Assessment of the temperature influence on the tensile strength and elongation of woven geotextiles used in landfill

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ABSTRACT: The use of geosynthetics in soil reinforcement applications requires the selection of a synthetic materials which take into account the tensile strength necessary for the planned effect of strengthening the ground and strain appropriate to the expected degree of subsidence. The paper presents the research's methodology and results of analyses obtained from laboratory tests of tensile strength of the samples of woven geotextiles used for soil reinforcement in the forming solid waste landfill located in Warsaw, the capital city of Poland. Because of adapting the old municipal landfill into a winter sport complex, the slopes of the structure required major reinforcements. What is important geosynthetics in the landfill can be exposed to elevated temperatures, so the aim of the research was to determine tensile strength and elongation at temperatures from 20°C to 80°C. The results obtained allowed verification of the effectiveness of applied materials and assessment of its parameters. Also research results derived from information provided by the manufacturer data were compared. Obtained divergent values between test results and manufacturer characteristics should be considered in construction designing.

Keywords: woven geotextile, reinforcement, tensile strength, landfill

1 INTRODUCTION

Geosynthetics have found wide application in the design and construction of landfills. This application has been triggered by the economic and technical advantages that geosynthetics can offer in relation to more traditional materials (Koerner 1999; Bouazza et al. 2002). The service life of a structure with a geosynthetic material largely depends on its durability over time (Greenwood et al. 2012).

Woven geotextiles are widely applied in environmental structures, where various factors, such as high temperatures, changes in a wide range of pH values and mechanical stress may affect their durability and consequently their useful lifetime (Koda et al. 1993; Mathur et al. 1994; Castro et al. 2014; Koda et al. 2016; Kiersnowska et al. 2017).

Even in a relatively inert environment, synthetic materials deteriorate over time when exposed to mechanical stress. However, given the conditions prevailing at waste landfills, the geosynthetics are exposure to the hazardous substances. Thus it is important to assess the long-term performance and deduce service life of the woven geotextiles for exposure conditions.

The temperature has effects on physical and mechanical woven geotextiles, including tensile strength (Karademir and Frost 2014). It is very important in the landfill, where temperature may exceed 70°C (Yoshida and Rowe 2003). However, the average temperature varies depending on location and season. The temperature and strain rate effect on tensile strength need comprehensive investigation. The selection of reinforcement material is not simple. The knowledge of the environment are very important here, as well as laboratory tests carried out taking into account the functions that the material in the structure (Chiwan and Yen-Chen 2008; Lejcuś et. al. 2015; Miszkowska et al. 2015; Stępień and Szymański, 2015).

2 MATERIALS AND METHOD

2.1 *Materials*

In this study one type of polypropylene woven geotextile taken from the reinforced embankments at the Radiowo landfill were employed.

In the future the landfill site is planned to be used as a ski slope, so one of the main challenges of reclamation works of the landfill was to improve the stability conditions. For that reason in the west side of the landfill, a masonry retaining wall with backfill reinforced by tested geotextiles has been constructed (Figure 1). Table 1 summarizes the main properties of the applied woven geosynthetics.

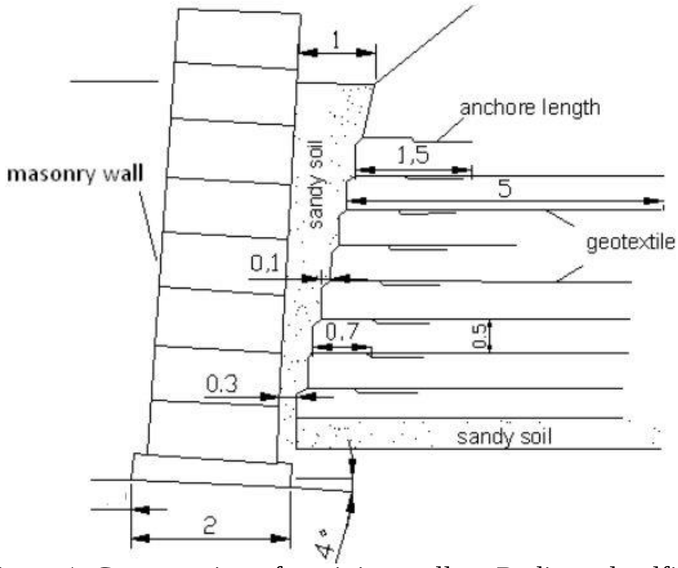

Figure 1. Cross section of retaining wall on Radiowo landfill.

Table 1. Specification manufacturer of the tested woven geotextile.

Parameter	Unit	Value
Mass per unit area (ISO 9864:2007)	kg/m^2	0.1±10%
Tensile strength along the fiber (ISO 10319:2015)	kN/m	≥23
Tensile strength cross the fiber (ISO 10319:2015)	kN/m	≥20
Tensile strain at rupture lengthwise (ISO 10319:2015)	%	18±4%
Tensile strain at rupture crosswise (ISO 10319:2015)	%	13±3%
Water permeability normal to the plane (ISO 11058:2010)	m/s	0.017±0.002
Characteristic Opening Size O_{90} (ISO 12956:2010)	mm	0.12±0.05

2.2 *Equipment and methodology used in the test*

The experimental work consisted in determining tensile strength T_{max} and strain ε_{max} at maximum tensile load at temperatures 20, 50 and 80°C ± 2°C to check and confirm the effect of the temperature on mechanical parameters of woven geotextile. The experiment tests was conducted according to ISO 10319:2015.

Figure 1 presents the laboratory equipment, located in the Laboratory Water Center at the Warsaw University of Life Sciences. The tensile testing machine includes: 1 – video extensometer, 2 – load frame, 3 – mechanical jaws, 4 – climatic chamber, 5 – tensile testing and climatic chamber driver, 6 – computer recording system and 7 – cylinder with liquid nitrogen.

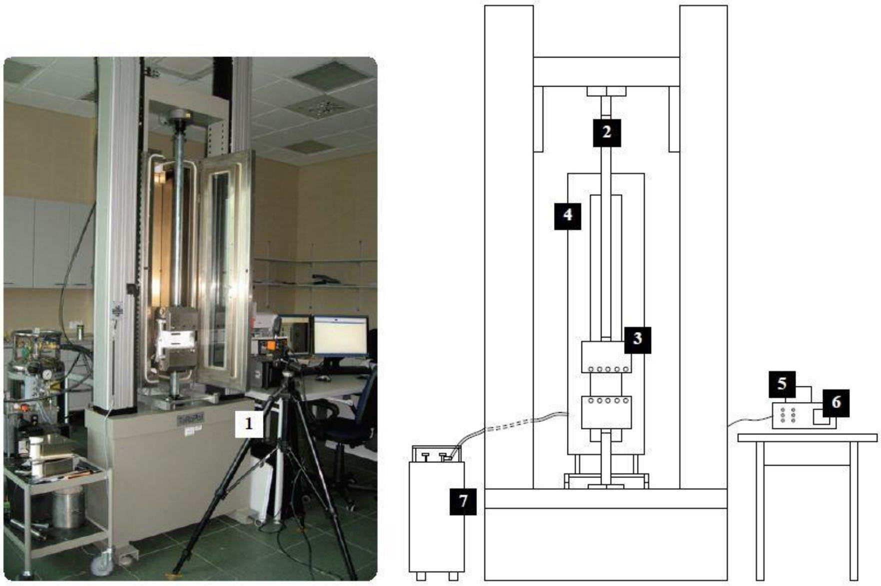

Figure 1. Laboratory equipment used for wide-width tensile test (Stepień and Szymański 2015).

The samples of 200 mm in width and 100 mm in length were prepared. The tested sample was mounted across the width of the mechanical jaws, which operate at constant strain rate of 20% per minute until the material was broken. Video extensometer was used to measure the change of the length of the tested material because this device followed the movement of the two references points that were marked on the sample axis of symmetry and spaced by 60 mm. Temperature inside the chamber, strain and tensile load were recorded using an automatic data acquisition system. To prepare statistical analyzes it was recommended to test minimum 5 samples in each temperature. Tests were conducted in the machine direction (MD) of woven geotextile samples.

The tensile strength T_{max} [kN/m] was calculated using the following expressions:

$$T_{max} = F_{max} c \tag{1}$$

Where: F_{max} = maximum tensile force [kN], $c = 1/B$ for woven geotextile (B is the nominal width of the specimen [m])

3 RESULTS

The obtained results confirm a reduction of tensile strength and increasing of strain as the temperature rises (Figure 2 and Table 2). It is very important observation especially in landfill, where temperature may exceed 70℃ (Yoshida and Rowe 2003).

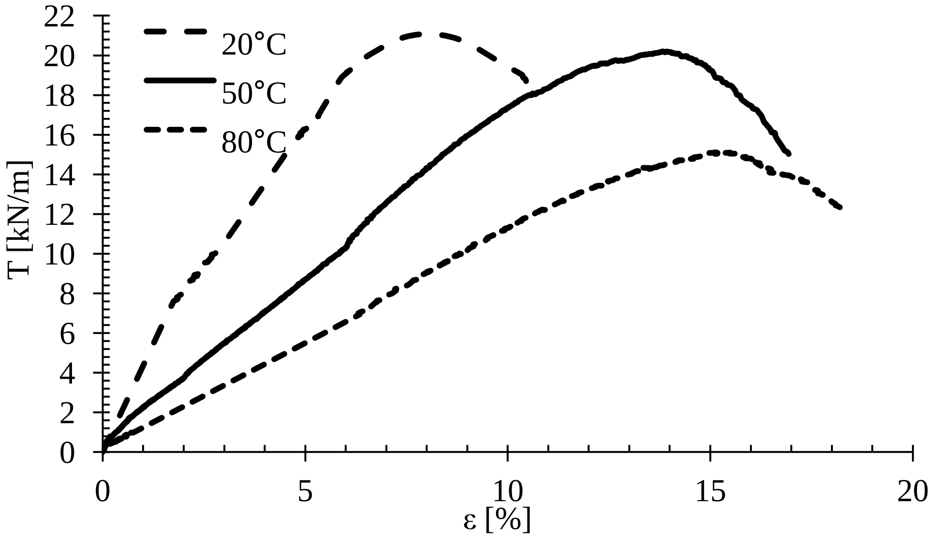

Figure 2. Relationship between load per unit and strain for tested woven geotextile samples from 20℃ to 80℃ (typical curves)

Table 2. Laboratory test results for tested woven geotextile samples at temperatures 20, 50 and 80℃.

No*	20°C		50°C		80°C	
	T_{max} [kN/m]	ε_{max} [%]	T_{max} [kN/m]	ε_{max} [%]	T_{max} [kN/m]	ε_{max} [%]
1	21.54	7.04	20.20	13.84	16.57	15.62
2	20.95	7.50	20.01	12.92	15.10	15.50
3	20.50	8.57	19.56	11.73	14.74	16.36
4	20.50	7.51	21.46	11.77	15.46	19.42
5	20.71	8.07	20.95	11.45	14.22	15.98
$\bar{x}$	20.84	7.74	20.43	12.34	15.22	16.57
s	0.43	0.59	0.76	1.01	0.88	1.62

*$\bar{x}$ – mean, s – standard deviation.

The smallest tensile strength was determined at 14.22 kN/m and the biggest at 21.54 kN/m at 80℃ and 20℃, respectively. So the tensile strength decreased even by 34%. What was interesting, at 50℃ values of tensile strength were similar to values obtained at 20℃. The mean value of tensile strength was only 0.41 kN/m lower in that case.

However, with increasing temperature, the increase of strain was observed in each temperature. The smallest strain at maximum load was determined at 7.04% at 20℃ and the biggest at 19.42% at 80℃. What is more, there is a linear relationship between strain at maximum load and increasing temperature (Figure 3) unlike relationship between tensile strength and temperature (Figure 4).

In comparison to manufacturer data (Table 1), the mean value of tensile strength at 20℃ decrease by 9.4% (2.16 kN/m).

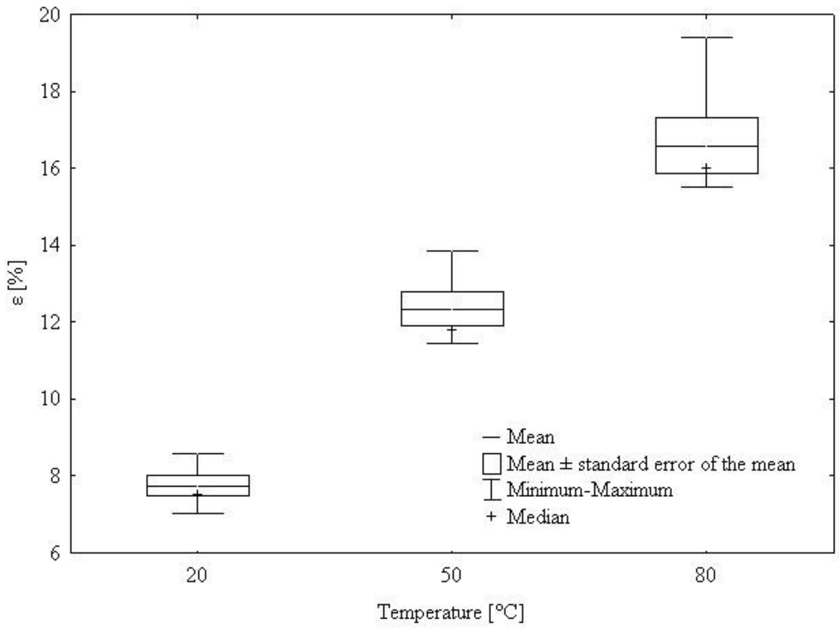

Figure 3. Statistical strain characteristics for tested woven geotextile samples from 20℃ to 80℃

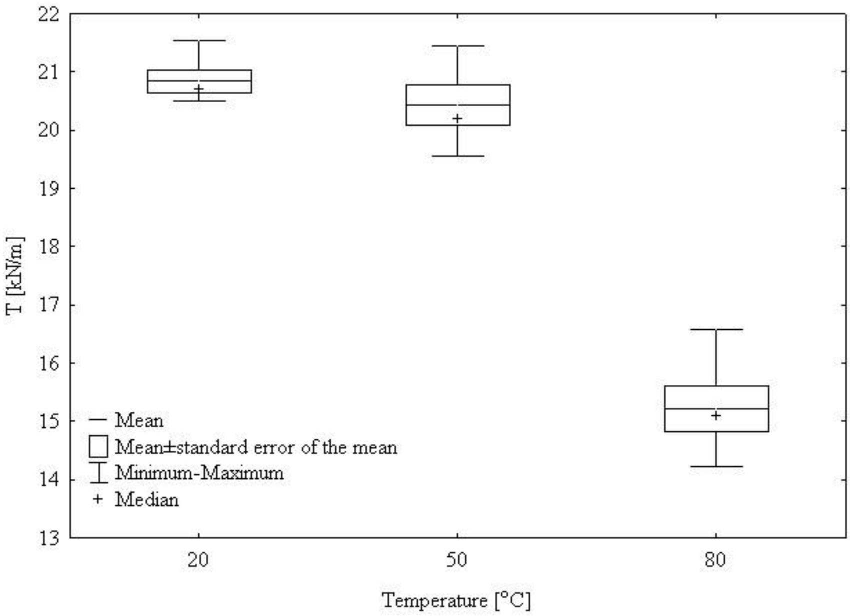

Figure 4. Statistical tensile strength characteristics for tested woven geotextile samples from 20℃ to 80℃

4 CONCLUSION

The average ground temperatures vary from location to location and season to season. The effect of increase of deformation is important for the design of reinforcement in landfills, where temperatures reach 70℃. The choice of woven geotextiles for engineering constructions should be made taking the reduction of strength due to temperature and strain rate. Therefore, the effect of temperature on the tensile behavior of woven geotextile was discussed in the paper. A series of tensile tests was conducted for the test woven geotextile at different temperatures. The test temperatures varied from 20℃ to 80℃. The research of the tensile strength using a wide-width strip geotextile has shown that a decrease in tensile strength was about 34% and an increase of the strain was 19.42% in the longitudinal direction. According to the standard ISO 10319:2015 sample should be extended at a constant strain rate. That geosynthetic works in different stretching conditions and higher temperatures, which reduces the strength and increase deformability of these materials substantially. Choice of materials for the layers of geosynthetic reinforcement is very important to ensure the efficient operation and durability of the structure.

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