Application of textile wastes for the production of innovative geotextiles designed for erosion control

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The coarse ropes designed for production of innovative protective geotextiles were obtained. For the production of ropes textile wastes were used. The ropes made from different materials were buried in the soil for six months. The mechanical parameters of materials forming the sheath and cover of the ropes before and after ground disposal were measured and morphology of the ropes were analysed. It was revealed that jute fabrics used as rope covers as well as sisal and cotton twine used for the formation of outer sheath degrade quickly. Cellulosic materials do not ensure the mechanical integrity of the ropes after ground disposal and are not suitable for the production thereof. On contrary, the wool nonwoven and nonwoven produced from recycled fibres biodegrade much slower. Despite of the degradation of outer sheath the ropes keep their integrity and may maintain their protective function in the ground for several months.
Key words: *geotextiles, erosion protection, Kemafil rope, textile waste, biodegradation*

1. Introduction

Production and use of textiles and clothing generate a significant amount of textile wastes, which are the cause of serious environmental problems.

Textile waste can be classified into two distinct categories: industrial and post-consumer waste. The industrial waste includes fibres, yarns and fabrics generated during textile and clothing production (textile waste cuttings). This category of waste is routinely recycled back into the manufacturing process. The post-consumer waste usually consists of clothing discarded by consumers due to damage, being worn out or simply out of fashion. This category can be re-used, recycled, incinerated or disposed in landfills.

Recycling of textiles includes open- and closed-loop recycling. Closed-loop recycling refers to manufacturing of products that are of similar commercial value to the original product. On contrary, open-loop recycling refers to using recycled fibres for the production of other products that have a lower commercial value. Both methods effectively extend the active life of constituent fibres, potentially for many years beyond the first use phase [1].

As for wool waste open-loop mechanical recycling is the most common and is often used for the production of nonwoven fabrics. The latter are obtained by means of garneting, carding or airlaying of webs followed by mechanical, thermal or chemical

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bonding. In this way thermal and acoustic insulating materials for automotive or construction industry are produced.

Other idea for utilization of wool textile wastes consists in the production of geotextiles designed for erosion control. Woollen geotextiles which are installed in the ground ensure good soil protection and favourable microclimat for seeds germination. Additionally, progressive decomposition of such geotextiles provides organic matter and nutrients to the soil, which may enhance its microbiological activity and accelerate the growth of protective vegetation.

Some years ago innovative geotextiles from thick ropes arranged in meander-like pattern connected by additional linking threads were invented (Fig.1) [2].

The meandrically arranged geotextiles were successfully used for the protection of steep slopes at road construction [3]. It was revealed that geotextiles absorb rain water and function like a water storage system. Ropes create a network of microdams which block the flow of water along the slope and reduce the transport of material detached from the soil by raindrops. Due to enhanced soil and water holding capacity, ropes promote plant growth.

For the production of ropes the Kemafil technology can be used [4]. The technology was developed in Germany few decades ago and is still used for manufacturing products for various purposes. Over many years the technology has been modified several times. After the last modification it enables production of thick ropes with a core – a mantle-like structure, which can be filled with various materials, covered by thin fabrics and wrapped by knitted sheath (Fig.2).

Ropes designed for erosion control can be produced from various materials easily accessible at the local market. So far coarse ropes filled with straw, hay and waste wool were obtained. For the production of ropes the textile wastes can be used as well. The nonwovens produced from recycled fibres can be used to form the cover of the ropes, while the shredded textile wastes can serve as a filling for the core.

The geotextiles produced from natural fibres, which are installed on a slope and covered by soil, biodegrade progressively. As a result, the mechanical parameters of the ropes gradually decrease. Due to the biodegradation of ropes their ability to fulfill the protective function is reduced and time-limited. The time must be sufficient for establishing natural vegetation, which takes over the protective function.

In our investigations the Kemafil ropes filled with wool and shredded textile waste were produced. The ropes were covered with different fabrics and entwined with various twines. The ropes were then buried in the ground. The morphology and mechanical properties of the materials used for the production of ropes before and after ground disposal were examined and the influence of biodegradation was analysed. On the basis of the obtained results the usefulness of the materials for the production of ropes was analysed.

2. Experimental

2.2. Material

Ropes with a thickness of 12 cm were produced. The ropes were filled with wool fibres, cutting waste from woollen nonwoven and shredded textile waste (Fig.3).

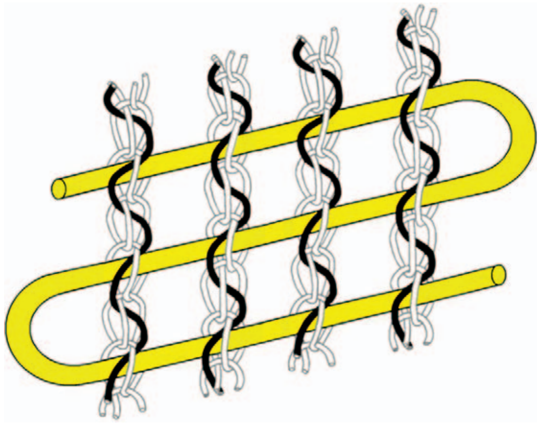

Fig.1 The structure of innovative geotextiles

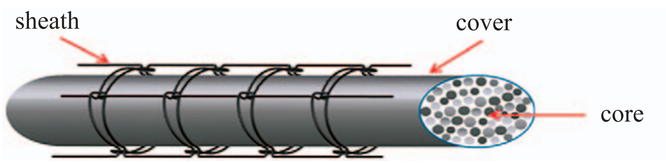

Fig.2 The structure of Kemafil rope

a) b) c)

Fig.3 Materials used for filling of the ropes: a) wool; b) waste - woollen nonwovens; c) shredded textile waste

To form the knitted sheath sisal and cotton twine were applied. Net and woven jute fabric, woollen needle punched nonwovens and nonwoven from recycled fibres were used as the cover of ropes. The basic parameters of the materials are presented in Table 1.

The ropes were buried in the neutral local ground (pH 7.2) in the autumn at the end of the vegetation season and were kept in the ground for six months (Fig.4). At the beginning of ground disposal an average daily air temperature was about 10 °C. Then, for several frosty days during the third and fourth month the temperature droped below 0 °C. Later the temperature rose again to more than 0 °C. During few weeks the ground was covered with snow.

2.2. Methods

The ropes before and after 6 months of ground disposal were visually examined. Then the basic geometrical and mechanical parameters of the materials used for the production of ropes were determined. The linear density, tenacity and elongation at break of twines were measured in accordance with standards PN-P-04653:1997 and PN-EN ISO 2062:1997. The thickness, mass per square meter, tensile strength and elongation at break of fabrics were determined in accordance with standards PN-EN ISO 9863-1:2007, PN-EN ISO 9864:2007 and PN- EN ISO 10319:2010. The mechanical parameters were measured in warp and weft direction. In measurements the thickness gauge for geotextiles ZAN/95 and the tensile machine KS50 Hounsfield equipped with a wide handles to samples with a width of 0.2 m were used.

Additionally, basic parameters used to characterize geotextiles, the static and dynamic puncture resistance were determined. The measurements were carried out according to PN-EN ISO 12236:2006 and PN-EN ISO 13433:2006 standards.

Tab.1 Parameters of fabrics used for the production of the ropes

Material	Thickness [mm]	Mass per square meter [g/m^2]
jute fabric	1.1 ± 0.02	287.0 ± 4
jute net	1.1 ± 0.04	105.0 ± 3
woollen nonwoven	5.8 ± 0.2	406.0 ± 15
nonwoven from recycled fibres	3.0 ± 0.4	265.0 ± 10

a) b)

Fig.4 Rope samples: a) before ground disposal; b) after 6 months

a) b)

Fig.5 Rope samples after ground disposal covered by: a) jute net and fabric; b) woollen and recycled fibres nonwovens

3. Results

Figure 5 presents the photographs of ropes after six months of ground disposal. After disposal the ropes covered by jute net and jute woven fabric are strongly damaged (Fig. 5a). The jute net as well as the jute woven fabric forming the cover of the ropes are totally disrupted in many places. Similar to the jute cover, sisal and cotton twines forming the sheath of the ropes are significantly degraded. The sheath, which should ensure the mechanical strength of the ropes is partly torn.

After 6 months of ground disposal the twines forming the sheath and the fabrics forming the cover already do not provide the mechanical cohesion of the ropes. The wastes constituting the core protrude from the ropes. The ropes can be easily torn and completely disintegrated by just a light mechanical impact.

Contrary to the ropes covered by jute fabrics the ropes wrapped by woollen nonwoven as well as nonwoven produced from recycled fibres exhibit good cohesion (Fig.5b). Despite the destruction of the outer sheath made from cotton or sisal twine the ropes maintain their mechanical integrity. The cover still quite well protects the core of the ropes.

Tab.2 presents the mechanical parameters of sisal and cotton twines determined before and after ground disposal. After 6 months of ground disposal the cotton twine degraded and it was impossible to determine their mechanical parameters. As for the sisal twine, a rapid decrease in strength was observed. Due to sisal degradation the tenacity of the twine decreased by more than 90 %. In the same time the elongation at break increased by 40 %.

Tab.3 presents the mechanical parameters of fabrics forming the cover of the ropes determined before and after ground disposal. The jute net torn apart in hands and the determination of its mechanical parameters after ground disposal was not possible. For jute fabric the tenacity drastically decreased by 98 %. For other materials the change of the tenacity was much lower. For wool nonwoven the tenacity along and across the material decreased by 51 % and 66 %, respectively. For nonwoven from recycled fibres the tenacity measured along the fabric decreased by 20 %. Simultaneously, the tenacity across the fabric increased by 55 %.

For jute fabrics after ground disposal the elongation at break increased. For both nonwovens the elongation at break in warp direction increased, while in weft direction minimally decreased. The increase of the elongation is connected with fibres degradation.

Tab.4 presents the values of the static and dynamic puncture resistance of fabrics. Again, because of the great progress of biodegradation the parameters for the jute net were determined only before ground disposal. As for

Tab.2 Mechanical parameters of twines used to form the rope sheath before and after ground disposal

Twine	Linear density [tex]	Tenacity [cN/tex]		Elongation at break [%]	
		before	after	before	after
Cotton	2328 ± 10	32.0 ± 0.3	-	14.5 ± 0.3	-
Sisal	3173 ± 13	13.1 ± 0.5	0.85 ± 0.5	4.4 ± 0.2	6.2 ± 0.2

Tab.3 Mechanical parameters of fabrics used to form the cover of the ropes before and after ground disposal

Material		Tenacity [kN/m]		Elongation at break [%]	
		before	after	before	after
jute fabric	warp	15.0 ± 0.1	0.3 ± 0.1	4.2 ± 0.6	8.0 ± 0.6
	weft	18.8 ± 0.4	0.32 ± 0.1	4.0 ± 0.4	7.0 ± 0.6
jute net	along	3.0 ± 0.1	-	4.7 ± 1	-
	across	2.8 ± 0.1	-	4.0 ± 0.1	-
woollen nonwoven	along	0.7 ± 0.1	0.34 ± 0.1	29.0 ± 3	39.0 ± 3
	across	1.9 ± 0.1	0.64 ± 0.1	56.0 ± 3	55.0 ± 3
nonwoven from recycled fibres	along	3.3 ± 0.1	2.6 ± 0.1	29.0 ± 4	31.0 ± 3
	across	0.9 ± 0.1	1.4 ± 0.1	34.0 ± 2	32.0 ± 14

Tab.4 Static and dynamic puncture resistance of fabrics used to form the cover of the ropes before and after ground disposal

Material	Static puncture resistance [kN]		Dynamic puncture resistance [mm]	
	before	after	before	after
jute fabric	1.11 ± 0.1	0.05 ± 0.02	19.6 ± 0.5	28.0 ± 0.5
jute net	0.32 ± 0.1	-	46.0 ± 0.5	-
woollen nonwoven	0.15 ± 0.1	0.02 ± 0.1	20.0 ± 0.5	28.0 ± 0.5
nonwoven from recycled fibres	0.41 ± 0.1	0.26 ± 0.1	31.0 ± 0.5	35.0 ± 0.5

other materials, after ground disposal the decrease of static puncture resistance and the increase of the dynamic puncture resistance were observed. The smallest change of both parameters, by 36 % for the static and by 13 % for dynamic puncture resistance, was registered for the nonwoven made from recycled fibres. For woollen nonwoven the change of both parameters is comparable with the change observed for the jute fabric. For both materials the static puncture resistance dropped drastically (by ca. 90 %) to very low value.

The decrease of the static puncture resistance is connected with the weakening of the materials caused by biodegradation. The increase of the dynamic puncture resistance is probably connected with clogging of textiles with soil particles.

4. Conclusions

During the ground disposal of the ropes biodegradation of the materials took place. Despite low temperatures and winter season biodegradation of jute occurred quickly, already after half year of the disposal. Similarly, during this period decomposition of sisal and cotton twines was observed. The biodegradation led to the significant decrease of the mechanical parameters of the materials or even their total destruction. Jute, sisal and cotton were chosen for the production of ropes because of their sufficient strength, good dimension stability, high moisture absorption capacity as well as low cost, availability and biodegradability. From the perspective of the production of geotextiles designed for erosion control the time of biodegradation for this materials is too short. It does not ensure the mechanical stability of the ropes and it is not sufficient for the development of vegetation which should take over the protective function of the geotextiles.

For wool nonwoven and nonwoven made from recycled fibres biodegradation occurs much slower. The decrease of the materials tenacity was much smaller, what ensured the ropes integrity after six months of the ground disposal. Contrary to the ropes made from cellulosic materials, they maintain their protective function much longer, what should be sufficient for establishing protective vegetation on the slope.

Acknowledgments

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