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Application of innovative meandrically arranged geotextiles for the protection of drainage ditches in the clay ground

Jan Broda [a,*], Andrzej Gawlowski [a], Ryszard Laszczak [a], Andrzej Mitka [b], Stanislawa Przybylo [a], Joanna Grzybowska-Pietras [a], Monika Rom [a]

[a] *University of Bielsko-Biala, Willowa 2, 43-309 Bielsko-Biala, Poland*
[b] *Eurovia Polska, Miedzyrzecze Gorne 83, 43-392 Bielsko-Biala, Poland*

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A B S T R A C T

The geotextiles produced from meandrically arranged Kemafil ropes were prepared. The ropes were produced from textile waste materials: woollen nonwoven and nonwoven from the blend of recycled fibres. The ropes were arranged into segments which were used for the protection of the bank of the deep drainage ditch and reinforcement of shallow roadside ditch in the clay ground. The geotextiles were installed in the ground and their behaviour during one vegetation season was observed. It was stated that during heavy rains the meandrically arranged ropes form a system of micro-dams which slow down the stream of water flowing down on the surface of the ditch bank as well as the stream flowing along the ditch. The geotextiles installed on the ditch banks eliminate the formation of erosive channels and protect the banks against sliding. The geotextiles absorb water what ensures retention of water flowing along the ditch. Due to enhanced soil and water holding capacity geotextiles protect grass seeds from being washed out and facilitate the development of protective vegetation. Materials used for the production of the ropes reveal sufficient resistance to biological degradation. Slow biodegradation of the materials enable keeping the protective potential of geotextiles for at least one vegetation season.

1. Introduction

Geosynthetics have been used for protection of slopes and embankments for over 50 years (Shukla and Yin, 2006). The first attempts of applying geosynthetics in erosion protection were undertaken in the late 1950s. In 1958 geosynthetic component was incorporated for the first time into an erosion control system (Theisen, 1992). Later, for erosion control, the jute blankets in the form of woven mesh of thick yarns were used (Abdullah, 2008; Ghosh, 2013; Ghosh et al., 2014).

In the following years roll-out mulch blankets from wood fibres and a twisted kraft paper were introduced. The great step which influenced the process of slope, channel and embankments protection, was the introduction of products made from polypropylene and other synthetic materials (Carroll et al., 1992). Synthetic products quickly gained a great popularity and were often used separately or as part of composite materials (Wu and Austin, 1992).

Nowadays geosynthetics play a major role in the erosion and sediment control industry (Pritchard et al., 2000; Rickson, 2006; Bhattacharya et al., 2010; Álvarez-Mozos et al., 2014a, 2014b). Geosynthetics are willingly used because of their light weight and relative low price. Contrary to hydroseeding, mulching or other protective methods applying geosynthetics provide immediate soil protection. Geosynthetics, usually supplied as rolled products, are easily spread on the slopes and – by using various anchoring devices – are easily fixed in place (Allen, 1996). A great variety of materials enables selection of the product most suitable for local conditions.

For erosion protection non-degradable and degradable geosynthetics are used. Once installed, the non-degradable products integrate with vegetation and provide long term protection for a period of at least a dozen years. The assortment of such geosynthetics includes spatial mats and nets from synthetic fibres, steel meshes, modular panels and geogrids. The second group, that is degradable geosynthetics, provides short term protection for 1–3 years, usually in the early stages of the development of protective

* Corresponding author. Institute of Textile Engineering and Polymer Materials, University of Bielsko-Biala, ul. Willowa 2, 43-309 Bielsko-Biala, Poland. Fax: +48 33 8279100.
E-mail address: jbroda@ath.bielsko.pl (J. Broda).

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vegetation, which later takes over the protective function. By progressive decomposition the degradable geosynthetics provide organic matter and nutrients to the soil, which may enhance its microbiological activity and accelerate the growth of protective vegetation. In some cases the degradable geotextiles contain seeds or seedlings. The degradable geosynthetics include anti-erosion mats from straw, paper or wood chips as well as non-woven fabrics made from natural fibres: jute, sisal, cotton, wool and coir (Anand, 2008; Leão et al., 2012; Vishnudas et al., 2006, 2012).

Besides the traditional products used in the practise for many years, new ideas are developed and new innovative products enter the market. In recent years an important research has been performed on using recycled plastics or biodegradable polymers produced from renewable resources (Lin et al., 2014; Trajković et al., 2015).

Some years ago in Poland some attempts to apply innovative geotextiles from recycled textiles were undertaken. The geotextiles designed for erosion control, built from coarse ropes made from textile wastes were obtained. The ropes were successfully used for the protection of sandy roadside slopes as well as banks of an expansion tank (Broda et al., 2015). In the experimental trials the ropes were laid on a slope diagonally to form 60–70 cm sided squares and fastened to the ground with metal anchors. The grid created from the ropes was covered with the soil and sown with grass seeds. After one year of exploitation it was stated that geogrid effectively protects the slope and has a positive effect on plant vegetation. Recently innovative geotextiles from coarse ropes arranged in meander-like pattern connected by additional linking chains have been invented (Helbig et al., 2006a, 2006b) The meandrically arranged geotextiles were successfully used in Germany for the protection of the steep slopes at road construction (Seeger, 2009).

For the production of coarse ropes various techniques can be used. In the above mentioned attempts the Kemafil technology, which was developed in 1974 at the Institute for Industrial Textiles Dresden in Germany, was applied (Berthold and Arnold, 1975). The technology involves the use of a circular knitting machine, which is equipped with four hooked loopers arranged around a guide tube. The threads guided by loopers form around the core tubular knitted sheath. The sheath consists of four stitch courses running parallel to the longitudinal axis of the ropes and the stitch wales running spirally around the rope (Arnold et al., 1993). During the years the Kemafil technology has been modified several times. After the last modifications the technology enables production of thick ropes with a core-mantle structure, which can be filled with various materials and covered by thin fabrics.

In our studies the Kemafil technology was used for the production of coarse ropes from textile waste materials. The ropes were meandrically arranged to form geotextiles designed for erosion control. The suitability of the geotextiles to protect drainage ditches and reduce the effect of water surface erosion of clay soil was evaluated.

2. Materials

The coarse Kemafil ropes with a 12 cm diameter were produced. For the production of ropes the woollen needle-punched nonwoven and stitch-bonded nonwoven from recycled fibres were used. The stitch-bonded nonwoven was produced by Maliwat system from the blend of natural and synthetic fibres. For stitching of the web the polyester multifilament thread with a linear mass density of 148 dtex was applied. To the nonwoven grass seeds were incorporated. The basic parameters of the used materials are presented in Table 1.

The net sheathing the ropes was made from the cotton twine with a diameter of 230 dtex. The number of rows on the length of 1 m of the sheath for woollen nonwoven and nonwoven from recycled fibres was 25 and 28 m^{-1}, respectively (Fig. 1).

The ropes were meandrically arranged in segments of a width of 1.8 m (Fig. 2). The subsequent turns of meandrically arranged ropes were connected with regularly spaced five chains formed from five subsequent loops produced with knitting technique. For the formation of chains the polypropylene three-wire twine from fibrillated fibres with a linear density of the 310 dtex was used.

3. Measuring methods

The basic geometrical and mechanical parameters of the materials used for the production of ropes were determined. The thickness, mass per square metre, tensile strength and elongation at break of nonwovens were measured in accordance with PN-EN ISO 9863–1 (2007), PN-EN ISO 9864 (2007) and PN-EN ISO 10319 (2010) standards. The mechanical parameters were measured in two directions, along and across the nonwovens. In measurements the thickness gauge for geotextiles ZAN/95 and the tensile machine KS50 Hounsfield were used. Additionally, the static and dynamic puncture resistance by CBR and cone drop tests were determined. The measurements were carried out according to PN-EN ISO 12236 (2006) and PN-EN ISO 13433 (2006) standards.

The thickness and mass per square metre were tested before forming the ropes. The measurements of other parameters were performed before installation and after six months of exploitation of the ropes in the soil. Before the measurements the samples were dried and preliminary cleaned from the soil particles and roots protruding from the ropes.

4. Site characteristics

The geotextiles were used experimentally for the protection of drainage ditches located in the area of newly formed investment zone in Miedzyrzecze near Bielsko-Biala (Silesia, Poland). The zone includes a slightly hilly terrain covering the area of 71 ha. The geological expertise of the terrain revealed that the soil has a compact structure and consists mainly of clay. As a result of that compact structure and composition, during dry periods the soil quickly dries and a hard shell is formed on its surface. In rainy seasons only a small amount of water infiltrates into the deeper layers of the soil. Large part of the rainwater remains on the surface and flows down along the slope. The surface water flow becomes merged in a small concentrated stream and begins to erode channels in the soil surface. Moreover, during the long rain or spring thaws the soil is plasticized and an earth flow is observed.

To drain the excess of precipitation flowing down the hills on the surface of the terrain a deep drainage ditch that drains water to the storage reservoir was built (Fig. 3a). The steep banks of the ditch with a slope inclination of 1:1.5 and a length of 4–6 m are exposed to the intense overland flow erosion. As a result, numerous open, unstable and deep erosive channels over 0.5 m deep were constantly created (Fig. 3b).

In order to eliminate the deep erosive channels the banks of the ditch were repeatedly levelled. The performed operations led only to temporary levelling of the slopes. After the next heavy rainfall new deep erosive channels were formed (Fig. 4a). Moreover, the

Table 1
Parameters of nonwovens used for the production of the ropes.

Material	Thickness [mm]	Mass per square metre [g/m^2]
Woollen nonwoven	5.7 ± 0.3	408.0 ± 26
Nonwoven from recycled fibres	2.9 ± 0.1	302.0 ± 9