective monitoring of microdamage of the filaments is carried out by computed X-ray tomography.

Using computed tomography, it becomes possible to build a three-dimensional model of the object under study, to obtain any of its sections and projections for further analysis. An YXLON Y.Cheetah high-resolution microfocus X-ray tomograph was used, equipped with an open type 20-160 kV x-ray tube. The characteristics of the tomograph are shown in Table 2.

Table 2. Characteristics of the tomograph.

Max.kV	Max.mA	Max.Tube Power	Max. Target	Min. FOD	Min. Focal Spot	Min. Detail Detectability

			Output			
160	1.0	64W	10W	250 μm	< 2 μm	< 0,5 μm

To process images in real time and improve the contrast of images in shades of gray created in the X-ray system, the contrast setting is used.

Samples of geomat filaments were selected for research arbitrarily from the considered points of selection. Bunches are formed from the selected filaments. Using computed tomography, mathematically reconstructed 3D models of prepared filament samples are obtained. Figure 4 shows a 3D model of the test sample.

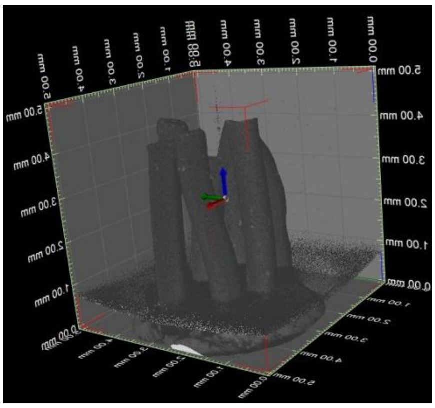
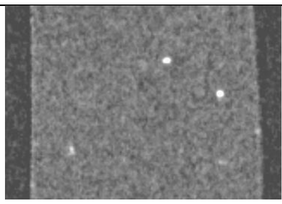
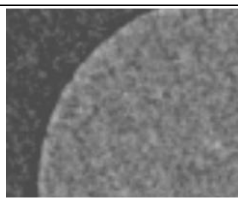


Figure 4. Reconstructed 3D model of the sample.

The presence/absence of micro/macrodamage of the geomat and its heterogeneities (inclusions differing in X-ray density in degree of grayness from the main material of the sample) was investigated. The dark areas of the resulting model correspond to the lowest X-ray density of the material – pores or defects in the limiting case, the brightest – to the most X-ray dense material. The brightest spots in the constructed images of the selected sections indicate the presence of X-ray dense inclusions in different sections of the samples of filaments. Intersections of microdamage of the material with different sections of the studied samples of threads appear in the form of dark lines.

Despite the fact that all samples of the material are now at the research stage, the results are shown for two samples taken at the sampling points P3U_Shd (the upper part of the slope, covered with steel mesh, in the shade) and P8D_Sun (the lower part of the slope, not covered with steel mesh, the sample was taken in the sun). The results of the tests are summarized in Table 3. Fiber strength correlates with the observed bulk density of microdamage.

Table 3. Test results.

Sample	Averaged maximum load per fiber (N)	Examples of characteristic longitudinal sections of individual filaments	Examples of characteristic cross sections of individual filaments	Comments
P3U_Shd	3.3±0.5			Minimum density of observed microdamage

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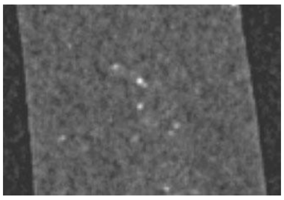
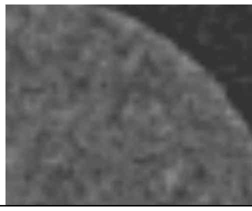
P8D_Sun	1.5±0.5			Maximum density of observed microdamage

4. Conclusion

Using an example of the complex of engineering measures for strengthening the slopes in the city of Svetlogorsk (Kaliningrad Region, Russia), an approach for assessing changes in the state of geosynthetic material used to hold landslide slopes, depending on actual operating conditions, is proposed. The approach is based on a rational choice of sampling points for geomat and objective control of structural and mechanical properties. The kinetics of changes in the properties of the geomat, which is used to stabilize sea slopes, and the determining factors of the studied changes in the characteristics of geomats of different types (corrosion) can be estimated from the results of regular monitoring. The results will form the basis for assessing the residual resource of the complex of engineering measures for strengthening the slopes, the selection of recommendations for its repair and optimization.

5. Acknowledgments

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