Influence of damage during installation on the hydraulic behaviour of geotextiles

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ABSTRACT: Mechanical damage during installation of geosynthetics affects short and long term properties of the materials. The hydraulic properties of the materials can be affected by DDI. Damage during installation was induced on two geotextiles, according with ENV ISO 10722-1: 1997. Then, the characteristic opening size of the geotextiles was defined, following EN ISO 12956, and the water flow capacity in the plane of the geosynthetics was determined, according with EN ISO 12958. Based on the performed study, reduction factors for the hydraulic properties considered are proposed to take into account the influence of damage during installation of geosynthetics.

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.

Traditionally the effects of DDI are assessed using mechanical properties; however, for some applications it is more significant to evaluate the changes in the hydraulic properties.

In this study the authors propose to study the effect of DDI on the short-term hydraulic behaviour of three geosynthetics. This study is focused on the functions of drainage and filtration of geotextiles.

2 GEOSYNTHETICS STUDIED

In the test program established, two nonwoven geotextiles (GTX1 and GTX2) were considered.

Both geotextiles are mechanically bonded continuous filament nonwovens made from polypropylene (PP). In Table 1 the main characteristics of these materials are presented, according with their producers.

Table 1 – Properties of the geotextiles studied.

Geosynthetic	Raw material	Mass per unit area (g/m^2)	Tensile strength (kN/m)	Puncture strength (kN)
		(EN ISO 9864)	(EN ISO 10319)	(EN ISO 12236)
GTX1	PP	200	15	2.35
GTX2	PP	700	42	7.2

3 TEST PROGRAM IMPLEMENTED

The test program implemented consisted in carrying out tests to determine the characteristic opening size and the water flow capacity in the plane of both intact and damaged samples of the three geosynthetics studied.

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.

To better understand the effect of the DDI induced on the three geosynthetics studied, visual observations of the specimens were done. Though being subjective, these were found helpful.

The tests to determine the characteristic opening size were carried out according with the procedures described in EN ISO 12956 (1999): Geotextiles and geotextile-related products. Determination of the characteristic opening size.

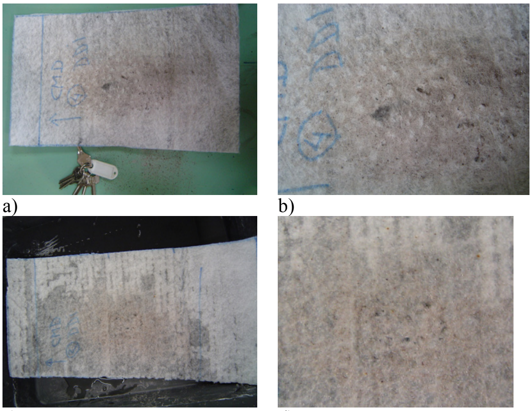
The tests to evaluate the water flow capacity in the plane were done by following the recommendations in EN ISO 12958 (1999): Geotextiles and geotextile-related products. Determination of water flow capacity in their plane.

4 TEST RESULTS

4.1 *Visual inspection*

To try to better understand the effect of the DDI induced on the geotextiles studied, it was tried to complement the test results with some visual inspection of the specimens.

The effect of the DDI induced was clear, as shown in Figure 1.



a) b) c) d)

Figure 1. Images of some specimens after DDI: a) and b) GTX1; c) and d) GTX2.

In fact, for GTX1 (Figure 1a and 1b), there were holes, openings and cuts on the geotextile surface as well as some surface abrasion. The existence of puncturing is also evident.

For GTX2 (Figure 1c and 1d), the effect of the DDI induced was not as significant. There is some surface abrasion and some holes, but their size and number is less important than for GTX1. This trend was expected, due to the difference on the mass per unit area of these geotextiles.

4.2 *Characteristic opening size*

The characteristic opening size was determined for the two geotextiles considered – GTX1 and GTX2.

In Table 2 the results obtained for the characteristic opening size are presented.

As expected, after submission to DDI through laboratory tests, the characteristic opening size of both geotextiles increases.

For GTX1 such increase is very significant, which reflects the sensitivity of this material to DDI. In fact, there is an increase of 95% of this value. Such effect will surely compromise the use of GTX1 as a filter.

For GTX2, there is also an increase of the characteristic opening size after DDI. Nevertheless, in this case such increase is very small – 14%, particularly when compared with the one for GTX1.

Table 2 – Characteristic opening size results.

Geosynthetic	O_{90} (μm)	
	Intact	After DDI
GTX1	115.7	225.6
GTX2	137.1	156.2

4.3 *Water flow capacity in the plane*

The results referring to the water flow capacity in the plane of the two geotextiles studied is presented in Table 3 and Table 4, for the machine direction (MD) and the cross machine direction (CMD), respectively. In these tables the values presented refer to confining stresses of 20, 100 and 200kPa and a hydraulic gradient of 0.1 and 1.0.

The results obtained refer to the intact samples (used as reference) and to the samples submitted to DDI laboratory tests.

Table 3 - Water flow capacity in the plane in the machine direction.

Geotextile	Water flow capacity (l/m/s)	Intact	After DDI
GTX1	$q_{20/0.1}$	1.80E-07	2.02E-07
	$q_{20/1.0}$	1.80E-06	2.22E-06
	$q_{100/0.1}$	4.16E-08	4.41E-08
	$q_{100/1.0}$	3.86E-07	4.92E-07
	$q_{200/0.1}$	3.17E-08	2.94E-08
	$q_{200/1.0}$	2.98E-07	2.75E-07
GTX2	$q_{20/0.1}$	9.12E-07	6.88E-07
	$q_{20/1.0}$	8.94E-06	6.50E-06
	$q_{100/0.1}$	2.05E-07	1.98E-07
	$q_{100/1.0}$	1.84E-06	1.76E-06
	$q_{200/0.1}$	1.20E-07	1.05E-07
	$q_{200/1.0}$	9.91E-07	9.30E-07

For the intact samples of GTX1 the water flow capacity is higher in the CMD than in MD. In fact, such variation (when considering CMD instead of MD) ranges from 29% to 100%, depending on the confining stress and hydraulic gradient considered. The highest difference corresponds to the water flow capacity determined for a confining stress of 100kPa and a hydraulic gradient of 0.1; while the lowest difference corresponds to a confining stress of 20kPa and a hydraulic gradient of 1.0.

After DDI, such difference decreases significantly. In fact, the variation mentioned ranges from 0.3% to 43%. This can mean that the effect of the DDI induced is not the same in both directions considered. In this case, the highest and lowest differences correspond to the water flow capacity determined under the same conditions than the intact samples.

Table 4 - Water flow capacity in the plane in the cross machine direction.

Geotextile	Water flow capacity (l/m/s)	Intact	After DDI
GTX1	$q_{20/0.1}$	2.38E-07	2.11E-07
	$q_{20/1.0}$	2.32E-06	2.21E-06
	$q_{100/0.1}$	8.32E-08	6.32E-08
	$q_{100/1.0}$	7.41E-07	6.27E-07
	$q_{200/0.1}$	5.14E-08	4.06E-08
	$q_{200/1.0}$	4.65E-07	3.67E-07
GTX2	$q_{20/0.1}$	1.01E-06	8.60E-07
	$q_{20/1.0}$	9.57E-06	7.97E-06
	$q_{100/0.1}$	2.42E-07	1.86E-07
	$q_{100/1.0}$	2.08E-06	1.75E-06
	$q_{200/0.1}$	1.30E-07	1.03E-07
	$q_{200/1.0}$	1.04E-06	8.60E-07

In Figure 2 it is possible to observe the variation of the values described for GTX1. Once again it is clear the differences related with the direction where the geotextile is tested, as well as the expected differences related with the hydraulic gradient.

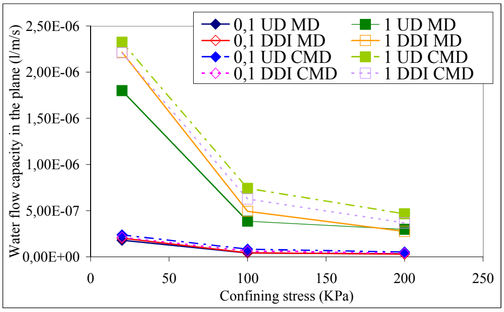


Figure 2. Water flow capacity in the plane of GTX1 before and after DDI tests.

For the intact samples of GTX2, the differences of values obtained in MD and CMD is not as important as for GTX1. In fact, for GTX2 the highest variation (when considering CMD instead of MD) ranges from 5.4% to 18%, depending on the confining stress and hydraulic gradient considered. The highest difference corresponds to the water flow capacity determined for a confining stress of 100kPa and a hydraulic gradient of 0.1; while the lowest difference corresponds to a confining stress of 200kPa and a hydraulic gradient of 1.0.

After DDI, the evolution of such variation is not as clear. In fact, there is, on one hand a decrease of the lowest variation (0.7% for GTX2 after DDI) and an increase of the highest variation (25% for GTX2 after DDI). This can mean that the effect of the DDI induced is not the same in both directions considered and for all the conditions used. In this case, the highest difference corresponds to the water flow capacity determined for a confining stress of 20kPa and a hydraulic gradient of 0.1; while the lowest difference corresponds to a confining stress of 100kPa and a hydraulic gradient of 1.0.

In Figure 3 it is possible to observe the variation of the values described for GTX2. Once again it is clear the differences related with the direction where the geotextile is tested, as well as the expected differences related with the hydraulic gradient.

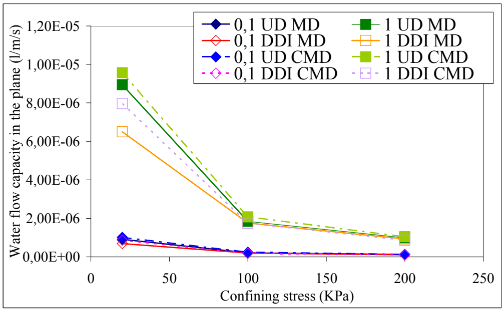


Figure 3. Water flow capacity in the plane of GTX2 before and after DDI tests.

5 REDUCTION FACTORS FOR DDI

Similarly to what is done currently for applications of geosynthetics where the more relevant properties are the mechanical ones, in this case, reduction factors were determined. These represent the changes due to the effect of DDI induced on the characteristic opening size and the water flow capacity in the plane of the geotextiles studied.

In Table 5 the values obtained for the characteristic opening size are presented and in Table 6 the values obtained for the water flow capacity in the plane of the geotextiles are shown.

These values were determined using Equation 1, where X_{intact} is the same parameter corresponding to reference (intact) samples and $X_{damaged}$ is the value of the property after DDI.

$$RF_{DDI} = \frac{X_{int\,act}}{X_{damaged}} \quad (1)$$

Table 5 – Reduction factor after DDI for the characteristic opening size.

Geosynthetic	RF_{DDI} (O_{90})
GTX1	0.51
GTX2	0.88

As expected, the reduction factor for the opening characteristic size of the two geotextiles considered increases after DDI. Therefore, the reduction factor, defined traditionally it is lower than 1.0 and, thus, useless. Therefore, to represent the effect of DDI in the opening characteristic size for design of geotextiles another formulation has to be used, by considering such increase and its consequences on the performance of the material.

Thus, it is important to quantify the increase of such quantity after DDI and consider it in the design of geosynthetics

Table 6 - Reduction factor after DDI for the water flow capacity.

Geotextile	Water flow capacity	MD	CMD
GTX1	$q_{20/0.1}$	**0.89**	1.13
	$q_{20/1.0}$	**0.81**	1.05
	$q_{100/0.1}$	**0.94**	1.32
	$q_{100/1.0}$	**0.79**	1.18
	$q_{200/0.1}$	1.08	1.27
	$q_{200/1.0}$	1.08	1.27
GTX2	$q_{20/0.1}$	1.32	1.18
	$q_{20/1.0}$	1.38	1.20
	$q_{100/0.1}$	1.04	1.30
	$q_{100/1.0}$	1.05	1.19
	$q_{200/0.1}$	1.15	1.26
	$q_{200/1.0}$	1.07	1.21

For the water flow capacity in the plane of the geotextiles, the situation is different. The reduction factors obtained are range from 1.0 to 1.38. Note that the bolded values in the table are lower than the minimum and, therefore, in such cases the value 1.0 should be considered.

6 CONCLUSIONS

In this study two nonwoven geotextiles were submitted to DDI laboratory tests. Then, their hydraulic behaviour was evaluated by determining the characteristic opening size and their water flow capacity in the plane.

From this study it can be concluded that for both geotextiles, the DDI induced is quite important, resulting in cuts, perforations and surface abrasion. As expected, the damage induced is more severe for the material with lower mass per unit area.

For the characteristic opening size, it is clear that, for the geotextiles studied, after DDI there is an increase of this quantity. In fact, such effect has to be considered properly in the design of such materials in order to ensure that the function of filter is not compromised immediately after installation of the material. Thus, it seems wise that an assessment of the effect of DDI on the characteristic opening size is done, to consider the real value of this property (available after installation) in the design of geotextile filters.

On the other hand, when analysing the function of drainage of these geotextiles, the effect of the DDI induced in laboratory in the water flow capacity in the plane was analysed.

It is clear that the DDI induced changes this quantity. However, the trend observed is not the same for both geotextiles.

GTX1, with lower mass per unit area, has lower values of the water flow capacity in the plane, reflecting its little adequacy to be used as a drain. This geotextile is the least affected by DDI, as the reductions observed are not as important.

For GTX2, with higher mass per unit area, the water flow capacity in the plane is initially higher. However, after DDI there is a decrease of this quantity, reflected by the higher corresponding reduction factors for DDI.

Therefore, for the materials studied, it seems important to assess the values of the functional properties of the materials after DDI. In fact, those are the values that will be available (for service) and must be considered in the design of geotextile drains.

It should be pointed out that for performing either as filter or drains, the geotextiles have to survive the installation procedures. Only with that guarantee a study similar to the one presented can be done and the adequate reduction factors to be used in the design can be determined.

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