Influence of abrasion on the tensile behaviour of reinforced geotextiles

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ABSTRACT: This paper deals with the influence of abrasion on the tensile behavior of reinforced geotextiles. Two polypropylene (PP) nonwoven spunbonded geotextiles reinforced unidirectionally with polyester (PET) filaments, with different tensile resistance, were submitted to abrasion according EN ISO 13427: 1998 (abrasion damage simulation (sliding block test)) in machine and cross machine directions. Abrasion was induced on both lateral surfaces of the geotextiles. Tensile properties of undamaged and damaged geotextiles were defined according EN ISO 10319: 2008 (geosynthetics – wide width tensile tests).
The results of the study showed that abrasion damage in cross machine direction, on both lateral surfaces, is not significant. However, in machine direction the abrasion damage is important, especially on lateral surfaces with PET filaments reinforcements where its relevance increase with the tensile properties of undamaged materials. In fact, both reinforced geotextiles show similar tensile properties after abrasion.

1 INTRODUCTION

Two types of abrasion can be considered: a) due to installation damage (Allen and Bathurst, 1994; Bräu, 1998); b) time-dependent abrasion during the materials' service lifetime (Shukla, 2012). In this paper the second type of abrasion will be considered, this is, that resulting from cyclic relative motion (friction) between geosynthetic and contact material during service. Time-dependent abrasion is particularly relevant for geosynthetics in railway applications, temporary roads, canals revetments, sea shores with sediments and sliding masses washing up and down (Watn and Chew, 2002).

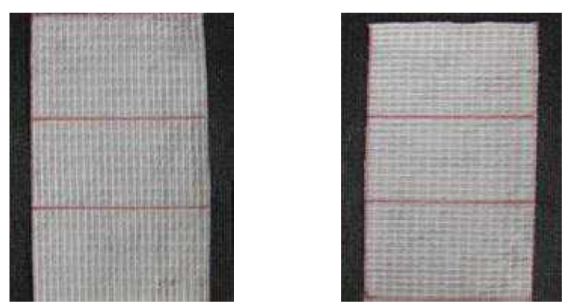
Some studies on abrasion of geosynthetics have been performed, in particular for railway applications (Van Dine *et al*., 1982; Hausmann *et al*., 1990). Van Dine *et al*. (1982) reported abrasion severity on woven and non woven geotextiles with mass per unit area in the range of 137 and 730 g/m^2. Hausmann *et al*., 1990 concluded that the loss of tensile strength seems to be associated to the mass per unit area of the geosynthetic and to the volume of traffic.

Lopes and Pinho-Lopes (2010) and Rosete *et al*. (2013) reported the synergetic effect of two important durability factors for geosynthetics: installation damage and abrasion.

This paper aims to contribute to understanding abrasion durability of reinforced geotextiles by studying abrasion effects on the mechanical properties of two geosynthetics using laboratory tests.

2 GEOSYNTHETICS

The materials studied were two non woven reinforced geotextiles (RG) consisting of continuous mechanically bonded polypropylene (PP) filaments reinforced uniaxially with polyester (PET) filaments (Figure 1). The nominal values of peak tensile strength (T_{max}) and extension at break (ε_f) at machine direction (MD) were for RG1 58 kN/m and 10%, and for RG2 100 kN/m and 10%.



a) b)

Figure 1. Reinforced geotextile: a) machine direction (MD); b) cross machine direction (CMD).

3 LABORATORY TESTS

The test program consisted of performing laboratory tests on geosynthetic samples to simulate abrasion damage. To characterize the undamaged and damaged samples wide-width tensile tests were performed according EN ISO 10319: 2008.

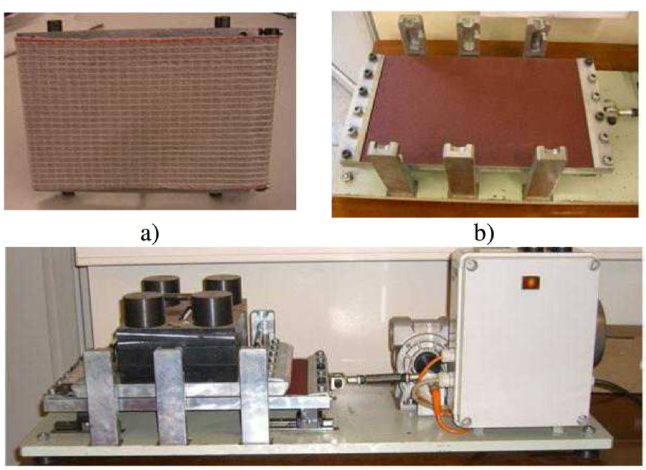
As reinforced geotextiles have different lateral surfaces (one reinforced with PET filaments and the other without PET filaments) the abrasion damage was analyzed in both lateral surfaces. The abrasion damage on the reinforced lateral surface will be studied in both directions: machine direction (MD) and cross machine direction (CMD). Table 1 summarizes the test program implemented.

Table 1. Test program implemented.

Geosynthetic	Lateral surface	Direction	Undamaged	Abrasion damage
RG1	rPET	MD	X	X
		CMD	X	X
	unPET	MD	X	X
		CMD	X	X
RG2	rPET	MD	X	X
		CMD	X	X
	unPET	MD	X	X
		CMD	X	X

rPET - lateral surface reinforced with PET filaments
unPET - lateral surface without PET filaments

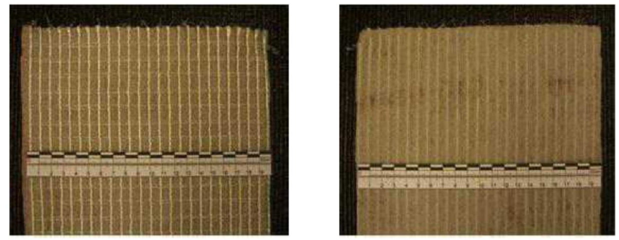
For abrasion damage simulation the procedures described in EN ISO 13427: 1998 were used. The test consists of placing a geosynthetic specimen on the upper plate of the stationary platform (Figure 2a) where it is rubbed by a P100 abrasive. The abrasive is placed on the lower plate (Figure 2b) and moved along a horizontal axis under controlled pressure (Figure 2c).



a) b) c)

Figure 2. Abrasion damage simulation: a) geosynthetic placed on the upper plate; b) abrasive placed on the lower plate; c) general view of the equipment.

It must be noted that all the reinforced geotextiles specimens were cut with the same number of PET filaments independent the lateral surface submitted to abrasion damage (Figure 3).



a) b)

Figure 3. Reinforced geotextile specimens: a) lateral surface reinforced with PET filaments; b) lateral surface without PET filaments.

As referred the tensile tests were carried out using the procedures described in EN ISO 10319:2008 and the strains were measured with a video-extensometer.

4 RESULTS AND DISCUSSION

4.1 *Undamaged Geosynthetics*

Figures 4 and 5 show the tensile force - extension curves for the 5 specimens tested in MD and CMD directions, as well as the mean curve of the undamaged reinforced geocomposites RG1 and RG2, respectively.

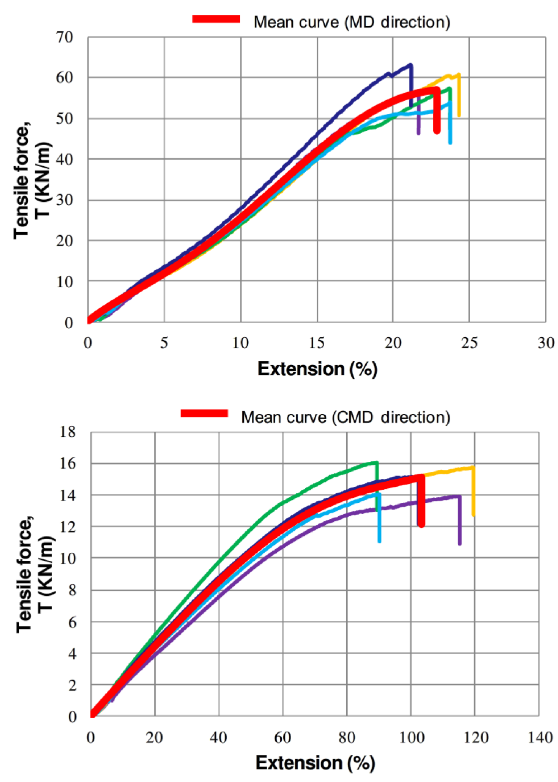


Figure 4. RG1 (undamaged) – Tensile force-extension curves.

Table 2 includes the mean values of tensile tests: peak tensile strength ($\mathbf{T}_{max}^{un}$) and extension at break (ε_f^{un}). Nominal values for the same parameters are also presented in Table 2.

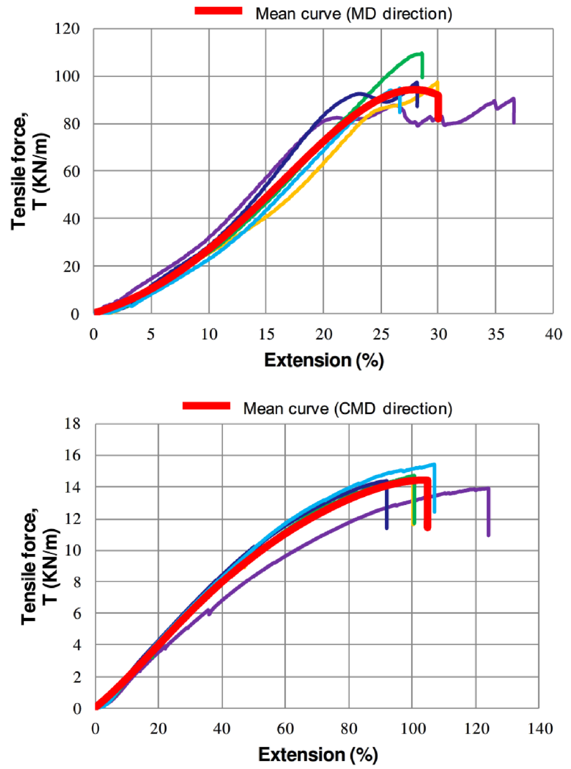


Figure 5. RG2 (undamaged) – Tensile force-extension curves.

Table 2. Undamaged geosynthetics: peak tensile strength and extension at break.

Geosynthetic	Direction	Mean values		Nominal values	
		T_{max}^{un} (kN/m)	ε_f^{un} (%)	T_{max} (kN/m)	ε_f (%)
RG1	MD	58	23	58	10
	CMD	15	103	12	85
RG2	MD	99	20	100	10
	CMD	15	105	12	95

The mean values of the maximum tensile strength achieved in the tensile tests are very close to the nominal ones. However, mean values of extension at break are higher than the nominal ones. The difference is more significant in machine direction (MD).

In this study, the influence of abrasion on the tensile behavior of reinforced geotextiles will consider the mean values of tensile tests.

4.2 *Damaged Geosynthetics*

4.2.1 *Lateral surface reinforced with PET filaments*

Table 3 presents the mean values of peak tensile strength (T_{max}^{dam}) and of extension at break (ε_f^{dam}) of the reinforced geotextiles damaged by abrasion on the lateral surface reinforced with PET filaments. Residual values of the maximum tensile strength and extension at break are also shown in Table 3.

Table 3. Damaged geosynthetics on the lateral surface reinforced with PET filaments: peak tensile strength, extension at break, residual peak tensile strength and residual extension at break.

Geosynthetic	Direction	Mean values		Residual values	
		T_{max}^{dam} (kN/m)	ε_f^{dam} (%)	T_R (%)	ε_R (%)
RG1	MD	21	17	36,2	74
	CMD	15	112	100	108,7
RG2	MD	23	15	23,2	75
	CMD	16	108	106,7	102,9

$$T_R = \frac{T_{max}^{dam}}{T_{max}^{un}} \; x \; 100\% \qquad (1)$$

$$\varepsilon_R = \frac{\varepsilon_f^{dam}}{\varepsilon_f^{un}} \; x \; 100\% \qquad (2)$$

It must be noted that the effect of abrasion in cross machine direction (CMD) of both reinforced geotextiles is negligible in terms of peak tensile strength and extension at break. However, if abrasion is induced in machine direction (MD) the maximum tensile strength reduces significantly (about 64% and 77% for RG1 and RG2, respectively). For both reinforced geotextiles the reduction on extension at break is about 25%.

As the geotextiles are uniaxially reinforced the PET filaments (reinforcing filaments) are placed in the machine direction. The abrasion on this direction danifies the reinforcing filaments compromising their reinforcement function.

Figures 6 and 7 show specimens of the reinforced geotextile RG1 before and after abrasion in machine direction (MD) and cross machine direction (CMD), respectively.

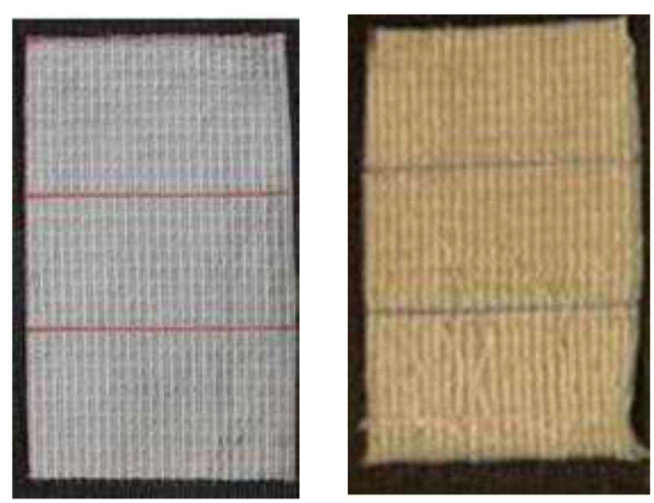


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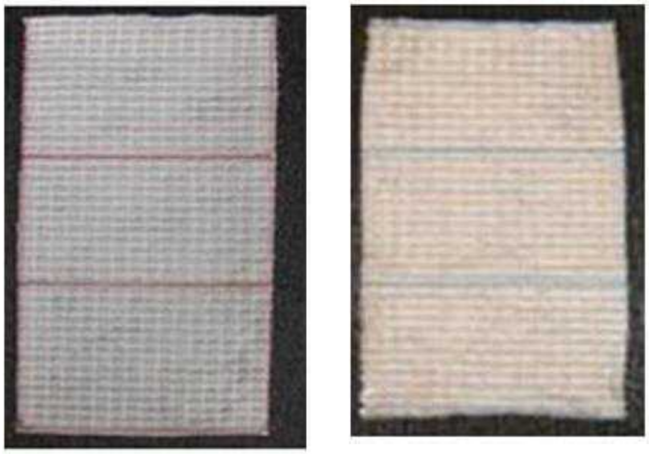
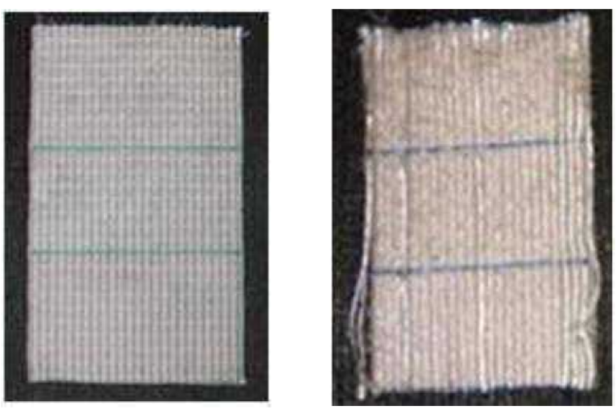
Figure 6. Reinforced geotextile RG1: a) undamaged MD; b) abrasion damaged MD.



a) b)

Figure 7. Reinforced geotextile RG1: a) undamaged CMD; b) abrasion damaged CMD.

Figure 8 shows specimens of RG2 before and after abrasion in machine direction (MD).



a) b)

Figure 8. Reinforced geotextile RG2: a) undamaged MD; b) abrasion damaged MD.

It is observed that the PET filaments reinforcement is highly damaged by abrasion on machine direction in both reinforced geotextiles.

When the direction of abrasion is cross machine the visual damaged effects on the geosynthetics is negligible.

4.2.2 *Lateral surface without PET filaments*

Table 4 presents the mean values of peak tensile strength (T_{max}^{dam}) and of extension at break (ε_f^{dam}) of the reinforced geotextiles damaged by abrasion on the lateral surface without PET filaments. Residual maximum tensile strength and residual extension at break are also shown in Table 4.

Similarly to what happens for the lateral surface reinforced with PET filaments in cross machine direction (CMD), the effect of abrasion on the lateral surface without PET filaments in the same direction is almost negligible for both reinforced geotextiles in terms of peak tensile strength and extension at break. When abrasion is induced on lateral surface without PET filaments in machine direction (MD) the peak tensile strength reduces about 24% and 38% for RG1 and RG2, respectively. The extension at break increases 17% and 20%, respectively, for RG1 and RG2.

Table 4. Damaged geosynthetics on the lateral surface without PET filaments: peak tensile strength, extension at break, residual peak tensile strength and residual extension at break.

Geosynthetic	Direction	Mean values		Residual values	
		T_{max}^{dam} (kN/m)	ε_f^{dam} (%)	T_R (%)	ε_R (%)
RG1	MD	44	27	76	117
	CMD	15	111	100	107,8
RG2	MD	60	24	61,6	120
	CMD	16	112	106,7	106,7

Abrasion danifies the sewing of the PET filaments to the nonwoven geotextiles, as well as their lateral surface leading to peak tensile strength reduction and extension at break increment.

4.2.3 *Comparison of results*

Residual values of maximum tensile strength and extension at break due to abrasion on both lateral surfaces of reinforced geotextiles RG1 and RG2 are presented in Table 5 and Figure 9.

Table 5. Residual values of peak tensile strength and extension at break.

Geosynthetic	Direction	Residual values: Surface with PET filaments		Residual values: Surface without PET filaments	
		T_R (%)	ε_R (%)	T_R (%)	ε_R (%)
RG1	MD	36,2	74	76	117
	CMD	100	108,7	100	107,8
RG2	MD	23,2	75	61,6	120
	CMD	106,7	102,9	106,7	106,7

The influence of abrasion in cross machine direction on both reinforced geotextiles is negligible. However, abrasion in machine direction is significant although different, depending on the lateral surface of the geosynthetic.

In the lateral surface with PET filaments the reduction on peak tensile strength is higher than the reduction in the surface without PET filaments. In the first case the abrasion is induced directly to the PET filaments, so their reinforcement function is more compromised than when the abrased surface is the opposite one.

In both cases the stiffness at break reduces, but more significantly when the surface submitted to abrasion is that with PET filaments.

It should be pointed out that the effect of abrasion was found heavier for the reinforced geotextile with higher nominal maximum tensile strength (GR2).

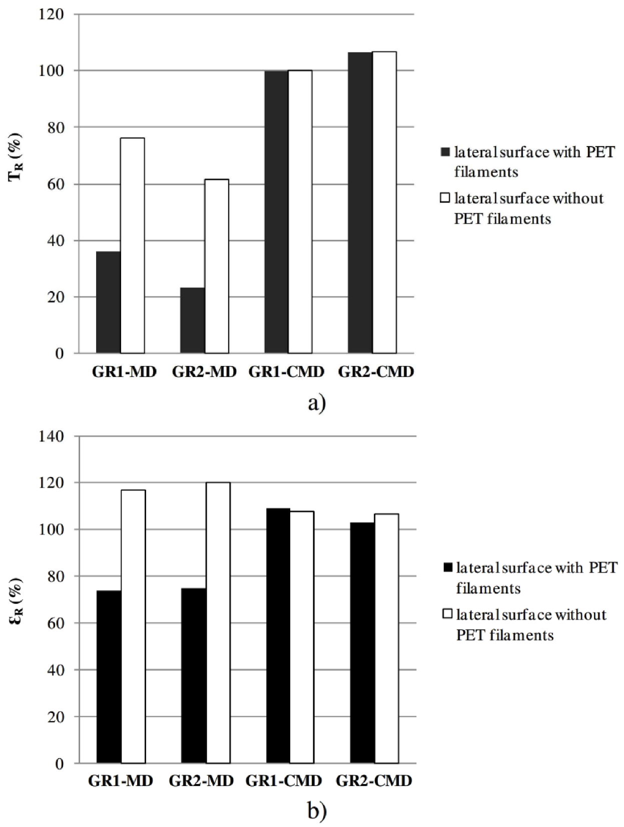


Figure 9. Residual values: a) peak tensile strength; b) extension at break.

5 CONCLUSIONS

This paper studies the influence of abrasion on peak tensile strength and extension at break of two uniaxially reinforced geotextiles with different nominal tensile strength. The abrasion was induced in both lateral surfaces of the geosynthetics and in machine direction and cross machine direction.

Based on the presented results the main conclusions can be put forward.

- The influence of abrasion in cross machine direction on the studied reinforced geotextiles is negligible.
- The influence of abrasion in machine direction is important.
- The importance of the effect of abrasion in machine direction depends on the damaged lateral surface of the geosynthetic.
- The abrasion in both lateral surfaces leads to reduction on peak tensile strength. However, that reduction is higher when the abrased lateral surface is that with PET filaments, as they are directly damaged, their reinforcement function is compromised.
- The stiffness at break reduces, but more significantly when the surface submitted to abrasion is that with PET filaments.
- The effect of abrasion increases with the nominal strength of the reinforced geotextile.

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REFERENCES

Allen, T.M. & Bathurst. R.J. 1994. Characterization of geosynthetic load-strain behavior after installation damage. *Geosynthetics International,* 1, Nº 2, 181-199.

Bräu, G. 1998. Experience with damage during installation in Germany – Field and laboratory testing. *Seminar on Installation damage in Geosynthetics*, ERA Technology, UK, pp. 2.1.1-2.1.15.

Hausman, M.R., Ring, G.J. & Pitsis, S.E. 1990. Abrasion of geotextiles in railway track applications. *4th International Conference on Geotextiles, Geomembranes and Related Products*, The Hague, Netherlands, pp. 192-196.

EN ISO 10319: 2008. Geosynthetics. Wide-width Tensile Test. CEN, Brussels.

EN ISO 13427: 1998. Geotextiles and Geotextile-related Products. Abrasion Damage Simulation (sliding block test). CEN, Brussels.

Lopes M.L. & Pinho-Lopes, M. 2010. Combined effect of damage during installation and abrasion on the tensile behaviour of geotextiles. *9th International Conference on Geosynthetics*, Guarujá, Brazil, Vol 2, pp. 773-776.

Rosete, A., Mendonça-Lopes, P., Pinho-Lopes, M., Lopes, M.L. 2013. Tensile and hydraulic properties of geosynthetics after mechanical damage and abrasion laboratory tests, *Geosynthetics International,* 20, Nº 5, 1-17.

Shukla, S.K. 2002. Fundamental of geosynthetics. *Geosynthetics and Their Applications,* Shukla, S.K. Editor, Thomas Telford, UK.

Van Dine, D., Raymond, G. & Williams, S.E. 1982. An evaluation of abrasion tests for geotextiles. *2nd International Conference on geotextiles*, Las Vegas, USA, pp. 811-816.

Want, A. & Chew, S.H. 2002. Geosynthetic damage – from laboratory to field, Keynote Lecture. *7th International Conference on Geosynthetics*, Nice, France, Vol. 4, pp. 1203-1226.