Short-term mechanical behaviour of geotextiles after laboratory DDI tests

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ABSTRACT: Damage during installation (DDI) influences short and long-term behaviour of geosynthetics. In this paper two nonwoven geotextiles, with different mass per unit area values, were submitted to damage during installation, according with the standard EN ISO 10722: 2007, and some of the retained properties of the geotextiles were measured. The short-term mechanical behaviour of the geotextiles is evaluated by laboratory tests, namely, wide-width tensile tests and tear tests. Reduction factors to be used in the design of these geotextiles for the effects of DDI are proposed. The results of this study are compared with those obtained from previous studies to verify the prediction of reduction factor for DDI. From the results presented, it is clear that the use of interpolations is possible and quite effective.

1 INTRODUCTION

The durability of geosynthetics is associated with the endurance and the degradation of the materials. Among the first, the effect of the installation procedures has great impact. Often there is no opportunity to study the effects of DDI on the mechanical behaviour of a certain product. Then, the use of interpolations from results obtained for similar products is an option (as recommended in ISO/TR 13434:2008).

In this paper the effect of DDI on the short-term mechanical behaviour of two geotextiles is analysed and the validity of using interpolation of results obtained for similar products to estimate the reduction factors for DDI is evaluated and discussed.

2 GEOTEXTILES STUDIED

In the test program established two polypropylene nonwoven geotextiles (GTX1 and GTX2) were considered, with mass per unit area (m.u.a.) of 800 g/m^2 and 190 g/m^2, respectively.

A high density polyethylene geomembrane (GM) of 2mm in thickness was also included.

3 TEST PROGRAM IMPLEMENTED

The test program implemented consisted of: wide-width tensile tests (EN ISO 10319: 1996) and tear tests (ASTM D4533–04) of intact samples of the geotextiles and of samples submitted to laboratory DDI tests (EN ISO 10722: 2007).

The tests consist in filling a lower box (300 mm x 300 mm x 75 mm) with two compacted layers of granular material. On the top of the box the aggregate surface must be levelled; the specimen of geosynthetic is placed in the box centre.

An upper box (300 mm x 300 mm x 75 mm) is then assembled and filled with loose aggregate, with a total height of 75 mm of aggregate over the geosynthetic. The loading plate (100mm x 200mm x 15mm) is placed on the box centre and dynamic loading is applied. The loading is cyclic from 5 kPa to 500 kPa at a frequency of 1 Hz for 200 loading cycles.

At the end of the test the aggregate is carefully removed and the geosynthetic specimen is recovered.

Table 1 shows the test samples considered. Besides studying the effect of DDI on each of the geotextiles alone, samples of geotextile over a geomembrane were also considered. Later the geotextiles were tested separately to evaluate the changes on their short-term mechanical behaviour.

Table 1 – Types of samples considered

Geotextile	Type of sample	Designation
GTX1	Intact	GTX1
	After DDI, isolated	GTX1d
	After DDI, with GM	GTX1d+GM
GTX2	Intact	GTX2
	After DDI, isolated	GTX2d
	After DDI, with GM	GTX2d+GM

It must be referred that the conditions in which DDI tests of the sets were carried out are different than the ones in real applications. Therefore, such results must be analysed with caution.

4 TEST RESULTS

4.1 *Wide-width tensile tests*

The main results of the tensile tests are presented in Table 2: tensile strength (T) and strain (ε) and coefficients of variation (CV_T and CV_ε, respectively).

Table 2 – Wide-width tensile tests results.

Geotextile	T (KN/m)	CV_T (%)	ε (%)	CV_ε (%)
GTX1	41.46	2.29	118.27	5.08
GTX1d	41.31	5.05	115.11	12.21
GTX1d+GM	40.33	6.73	110.46	12.57
GTX2	11.07	8.64	46.67	16.07
GTX2d	8.68	6.19	24.05	15.59
GTX2d+GM	9.04	9.42	30.46	31.55

It is clear that after DDI there is a reduction of the tensile strength and of the corresponding strain.

The values of the retained tensile strength are, in general, considerably high (over 78%) and can be due to the fact that the geotextiles are nonwoven. Previous studies (Paula 2003, for example) revealed a larger sensitivity of woven geotextiles to DDI than similar nonwoven materials. Besides this, it is important to refer that the current version of the DDI test (EN ISO 10722: 2007) is less severe than the previous one (ENV ISO 10722-1: 1997), used in most of the studied carried out until recently. The main difference refers to the value of the maximum applied stress: 500kPa in the current version of the standard and 900kPa in the previous one.

The behaviour of GTX1 and GTX2 shows different tendencies after being submitted to DDI alone or in a set with a GM.

In fact, when tested over a GM, GTX1 exhibits a value of the retained strength (97.3%) lower than the one obtained for GTX1d (99.6%). However, as the difference of values is quite small (~2%) it can be concluded that the behaviour of the GTX1 is almost unaffected by the presence of the GM, probably due to its higher m.u.a (800 g/m^2).

For GTX2 the trend observed is the opposite: after DDI, the retained tensile strength of the geotextile tested over the GM is higher (81.7%) than for GTX2d (78.4%). In this case it is apparent that the GM acts as a protective element in relation to the DDI action on the geotextile. These results show the influence of the m.u.a. of GTX on the behaviour of the set GTX+GM. In fact, for GTX1, with m.u.a. of 800 g/cm^2, there is no influence of the presence of the GM, while for GTX2, with 190 g/cm^2, the GM reduces the DDI action on the geotextile. Again, due to the tests conditions, such results should be considered with care.

As expected, for the same type of samples, GTX1 exhibits higher retained tensile strength than GTX2, due to the difference of m.u.a. of these materials.

The values obtained for CV_T show that the vulnerability to DDI of GTX2 is higher than that of GTX1.

It is curious to observe that the values of CV_T are higher for the samples of the sets GTX+GM, than for the ones submitted to DDI tests isolated.

The trend observed for the variation of the retained strain of GTX1 and GTX2 is similar to the one of the tensile strength, but with lower values.

Once again the different response of the geotextiles is clear: for GTX1 the retained strain is near 100% (97% and 93% for GTX1d and GTX1d+GM; respectively), which indicates that the strain was practically not affected by the DDI induced; GTX2 exhibits lower retained strain values (52% and 65% for GTX2d and GTX2d+GM; respectively). These results show the strain of GTX2 has a higher sensitivity to DDI than the corresponding tensile strength.

Again, the trend of the variation of the retained strain for the sets GTX1+GM and GTX2+GM, is similar to the one observed for the retained tensile strength, though with different values.

In short, each geotextile shows a different behaviour. In fact, though both geotextiles maintain a significant part of their resistance, in terms of strain GTX1 maintains its properties, while GTX2 suffers an important reduction.

For CV_ε there isn't a large disparity of values (with the exception of GTX2+GM – 31.6%). However, after DDI in general these values are low. This trend is typical of samples submitted to laboratory tests, carried out under similar conditions. Nevertheless, generally the variability of results after DDI laboratory tests is larger than the one for the corresponding intact samples.

4.2 *Tear tests*

The results of the tear tests are presented in Table 3: maximum tear force (F_T) and corresponding coefficient of variation (CVF_T).

Table 3 – Tear tests results.

Geotextile	F_T (N)	CV_T (%)
GTX1	1324.60	6.00
GTX1d	905.40	3.79
GTX1d+GM	1131.00	6.50
GTX2	342.20	11.79
GTX2d	176.40	11.44
GTX2d+GM	294.40	18.68

From the tear tests results it is clear that after DDI the tear strength of the samples suffers a significant reduction: 32% for GTX1d and 48% for GTX2d. The specimens of GTX1 and GTX2 damaged over a

GM suffer a lower reduction of the tear force (about 15% and 13% for GTX1 and GTX2, respectively). This is due to the test conditions used in the corresponding DDI laboratory test: there is a layer of aggregate under the geomembrane Thus, contrary to what normally happens, the geomembrane also gives some protection to the geotextile. This protection effect is not the same in terms of tensile strength and tear strength.

It is also clear that the specimens of GTX2 tested over a GM (GTX2+GM) have a CV_T (18.7%) slightly higher than the other samples.

5 REDUCTION FACTORS

In Table 4 the reduction factors for DDI (RF_{DDI}) determined are shown. They were obtained by comparing the tensile strength of the intact samples with the one of the corresponding damaged samples.

These values reflect the comments done for the tensile strength of the materials. In fact, the effects of DDI are not particularly relevant, as the highest value is 1.28. Again the different trend observed for GTX1 and GTX2 is clear.

Table 4 – Reduction factors for DDI.

Geotextile	Isolate d	Tested with GM
GTX1	1.00	1.03
GTX2	1.28	1.22

6 USING INTERPOLATIONS TO ESTIMATE THE RF_{DDI}

To estimate the RF_{DDI} to use in the design of geosynthetics it is possible to use interpolations from data available for similar products. Therefore, in this study it was tried to verify the validity of using such procedure for the geotextiles tested.

First, the results obtained by Paula 2003 were used. This author studied GTX1 using wide-width tensile tests of samples previously submitted to laboratory DDI tests, according to ENV ISO 10722-1: 1997. Paula 2003 used two natural soils (one from granite and another from limestone) in alternative to the corundum, but with similar soil grain sizes. More details can be found in Paula et al 2004.

It should be noted that in the work of Paula 2003 the maximum stress applied in the DDI tests was of 900kPa (ENV ISO 10722-1: 1997). The results obtained in the present work refer to maximum stress of 500kPa (EN ISO 10722: 2007).

In Table 5 the RF_{DDI} obtained for GTX1 are presented, as well as the values of the coefficient of variation for the tensile strength (CV_T).

It is clear that the granite aggregate is the natural soil with more significant consequences for GTX1. More, the granite aggregate produces a greater heterogeneity in the results (higher CV_T).

Table 5 – Reduction factors for DDI – GTX1.

Sample of GTX1	CV_T (%)	RF_{DDI}
Corundum 500KPa	5.05	1.00
Granite 900KPa	9.40	1.29
Limestone 900KPa	3.03	1.13

Although for other geosynthetics, Pinho-Lopes 2006 and Paula et al 2004 conclude that (for the same test conditions) the results obtained with the granite aggregate are very close to the ones obtained with the synthetic aggregate (corundum). These conclusions were derived using ENV ISO 10722-1: 1997 - maximum applied stress of 900kPa.

Considering this conclusion, DDI tests of GTX1 using the synthetic aggregate and a maximum stress of 900kPa (conditions of ENV ISO 10722-1: 1997) should give an RF_{DDI} similar to the value obtained with the granite soil (1.29) (Table 5).

However, as the RF_{DDI} for GTX1 defined in the current paper was obtained according to the conditions in EN ISO 10722: 2007 (synthetic aggregate and maximum stress of 500kPa) the RF_{DDI} obtained (1.00) is lower than the one defined by Paula 2003 (1.29).

In fact, the RF_{DDI} obtained using corundum and a maximum stress of 500KPa is the less conservative and is closer to that resulting of the use of the limestone aggregate and of a maximum stress of 900KPa. From the data presented, it can be stated that such relationship is due essentially to the difference of the maximum stress applied during DDI tests. Thus, for the RF_{DDI} of GTX1 the influence of the applied stress applied (500kPa and 900kPa) is more significant than the aggregate used (corundum or limestone), for the conditions considered.

For GTX2, the results presented by Morel 2003 are used. The author studied two geotextiles similar to GTX2, here named GTX2i and GTX2s. In Table 6 the characteristics of these geotextiles, which allow the comparison of results, are indicated (nominal strength and m.u.a.). Geotextiles GTX2i and GTX2s were submitted to the DDI laboratory tests with the natural aggregates mentioned before and with the application of the maximum stress of 500kPa. As the m.u.a. of GTX2 is between the corresponding values for GTX2i and GTX2s, the RF_{DDI} for GTX2 can be determined by interpolation from the results obtained by Morel 2003 (for the RF_{DDI} for GTX2i and GTX2s using a particular aggregate).

Table 6 – Nominal strength and m.u.a. – GTX2, GTX2i and GTX2s.

Geotextile	Nominal strength (KN/m)	m.u.a. (g/m^2)
GTX2i	12	165
GTX2	12.8	190
GTX2s	29	375

In Table 7 and Figure 1 values of RF_{DDI} of the geotextiles defined in DDI tests with a confining pressure of 500kPa are presented, as well as the values of the same parameter obtained by interpolation, as is the case of RF_{DDI} for GTX2 with the granite and the limestone soils, respectively 1.40 and 1.23.

The values of the RF_{DDI} of GTX2i and GTX2s using corundum were also estimated (1.31 and 1.05, respectively), assuming similar relationship of values of RF_{DDI} for the three geotextiles (GTX2, GTX2i e GTX2s) tested with the three aggregates.

Table 7 – RF_{DDI} after laboratory tests and after interpolations.

Sample of geotextile	$C.V._T$ (%)	RF_{DDI}	Type of result
GTX2 Corundum	6.19	1.28	Test
GTX2i Granite	11.60	1.45	Test
GTX2i Limestone	3.86	1.26	Test
GTX2s Granite	3.10	1.08	Test
GTX2s Limestone	3.86	1.04	Test
GTX2 Limestone	-	1.23	Interpolation
GTX2 Granite	-	1.40	Interpolation
GTX2i Corundum	-	1.31	Interpolation
GTX2s Corundum	-	1.05	Interpolation

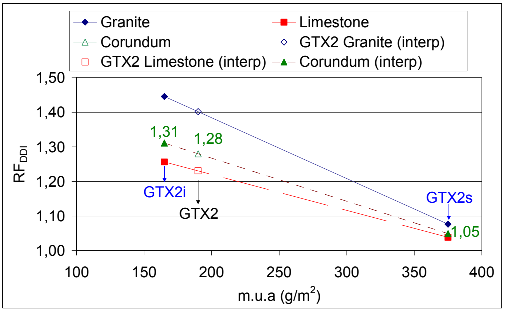

Figure 1. Reduction factor for GTX2 – interpolation.

In accordance with the observed for GTX1, Table 7 and Figure 1 show that DDI induced with the corundum on GTX2 is closer the trend line corresponding to the effect of the limestone aggregate.

These results are opposite to the ones observed by Paula et al 2004, for a maximum applied stress of 900kPa and for other geosynthetics (woven polypropylene geotextile, GTXw; biaxial woven polyester geogrid, GGRw; and biaxial extruded high density polyethylene geogrid, GGRe). This can indicated that this relationship depends on the maximum stress applied and on the type of geosynthetic considered.

7 CONCLUSIONS

The main conclusions from this study are now put forward.

After being subjected to DDI tests isolated, GTX1 and GTX2 exhibit a reduction of their tensile strength: quite low for GTX1 (≈0,4%) and more significant for GTX2 (≈11,6%).

The changes in the strain for the tensile strength are similar: for GTX1 the strain reduction is of about 2.7% and for GTX2 is of 48.5%. For GTX2 the reduction in strain is much more important than the corresponding reduction in tensile strength.

Thus, as expected, the DDI induced is more severe for lower values of the m.u.a. of the geotextiles.

When used over the GM in the DDI laboratory test, GTX1 suffers a tensile strength reduction more important than when it is tested isolated; however, such reduction is low (2.8%). For GTX2, the trend observed is opposite, as the tensile strength reduction is more important when it is damaged isolated (21.6%).

Again, GTX2 is the most sensitive to DDI, under the conditions considered.

To check the validity of using interpolations of results from similar products to assess the RF_{DDI} to use in the design of GTX1 and GTX2, some comparison of results were carried out.

The results available for comparison indicate that, for these geotextiles, the use of interpolations can be done with confidence.

The results presented indicate that, for these geotextiles, the test conditions used in the DDI laboratory tests can play an important role, particularly the maximum stress applied.

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