Combined effect of damage during installation and abrasion on the tensile behaviour of geotextiles

Lopes, M.L.
University of Porto, Portugal, lcosta@fe.up.pt
Pinho-Lopes, M.
University of Aveiro, Portugal, mlopes@ua.pt

Keywords: DDI, abrasion, tensile behaviour, geotextiles

ABSTRACT: Damage during installation and abrasion are two mechanical agents that influence short and long term behaviour of geosynthetics. Traditionally, the effects of damage during installation (DDI) and of abrasion on the behaviour of geosynthetics are evaluated separately. However, as even when good construction practices are followed some DDI of geosynthetics is almost inevitable, the combined effect of DDI and other degradation agents must be studied. In this paper two intact non woven spunbounded geotextiles, with different mass per unit area (m.u.a.), were, firstly, damage during installation, according with the standard ENV ISO 10722-1: 1997, and the retained tensile strength of the materials measured. Nowadays, there is a more recent version of this standard (EN ISO 10722: 2007); however the test conditions here included are less severe. Then, the intact geotextiles were submitted to abrasion, according with EN ISO 13427 standard, and the retained tensile strength of the materials defined. Finally, the damaged during installation geotextiles were submitted to abrasion and the retained tensile strength of the materials measured. It was observed that when evaluated separately, DDI influence on geotextiles tensile strength is much higher than abrasion. It was also concluded that the synergetic effect (positive or negative) of the combined effect of DDI and abrasion on the tensile strength of geotextiles depends on the m.u.a.of the geosynthetics. The synergetic effect is negative for the geotextile with lower m.u.a. and positive for the geotextile with higher m.u.a..

1 INTRODUCTION

There are two groups of items associated with the durability of geosynthetics (according with Koerner 1998): 1) related to the endurance of the materials, and include damage during installation (DDI), creep, stress relaxation, abrasion and compressive creep; and 2) related to the degradation, and include oxidation, UV radiation, hydrolysis and chemical and biological agents.

Among the endurance factors, the effect of the installation procedures stands out. These can be very important and, in general, imply immediate and significant reductions in the properties of the geosynthetics, which can compromise their performance and, in some structures can lead to their failure.

For some applications of geotextiles abrasion is also a significant factor. For example, for railway works, these two phenomena influence the response of geosynthetics.

In this study the authors propose to study the combined effect of these two endurance durability factors of geosynthetics, particularly geotextiles.

2 GEOTEXTILES STUDIED

In the test program established, two nonwoven geotextiles (GTX1 and GTX2) were considered. These materials were selected to fulfil the functions of filtration, protection and separation.

Both geotextiles are mechanically bonded continuous filament nonwovens from 100% UV stabilized polypropylene. In Table 1 the main characteristics of these materials are presented, according with their producers.

3 TEST PROGRAM IMPLEMENTED

The test program implemented consisted in carrying out wide width tensile tests of intact samples of the geotextiles and of samples submitted to DDI, to abrasion and to DDI + abrasion. These last samples were first submitted to DDI in laboratory, followed by abrasion tests. The number of specimens of each geotextile (GTX1 and GTX2) tested is included in Table 2.

Table 1 – Properties of the geotextiles studied.

Property		GTX1	GTX2
Mass per unit area (m.u.a) (EN ISO 9864)	g/m2	700	285
Thickness (EN ISO 9863-1)	mm	5.3	2.5
Tensile strength (EN ISO 10319)	KN/m	42 (MD) 42 (CMD)	21,5 (MD) 21,5 (CMD)
Strain for maximum load (EN ISO 10319)	%	95 (MD) 80 (CMD)	100 (MD) 40 (CMD)
Static puncture resistance (CBR) (EN ISO 12236)	KN	7.2	3.3
Opening size (O90) (EN ISO 12956)	µm	-	95
Water permeability normal to the plane (Δh=50mm) (EN ISO 11058)	l/m2.s	-	70
Water flow rate in the plane (20 KPa) (EN ISO 12958)	m2/s	-	6.8
MD – Machine Direction CMD – Cross Machine Direction			

Table 2 – Test program implemented – number of specimens tested for each geotextile.

Type of test		Identification	After DDI	After abrasion	After DDI + abrasion
Wide-width tensile (EN ISO 10319)	MD	6	6	6	6
	CMD	6	6	6	6
DDI (ENV ISO 10722-1)		17	-	-	-
Abrasion (EN ISO 13427)		17	-	-	-

The procedures used to carry out the DDI tests are the ones in ENV ISO 10722-1 (1997). However, there is a more recent of this standard (EN ISO 10722: 2007). Nevertheless, the main difference between these standards is the maximum pressure applied during the test: 900KPa in the previous standard and 500KPa nowadays. Therefore, as the first version of the standard is more conservative, the test conditions used in this study are still relevant.

The standard (both versions) refers the use of a synthetic aggregate. Nevertheless, the aggregate used in this test was different: a natural granite material with angular particles, with grain sizes ranging from 31.5mm and 63mm and an LA coefficient of 16.9%. This material, railway ballast, was used to try to reproduce the conditions in which geosynthetics are installed when confined in ballast in railway applications. To try to maintain the aggressiveness of the aggregate through out the tests, this material was sieved after every four uses (31,5mm sieve) and discard after 8 uses.

The abrasion tests were carried out according with the procedures described in EN ISO 13427 (1998): Geotextiles and geotextile-related products – Abrasion damage simulation. In this standard it is recommended that the tensile tests be done using the conditions in EN ISO 13934-1 (1999): Textiles. Tensile properties of fabrics. Part 1: Determination of maximum force and elongation at maximum force using the strip method. However, it was decided to use the method more used and more consensual – wide-width tensile tests (EN ISO 10319: 1996).

4 TEST RESULTS

4.1 *Wide-width tensile tests*

The results of the wide width tensile tests are presented in Table 3. In this study only the values of the tensile strength are analysed.

Table 3 – Wide-width tensile tests results.

Geotextile	Type of sample	Direction tested	Tensile strength (KN/m)	Coefficient of variation (%)
GTX1	Intact	MD	43.98	6.25
		CMD	45.15	4.20
	After DDI	MD	42.24	12.70
		CMD	43.65	7.89
	After abrasion	MD	55.65	4.29
		CMD	54.19	2.50
	After DDI + abrasion	MD	42.26	5.21
		CMD	48.29	7.77
GTX2	Intact	MD	24.45	4.13
		CMD	24.59	6.35
	After DDI	MD	15.83	11.89
		CMD	16.58	8.41
	After abrasion	MD	24.42	14.32
		CMD	24.27	2.94
	After DDI + abrasion	MD	13.72	23.23
		CMD	18.20	6.49

Though the geotextiles are biaxial, the response on both MD and CMD is not exactly the same, particularly in terms of strain for the maximum load (values that are not included here). This behaviour is typical of nonwoven spunbonded geotextiles).

The difference between these two geotextiles is clear, as the tensile strength of GTX2 is lower than for GTX1. This is true for all the types of samples.

As far as the samples submitted to DDI are concerned, before being tested they were visual inspected. It was clear that there were some cuts, perforations and surface abrasion.

The cuts and perforations of GTX2 had larger dimensions (maximum diameter of 8mm), relatively to GTX1 (3 to 4mm).

After DDI it is clear that the reduction in tensile strength is higher for GTX2. This is due to the lower thickness and m.u.a. of this geotextile, when compared with GTX1.

As clear from other studies (Pinho-Lopes et al. 2002 and 2000), generally after DDI the coefficient of variation of the tensile strength increases, particularly for the materials more severely damaged. In this case, after DDI there is an increase of such value.

For the samples submitted to abrasion tests it is necessary to refer some difficulties. In fact, for GTX2 it was difficult to carry out the abrasion tests. The low tensile strength of the material and its low stiffness resulted in serious problems: there were gaps between the geotextile and the upper plate of the test equipment, as well as adherence of GTX2 to the abrasive material. Thus, in some cases the abrasion could not be properly simulated. If this is a problem in the laboratory, it is an advantage in field. In fact, while deforming, this geotextile can adapt to the shape of the particles of ballast.

In spite of the difficulties described, it was possible to induce abrasion in some specimens, which suffered severely: partial or total surface disaggregation, creation of nodules, alignment of filaments in the direction of abrasion and separation. This is consistent with Raymond (1982).

For GTX1 there were no such problems. In fact, it was observed that the abrasion induced was significant only in 1.4mm of the thickness of GTX1 and consisted in: preferential reorientation of the filaments (in the abrasion direction), creation of nodules (in some points) and partial surface disaggregation. In fact, as the filaments are continuous, the surface disaggregation only occurs partially and the filaments do not become detached of the structure of the geotextile.

From Table 3 it is clear that, for GTX1 there is an increase of the tensile strength (27% and 20%, MD and CMD, respectively), when compared with the intact material. This can be due to the reorientation of some filaments and/or to the partial detachment of the surface layer, as some filaments are only under tensile forces after some deformation of the sample. If continuous filaments not constitute this material, probably there would be a loss of tensile strength, as the filaments suffering detachment would not contribute to the tensile properties of the geotextile.

For GTX2, there is practically no change of its tensile strength (maximum reduction of 1%). This reflects the difficulties mentioned and the reduced number of specimens tested. Therefore, these results must be considered with caution.

For the samples of geotextile submitted to abrasion there is no significant change of the coefficient of variation of the tensile strength.

As mentioned before, there were some samples submitted to DDI and then submitted to abrasion. These samples were also visually inspected.

As a consequence of DDI, GTX1 suffered some cuts and perforations (about 4mm) and some surface abrasion, presenting some ballast particles within its structure. After abrasion, there was creation of nodules and a slight detachment of the superficial filaments, without increase of the openings resulting from DDI.

After DDI GTX2 also suffered cuts and perforations (up to 15mm) and some surface abrasion and the fine material resulting from the crush of the particles of ballast was caught on the structure of the geotextile. This last phenomenon allowed inducing abrasion with fewer problems, as there was an increase of the stiffness of the surface layer of GTX2. Such increase is probably due to the fact that these soil particles restricted the movement of some filaments on the surface of the geotextile. The abrasion induced led to a slight increase of the width of the cuts and openings, which was up to 17mm.

The creation of nodules was common to GTX1 and GTX2 and results from the fact that the incrustation of soil particles increases the stiffness of the geotextiles. In fact, this is the main type of abrasion observed, as the filaments of geotextile have their movements restricted, that results in a superficial disaggregation and in an increase of the wearing of the surface of geotextile in contact with the abrading material. The increase of the wearing mentioned, leads to the cut of some filaments, with the creation of nodules.

Analysing the results in Table 3, for GTX1 there is no significant change on the tensile strength of the material: reduction of 2% in MD and increase of 7% in CMD. This increase is probably due to the combination of some reorientation of filaments of the geotextiles' structure and the presence of some fine particles of ballast in that structure.

For GTX2 there is a significant reduction of the tensile strength: 44% in MD and 26% in CMD. Thus, as these reductions are higher than the ones observed for the individual phenomena, in this case besides DDI there was abrasion.

The coefficient of variation of these results generally increases, as a consequence of the cuts and perforations randomly distributed due to the ballast in DDI test and its increase in the abrasion test. Then, these types of agents change the mechanical response of the geotextiles studied, with an increase of the variability of the results of the tensile tests.

4.2 *Discussion of the results*

The visual inspection of the samples submitted to abrasion shows that the processes of abrasion observed are consistent with the ones reported by Raymond 1982: cuts, perforations, superficial abrasion, alignment of filaments, creation of nodules and superficial disaggregation.

In Figure 1 the results are presented in terms of retained tensile strength of GTX1 and GTX2 for the three types of samples, when compared with the corresponding intact material.

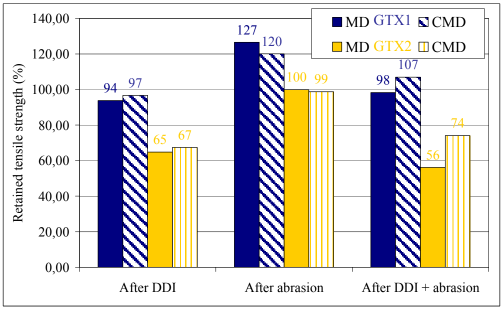

Figure 1. Retained tensile strength – GTX1 and GTX2.

From the graph, it is clear that the agent that influences the most the tensile strength of these geotextiles is DDI acting isolated. Contrary to what could be expected, the combined effect of DDI and abrasion results in lower reductions of tensile strength, than the ones resulting from the same agents acting isolated. This is probably due to the reorientation of the filaments within the structure of the geotextiles.

It is also clear the inexistence of abrasion of GTX2, and the increase of tensile strength of GTX1, after abrasion (again, due to the reorientation of filaments referred).

The results obtained for GTX2 are optimistic when compared with the ones obtained by Hausmann et al. (1990). This author exhumed geotextiles from real applications and measured tensile strength reductions of 67% to 74%, for a material with m.u.a. similar to GTX2 (strength reduction of 44%). This can be due to the difficulties presented in carrying out the abrasion tests of this geotextile.

The simulation of DDI in laboratory using ballast can be considered pessimist relatively to the real conditions, as the layers that suffer compaction over the geotextiles *in situ* have a thickness (about 40 cm) higher than the one used in laboratory (15cm).

5 CONCLUSIONS

In this study two nonwoven geotextiles were submitted to DDI, abrasion and DDI + abrasion tests. Then, their short-term mechanical behaviour was evaluated by using wide-width tensile tests.

From this study it can be concluded that for both geotextiles, DDI induced is quite severe, resulting in cuts and perforations. This is due to the characteristics of the ballast particles (large dimensions and angular) and to the test conditions (more severe than *in situ*). The damage induced is more severe for the material with lower m.u.a. Thus, even when using a product with high m.u.a. it is recommendable to use a layer of sand in the ballast-geotextile interface in order to minimise such damage. This procedure is recommended in the bibliography specific of railway applications.

For the abrasion phenomenon, acting isolated, it only had meaning for GTX1. This can mean that the use of such test procedure (EN ISO 13427: 1998) should be done carefully for geotextiles with low tensile strength and corresponding strain. For GTX1 it was observed that the processes of abrasion are similar to the ones reported by other authors, namely from exhumed materials. After abrasion, the tensile strength of GTX1 was not significantly affected, likely due to the type of filament that constitutes the geotextile (continuous). Thus, it is important to consider the use of such structure, particularly when the function of reinforcement is relevant.

The consequences of the combined effect of DDI and abrasion were different for the two geotextiles considered. For GTX2, the tensile strength was significantly affected, which could compromise its use in railway applications, unless some measures of protections against the direct action of the ballast are taken. On the contrary, GTX1 was practically insensitive to the two phenomena as far as the tensile strength is concerned. Thus, its use in railway applications is not compromised.

Last, it is important to mention that it was tried to simulate to most severe conditions for the geotextiles: rehabilitation of railways (where the geotextile is placed in contact with ballast in both faces). Therefore, the results obtained can be considered conservative.

ACKNOWLEDMENTS

The authors would like to thank the financial support and patronage of FCT, Research Project PTDC/ECM/67547/2006 and Research Project PTDC/ECM/099087/2008.

REFERENCES

Hausmann, M. R., Pitsis, S. E., Ring, G. J. (1990). “Abrasion of geotextiles in railway track applications”, Proceedings of the 4th Int. Conf. on Geotextiles, Geomembranes and Related Products, Vol. 1, pp. 193-196.

Pinho-Lopes, M., Recker, C, Lopes, M. L., Müller-Rochholz, J. (2002). “Experimental analysis of the combined effect of installation damage and creep of geosynthetics – new results”, Proceedings of the 7th Int. Conf. on Geosynthetics, Vol. 4, pp. 1539-1544.

Pinho-Lopes, M., Recker, C., Müller-Rochholz, J., Lopes, M.L. (2000) “Installation damage and creep of geosynthetics and their combined effect – experimental analysis” Proceedings of Eurogeo 2000, Vol. 2, pp. 895-897.

Raymond, G. (1982). “Geotextiles for railroad bed rehabilitation”, Proceedings of the 2nd Int. Conf. on Geotextiles, Geomembranes and Related Products, Vol. 2, pp. 479-484.