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Effect of mechanical damage under repeated loading and abrasion on the tensile behaviour of a reinforcement geocomposite

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Abstract. The installation process and the occurrence of abrasion may cause unwanted changes on the properties of the geosynthetics. When identified as relevant degradation agents for a given application, their effect has to be properly taken into account during the design phase in order to guarantee that the geosynthetics will perform correctly their functions over time. In this work, a reinforcement geocomposite (formed by a nonwoven polypropylene geotextile reinforced with polyethylene terephthalate filaments) was exposed to the isolated and combined effects of two degradation tests: mechanical damage under repeated loading and abrasion (the geocomposite was tested on both sides, which were structurally different). Damage assessment was performed by visual inspection and tensile tests. Based on the changes occurred in tensile strength, reduction factors were determined. The degradation tests provoked extensive damage on the geocomposite, having a negative impact on its tensile behaviour. Contrary to mechanical damage under repeated loading, the effect of abrasion on the geocomposite was influenced by the side that was tested. Finally, some differences were found between the reduction factors determined by the traditional method (multiplication of reduction factors obtained in isolation for each agent) for the combined effect of mechanical damage under repeated loading and abrasion and those resulting from the successive exposure to both degradation agents.

1. Introduction

It is unquestionable that the higher the level of knowledge about the construction materials, the higher is the reliability on the correct behaviour of the structures in which they are applied. Therefore, it is important to characterize the performance of many materials available in the market in order to avoid committing errors at the design phase. Regarding geosynthetics, this task comprises, among other things, carrying out investigations for improving the knowledge about their response when exposed to the action of different degradation agents, which may cause undesirable changes in their properties. Examples of degradation agents of geosynthetics include: installation damage, creep, abrasion, chemical substances like acids or alkalis, high temperatures, atmospheric oxygen, and weathering agents [1]. These agents may have a negative impact on the geosynthetics, consequently, affecting the stability and performance of the engineering structures in which these materials are used.

The installation on-site of geosynthetics involves carrying out different operations that may affect the properties of these construction materials. The placement and handling of the geosynthetics, as well as the placement and compaction of filling materials over them, in which heavy vehicles are often used, are examples of procedures that may induce damage to the geosynthetics. Indeed, in some applications, the geosynthetics may be submitted to stresses during the installation process higher than those expected during service life [2]. The installation procedures may also induce abrasion on the geosynthetics, since frictional forces can be mobilized in the interface between these materials and the filling materials. The possible occurrence of abrasion is not restricted to the installation process. In some applications, and due to the occurrence of cyclic loads (e.g. traffic of vehicles in roadways and railways infrastructures), abrasion may also occur over time.

The installation damage of geosynthetics can be evaluated by field tests or by laboratory tests (which try to simulate the damaging actions occurring under real conditions). The field tests are expensive, time consuming and require heavy equipment, being their use quite limited. For inducing mechanical damage under repeated loading on geosynthetics, a laboratory method (EN ISO 10722 [3]) was developed by the European Committee for Standardization. Many authors have employed this method to estimate the installation damage of geosynthetics [4-6], while others researched correlations between the method and the damage that occurs under real conditions [7,8]. For evaluating the resistance of the geosynthetics against abrasion, a method (EN ISO 13427 [9]) was also developed by the European Committee for Standardization.

When considering the use of geosynthetics to perform a specific function, it is important to know the effect of the degradation agents on their properties. To obtain the design values, partial reduction factors are used to account for the effect of each degradation agent. If it is necessary to consider the effect of two, or more, degradation agents, the partial reduction factors are usually multiplied (method often used at the design phase). For reinforcement applications, the design value of the tensile strength (T_D) of the geosynthetics can be given by [10,11]:

$$T_D = \frac{T}{RF_{CR} RF_{ID} RF_W RF_{CH} f_s} \tag{1}$$

where T is the tensile strength, RF_{CR}, RF_{ID}, RF_W and RF_{CH} are, respectively, the partial reduction factors accounting for the isolated effects of creep, mechanical damage, weathering, and chemical and biological agents, and f_s is a factor of safety (to allow for extrapolation uncertainly). The multiplication of partial reduction factors (each accounting for the isolated effect of an agent) may not always represent correctly the combined effect of the agents, leading to unreliable designs (which may result in a premature failure of the engineering structures). Indeed, previous works shown that the reduction factors obtained by this method for the combined action of the degradation agents may be inaccurate (by underestimating) when interactions occur between those agents [12-15]. Interactions have been found between: (1) damage during installation and creep [16,17], (2) mechanical damage under repeated loading and abrasion [12,13,15], and (3) between chemical agents [14,18].

In this work, a reinforcement geocomposite was submitted to the isolated and combined actions of mechanical damage under repeated loading and abrasion (the material was tested on both sides, which were structurally different). Damage assessment was carried out by visual inspection and by monitoring changes in the tensile behaviour of the geocomposite. Based on the changes occurred in tensile strength, reduction factors were determined. The reduction factors obtained by the traditional method for the combined effect of mechanical damage under repeated loading and abrasion (multiplication of reduction factors accounting for the isolated effect of each agent) were compared with those directly found in the successive exposure to both degradation agents.

2. Materials and methods

2.1. Geocomposite

The experimental campaign developed in this work was carried out with a geocomposite formed by a nonwoven geotextile made from polypropylene fibres, reinforced with polyethylene terephthalate (PET) filaments in both the machine and cross-machine directions of production. The filaments were attached to one side of the geotextile by seams (side with filaments). The other side of the geocomposite consisted of the geotextile (side without filaments) (the structure of the geocomposite is presented in section 3).

The geocomposite had, according to the manufacturer, a tensile strength of 42 kN.m^{-1} (EN ISO 10319 [19]) in both directions. Its mass per unit area and thickness were, respectively, 351 (±16) g.m^{-2} and 2.26 (±0.09) mm. These properties, which are presented with 95% confidence intervals determined according to Montgomery and Runger [20], were characterised in accordance with EN ISO 9864 [21] and EN ISO 9863-1 [22], respectively.

The geocomposite studied in this work can be used for performing the function of reinforcement in many engineering applications, including transportation infrastructures such as roadways or railways (in which abrasion might occur). In these infrastructures, the geocomposite can be applied, for example, in subgrade stabilisation, railtrack reinforcement, basal reinforcement or to steepen soil slopes. In addition to reinforcement, the material may also perform functions of separation, filtration or drainage.

2.2. Degradation tests
Two types of degradation tests were conducted: mechanical damage under repeated loading and abrasion tests (description of the degradation tests in the next two subsections). The geocomposite was exposed in isolation to each test (single exposures to mechanical damage under repeated loading and abrasion), and successively submitted to both tests (successive exposure). The degradation tests were carried out on both sides of the geocomposite (which were structurally different): the side with filaments and the side without filaments.

2.2.1. Mechanical damage under repeated loading. A prototype equipment developed at the Faculty of Engineering of the University of Porto, which is thoroughly described in Lopes and Lopes [23], was used to carry out mechanical damage under repeated loading tests (hereinafter MD tests) in accordance with EN ISO 10722 [3]. The first step of the MD tests was the placement of a sublayer of *corundum* (synthetic aggregate with a particle size distribution in the range of 5-10 mm) with a height of 37.5 mm in the lower box of the equipment, followed by compaction. Then, an additional sublayer of *corundum* of the same height was included in that box and also submitted to compaction (the compaction of both sublayers of aggregate was carried out by applying a pressure of (200 ± 2) kPa for 60 s over the area of the lower box). At the end of these procedures, the geocomposite (specimen with a length of 500 mm and a width of 250 mm) was placed over the compacted layer of *corundum* (formed by the two sublayers of 37.5 mm), and an upper box was installed and filled with a loose layer of the aggregate with a height of 75 mm (both the lower and upper boxes had square bases with a side of 300 mm and a height of 87.5 mm). The geocomposite (installed between the layers of *corundum*) was subjected to dynamic loading between (5.0 ± 0.5) kPa and (500 ± 10) kPa at a frequency of 1 Hz, for 200 cycles. Finished the loading, the test was stopped and the geocomposite carefully recovered in order to avoid additional damage. In total, 5 specimens were tested for each degradation condition.

2.2.2. Abrasion. The abrasion tests were performed in another prototype equipment developed at the Faculty of Engineering of the University of Porto. These tests, which were conducted according to EN ISO 13427 [9], consisted of submitting the geocomposite (attached to a stationary platform) to the action of a P100 abrasive sheet, which was fixed on a sliding platform. In order to promote the rubbing of the geocomposite, it was triggered a back-and-forth linear motion of the sliding platform, under a controlled pressure of 6 kPa, for 750 cycles (each cycle consisted of a double passage of the abrasive through the geocomposite). For each degradation condition, 5 specimens were tested.

2.3. Damage evaluation
The assessment of the damage occurred on the geocomposite during the degradation tests was carried out through the following approaches: qualitatively, by visual inspection, and quantitatively, through tensile tests. The results obtained for undamaged samples, which were also tested, were used as reference for comparison purposes.

The tensile tests were conducted in conformity with EN ISO 10319 [19] on a LR 50K testing machine from *Lloyd Instruments*. The geocomposite (specimens 100 mm long (between grips) and 200 mm wide) was tested in the machine direction of production under a displacement rate of 20 mm.min^{-1}. Tensile strength (T, in kN.m^{-1}) and elongation at maximum load (E_{ML}, in %) were the properties determined in these tests. The latter was assessed using a video-extensometer, which monitored the distance between two reference points separated from each other by 60 mm (30 mm above and 30 mm below the axis of symmetry of the specimen). The average values of the tensile properties were determined based on the results of 5 tested specimens and are presented with 95% confidence intervals according to Montgomery and Runger [20]. It was also calculated the residual tensile strength ($T_{Residual}$, in %), in order to represent by percentage the variations occurred in tensile strength after the degradation tests. This parameter was obtained by the quotient between the tensile strengths of the damaged and undamaged samples of the geocomposite.

2.4. Reduction factors

Based on the changes occurred in the tensile strength of the geocomposite (during the degradation tests), reduction factors (RF) for the isolated and combined effects of MD and abrasion were determined as:

$$\mathrm{RF}=\frac{T_{\mathrm{Undamaged}}}{T_{\mathrm{Damaged}}} \tag{2}$$

where $T_{Undamaged}$ and $T_{Damaged}$ correspond, respectively, to the tensile strength of the geocomposite before and after the degradation tests.

According to the traditional method, the reduction factor for the combined effect of two, or more, degradation agents can be obtained by multiplying the reduction factors obtained in isolation for each agent. When considering the combined effect of MD and abrasion, the reduction factor according to the traditional method ($RF_{MD+ABR\ TRAD}$) can be found using the following expression:

$$\mathrm{RF}_{\mathrm{MD+ABR\ TRAD}}=\mathrm{RF}_{\mathrm{MD}}\mathrm{RF}_{\mathrm{ABR}} \tag{3}$$

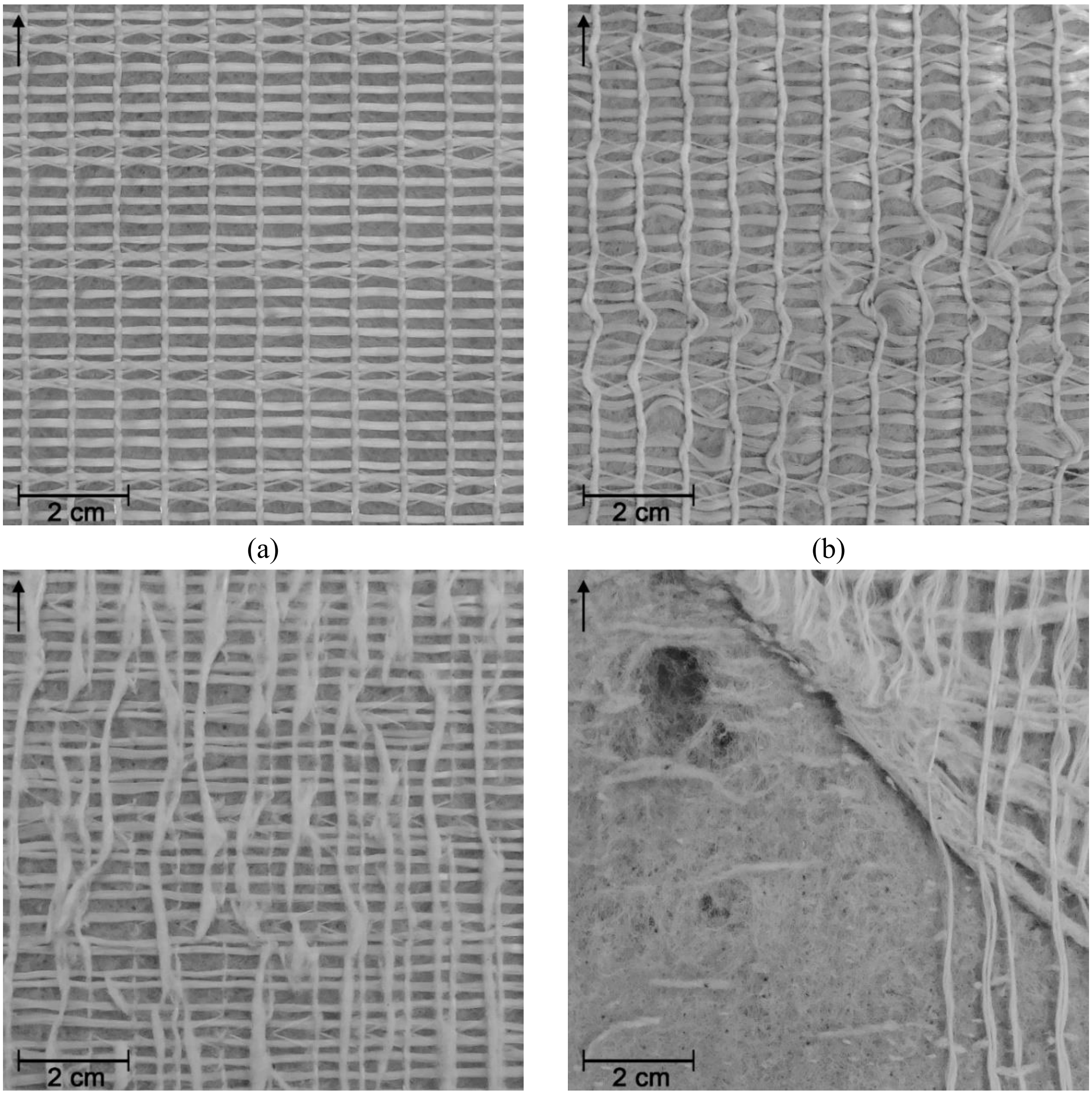
where RF_{MD} and RF_{ABR} represent, respectively, the reduction factors for the isolated actions of MD and abrasion.

It is important to stress that the reduction factors presented in this work were obtained in particular degradation conditions, which may not represent the *in situ* conditions of the engineering applications, and therefore should not be considered for design purposes. Their determination was performed in order to evaluate possible differences between the reduction factors obtained by the traditional method for the combined effect of MD and abrasion and their counterparts directly found in the successive exposure to both degradation agents.

3. Results and discussion

3.1. Visual inspection

3.1.1. Side with filaments. The degradation tests caused different types of damage on the geocomposite. From what it was possible to observe, the single exposure to MD was the least damaging degradation condition. Still, both the longitudinal and the cross-machine direction filaments, as well as the nonwoven geotextile, suffered some degradation (figure 1b). The original arrangement of the filaments suffered some changes (the distance between filaments and their linearity was affected) and some cuts occurred in the filaments (without completely breaking them). By carrying out a close observation, it was also possible to detect the existence of cuts in fibres, punctures and small holes in the nonwoven geotextile (defects not easily observed at the magnification of figure 1b).



(a) (b)

(c) (d)

Figure 1. Visual analysis of the geocomposite tested on the side with filaments: (a) undamaged sample; (b) single exposure to MD; (c) single exposure to abrasion; (d) successive exposure to MD and abrasion (the arrow indicates the machine direction of production)

The abrasion tests provoked the detachment and break of the longitudinal filaments (figure 1c), being the cross-machine direction filaments much less affected (since they are placed below the longitudinal filaments, they were not in direct contact with the abrasive). The action of the abrasive: broke the seams attaching the filaments to the nonwoven geotextile, led to a reduction in thickness of the longitudinal filaments, and promoted the formation of clusters of damaged longitudinal filaments above the cross-machine direction filaments. Regarding the nonwoven geotextile, which was not in direct contact with the abrasive, no relevant damage was observed.

The successive exposure to MD and abrasion left the geocomposite highly damaged (figure 1d). The longitudinal and cross-machine direction filaments were cut and detached from the nonwoven geotextile (all seams were cut), leading to the formation of large clusters of filaments (the original structure of the filaments was totally destroyed). In addition, cuts and detachment of fibres and formation of holes with significant diameter were observed in the nonwoven geotextile. The successive exposure to both degradation tests was, unquestionably, the worst scenario to the geocomposite.

3.1.2. Side without filaments. Excepting the single exposure to MD, the side in which the geocomposite was tested had a determinant impact on the degradation occurred. During the MD tests, in addition to cuts in fibres, the particles of *corundum* (with a rough and angular structure) provoked punctures and a large number of small holes on the nonwoven geotextile (defects not easily seen at the magnification of figure 2b). The seams that guaranteed the attachment of the filaments to the nonwoven geotextile have emerged practically unscathed. It is also worth mentioning that very small particles of *corundum*, which resulted from the splintering of particles of higher dimension, were detected imprisoned in the nonwoven structure. Regardless of the side in which the geocomposite was tested, the defects caused by the MD tests were similar (this section described only the damage found in the side without filaments, while the damage occurred in the opposite side was analysed in the previous section). This can be explained by the fact that the geocomposite was placed between two layers of *corundum* (both layers induced damage) independently of the side facing up during the MD tests (the MD tests imposed a cyclic vertical load to the geocomposite, being the side facing up defined as the side faced to the loading mechanism).

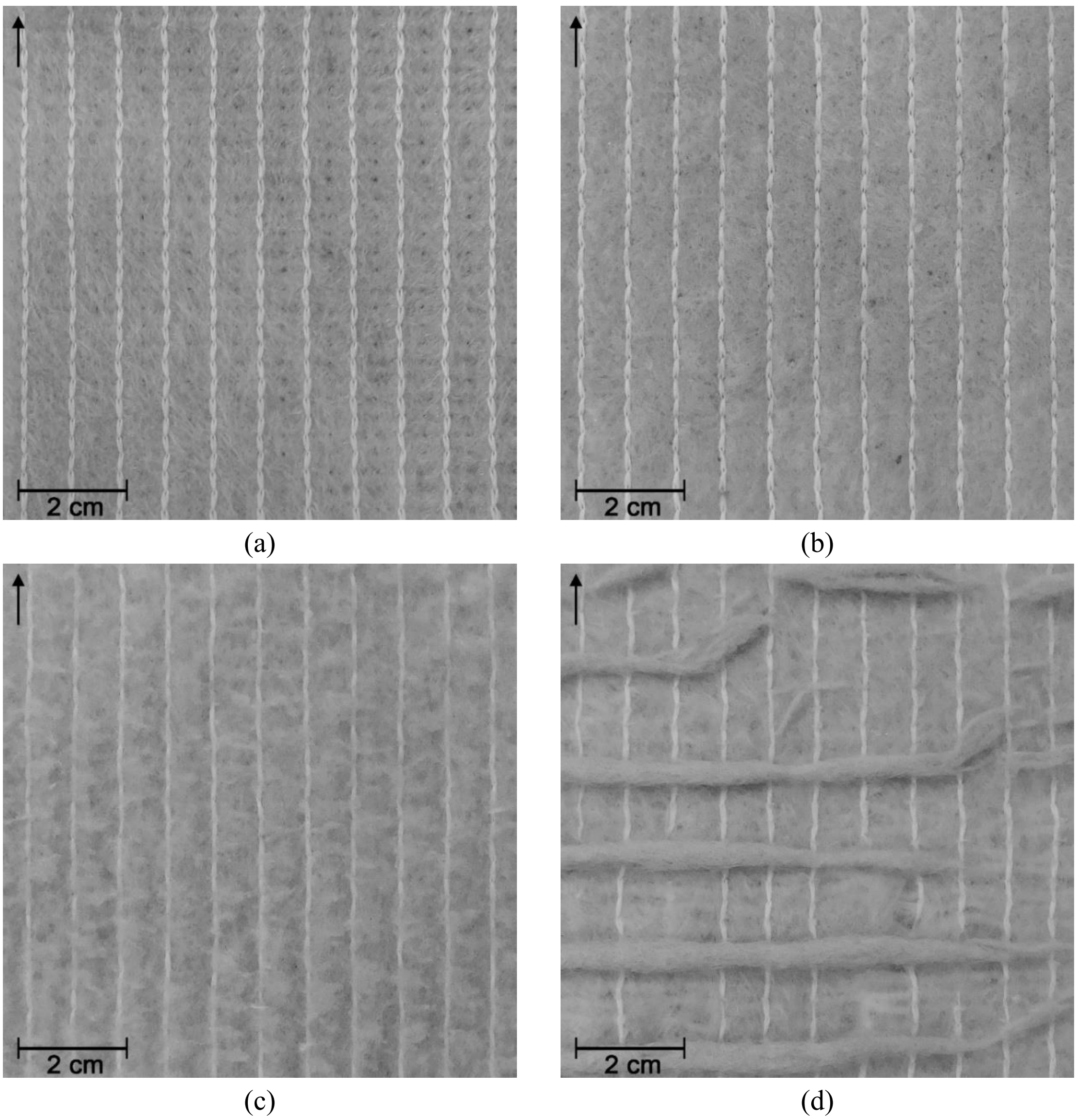


Figure 2. Visual analysis of the geocomposite tested on the side without filaments: (a) undamaged sample; (b) single exposure to MD; (c) single exposure to abrasion; (d) successive exposure to MD and abrasion (the arrow indicates the machine direction of production)

The abrasion tests caused the detachment and cut of fibres, resulting in the formation of small clusters of damaged fibres on the surface of the nonwoven geotextile (figure 2c). Most seams had the ability to withstand the action of the abrasive (only a small number of seams suffered damage). These defects, which were not highly pronounced, cannot be easily observed at the magnification of figure 2c, but a notorious change in texture can be seen compared to the undamaged sample (figure 2a). Regarding the filaments (which were on the other side), no relevant damage was found. This was an expected outcome since there was no contact between the filaments and the abrasive (the nonwoven geotextile, which was the element of the geocomposite directly exposed to the abrasive, protected the filaments from degradation). Indeed, and contrary to the MD tests, the damaging actions in the abrasion tests are mostly induced on one side of the specimens.

The successive exposure to both degradation tests had the most relevant impact on the geocomposite, leading to the formation of small holes and the detachment and cuts of fibres on the nonwoven geotextile (figure 2d). The fibres that were detached formed clusters significantly larger than those observed after the single exposure to abrasion. In addition, some seams were broken, resulting in potential weak points on the arrangement of the filaments. The defects found in the side with filaments were identical to those observed after the single exposure to MD (it is worth remembering that, contrary to abrasion, the MD tests are able to induce damage simultaneously on both sides of the geocomposite).

The different defects found in the geocomposite readily indicated the occurrence of relevant changes in its tensile behaviour, highly affecting its reinforcement function. To quantify those changes, tensile tests were performed, being the results presented in the following section.

3.2. Tensile behaviour

3.2.1. Undamaged samples. The damage suffered by the geocomposite during the degradation tests was quantitatively characterised by comparing the tensile behaviour of damaged and undamaged samples. A typical tensile force-elongation curve of an undamaged specimen can be seen in figure 3.

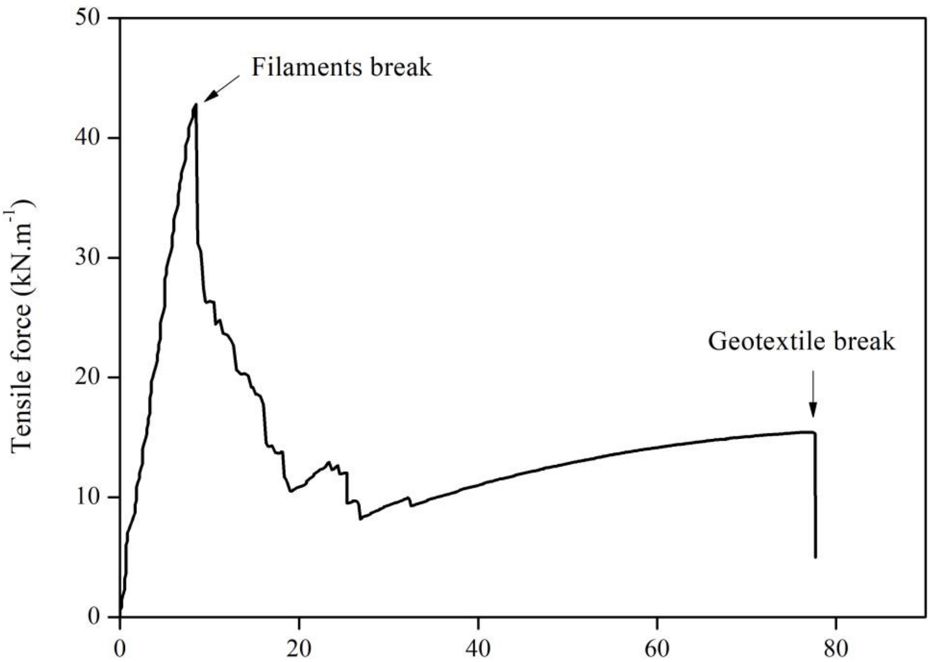


Figure 3. Tensile force-elongation curve of an undamaged specimen of the geocomposite

The tensile force-elongation curve shown in figure 3 reveals that the geocomposite undergoes two different peaks under loading. The first peak (maximum load of the geocomposite) corresponds to the break of the PET filaments (with low deformability) and occurs at a relatively low elongation (≈ 10%). Following the failure of the filaments, the nonwoven polypropylene geotextile (with high deformability and low mechanical strength compared to the filaments) is mobilized. The second load peak, which is observed at high elongations (≈ 70-80%) corresponds to the failure of the nonwoven geotextile. For the undamaged sample, the tensile strength and the elongation at maximum load of the geocomposite were of, respectively, 42.42 (±2.46) kN.m^{-1} and 10.4 (±0.5) % (tensile properties determined in the machine direction of production; 95% confidence intervals shown in brackets).

3.2.2. Side with filaments. The degradation tests caused considerable changes in the tensile behaviour of the geocomposite (when tested on the side with filaments) (table 1). Despite seeming to be much less aggressive than abrasion, the single exposure to MD had a significant impact on the tensile strength of the geocomposite (loss of 45.0%). This reduction in resistance can be associated with the rough nature and angular shape of the particles of *corundum*, which had the capacity to induce cuts on the filaments of the geocomposite, affecting its tensile strength. Despite the lower tensile strength, and considering the 95% confidence intervals, no relevant modifications were found in elongation at maximum load.

Table 1. Tensile properties of the geocomposite tested on the side with filaments.

Degradation test	T (kN.m^{-1})[a]	E_{ML} (%)[a]	$T_{Residual}$ (%)	RF
MD	23.31 (±2.28)	9.2 (±2.2)	55.0	1.82
Abrasion	15.45 (±4.68)	90.3 (±15.1)	36.4	2.75
MD + abrasion	7.23 (±1.85)	28.2 (±14.2)	17.0	5.87

[a] 95% confidence intervals in brackets.

The tensile behaviour of the geocomposite was more affected by the single exposure to abrasion than to MD, which is consistent with the defects visually detected. Indeed, a reduction of 63.6% occurred in tensile strength, being the maximum load achieved at a high elongation (90.3%). This high elongation corresponded to the failure of the nonwoven geotextile, which was less damaged than the filaments and was now the most resistant element of the geocomposite. It is important to refer that the maximum load observed at the break of the filaments (which are responsible for the geocomposite being able to perform the reinforcement function) was 7.53 kN.m^{-1}, corresponding to 17.8% of the original tensile strength of the geocomposite. This low value is in agreement with the extensive damage presented by the filaments (figure 1c).

The successive exposure to MD and abrasion provoked the highest reduction in tensile strength (loss of 83.0%), which was not a surprise considering the aspect of the geocomposite noticed during the visual inspection (figure 1d). Indeed, the non-existence of a structure of filaments, as well as the holes found in the nonwoven geotextile, were indicators of such outcome. The maximum force was observed at an elongation of 28.2%, corresponding to the failure of the nonwoven geotextile (which was considerably damaged). The highly damaged filaments had practically no contribution for the tensile behaviour of the geocomposite.

3.2.3. Side without filaments. When tested on the side without filaments, the geocomposite also suffered relevant changes in its tensile properties (table 2). However, some relevant differences compared to the tests performed on the side with filaments were noticed.

The results obtained after the single exposure to MD were relatively similar, regardless of the side in which the geocomposite was tested. Indeed, losses in tensile strength of 45.0% and 41.9% were observed when the geocomposite was, respectively, tested on the sides with filaments and without filaments. The corresponding elongations at maximum load were also very close (respectively, 9.2% and 9.3%). Taking into account the defects visually detected in the geocomposite, this result was somewhat expected. As mentioned before, both layers of *corundum* induced damage to the geocomposite during the MD tests, independently of the side facing up during those tests.

Table 2. Tensile properties of the geocomposite tested on the side without filaments

Degradation test	T (kN.m^{-1})[a]	E_{ML} (%)[a]	$T_{Residual}$ (%)	RF
MD	24.65 (±2.87)	9.3 (±1.0)	58.1	1.72
Abrasion	36.94 (±1.19)	11.1 (±2.7)	87.1	1.15
MD + abrasion	23.31 (±2.86)	9.9 (±2.4)	55.0	1.82

[a] 95% confidence intervals in brackets.

Contrary to what happened after the single exposure to MD, the results obtained after abrasion were highly dependent on which side the geocomposite was tested (an expected outcome taking into account the defects found during the visual analysis). The loss in tensile strength was only 12.9%, a significantly lower reduction compared to the case in which the side with filaments was directly exposed to the action of the abrasive (reduction of 63.6%). In addition, the elongation at maximum load was 11.1% (having no relevant changes compared to the undamaged sample), in contrast with the higher elongation found when the geocomposite was tested on the side with filaments (90.3%). This lower deterioration of the tensile behaviour of the geocomposite can be ascribed to the fact that the filaments (elements with higher resistance) have not been directly exposed to the abrasive (suffering only minor damage as indicated by the relatively small loss in tensile strength), being protected by the nonwoven geotextile.

The impact in the tensile behaviour of the geocomposite induced by the successive exposure to MD and abrasion was not much different from the single exposure to MD. Indeed, the tensile strength and elongation at maximum load of the geocomposite were quite similar after those tests. This shows that the exposure to abrasion (carried out after the exposure to MD) had no relevant impact in the tensile behaviour of the geocomposite. Despite the defects found in the nonwoven geotextile (figure 2d), the filaments had no additional damage compared to the single exposure to MD (as visually detected and corroborated by the tensile tests). Similar to what happened in the single exposures to abrasion, the exposed side had a relevant influence on the degradation suffered by the geocomposite. In fact, the loss occurred in its tensile strength was of 45.0% when exposed on the side without filaments, contrasting with the loss of 83.0% when exposed on the side with filaments. In addition, elongation at maximum load had no considerable differences compared to the undamaged sample when the tests were carried out on the side without filaments (increase from 10.4% to 28.2% after the tests performed on the side with filaments). The lower degradation when exposed on the side without filaments can be explained, once again, by the inexistence of contact between the filaments and the abrasive during the exposure to abrasion (the nonwoven geotextile was the element exposed to the abrasive and, consequently, the one which suffered more damage).

3.3. Reduction factors

The results presented in the previous section shown that, in some cases, the tensile behaviour of the geocomposite was different depending on the side (with or without filaments) that was directly exposed to the degradation agents. With the results obtained for tensile strength, reduction factors were calculated for the isolated and combined effects of MD and abrasion (tables 1 and 2). The reduction factors obtained directly from the successive exposure to MD and abrasion were compared to those determined by the traditional method (multiplication of the reduction factors obtained for the isolated effects of MD and abrasion) for the combined effect of those agents (figure 4).

When tested on the side with filaments, the reduction factor calculated through the traditional method for the combined effect of MD and abrasion was 14.7% lower than its counterpart directly found in the successive exposure to those agents. In this case, the traditional method was unable to account properly (by underestimating) the combined effect of the degradation agents. By contrast, a similar comparison when the geocomposite was tested on the side without filaments shown that the traditional method was slightly overestimating the combined effect of MD and abrasion. Indeed, the reduction factor determined by the traditional method was 8.8% higher than that found in the successive exposure to the degradation agents, setting a conservative approach.

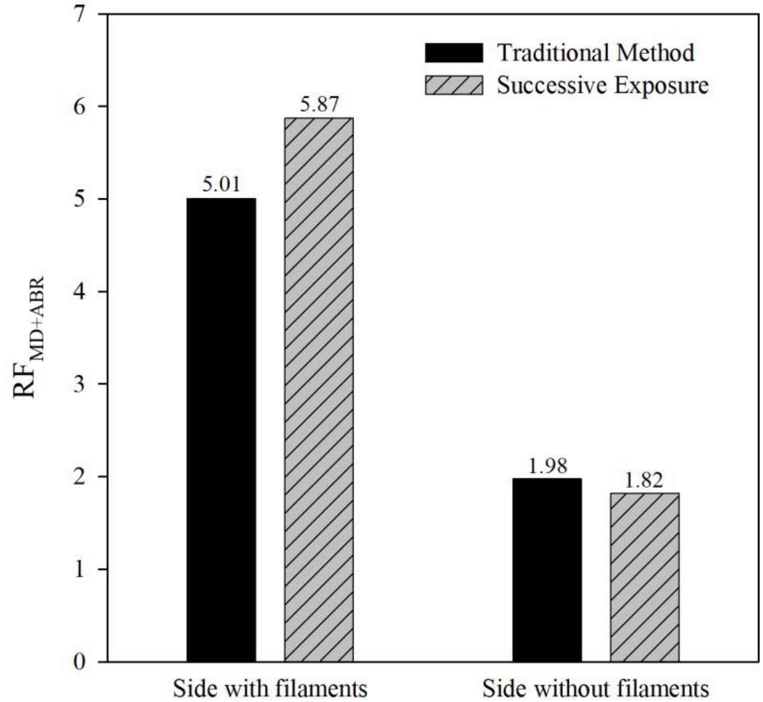


Figure 4. Comparison of the RF_{MD+ABR} obtained by the traditional method and from the successive exposure to mechanical damage under repeated loading and abrasion

The use of inaccurate reduction factors might result in an incorrect design. If conservative approaches are adopted, there are no strong reasons to question the normal behaviour of the structures in which the geosynthetics are installed. The same cannot prevail if the effect of the degradation agents is not properly accounted for, by underestimating. The reduction factors must represent correctly the combined effect of the degradation agents, taking into account the interactions (synergisms) that might occur between them.

4. Conclusions

The single and successive exposures to MD and abrasion induced considerable changes on the tensile behaviour of the geocomposite, compromising its ability to perform the reinforcement function. When tested on the side with filaments, abrasion was more damaging (higher impact in tensile behaviour) than MD. By contrast, the opposite occurred when the geocomposite was tested on the side without filaments. However, independently of on which side was tested, the MD tests induced similar changes on the tensile behaviour of the geocomposite. Therefore, the previous differences were due to the degradation caused by the abrasion tests, which was higher, or lower, depending on which side the geocomposite was tested. This can be ascribed to the characteristics of the MD and abrasion tests. Indeed, the MD tests can induce degradation simultaneously on both sides of the geocomposite (which was installed between two layers of *corundum*), while the abrasion tests can mostly induce degradation on the side directly exposed to the abrasive. This way, the PET filaments (most resistant elements of the geocomposite) were much more damaged when exposed to the abrasive than when protected by the nonwoven geotextile. It is worth referring that no relation has been researched between the standardized laboratory abrasion tests (EN ISO 13427 [9]) and the effects of abrasion under real degradation conditions (which might be different).

The comparison between the reduction factors determined by the traditional method for the combined effect of mechanical damage under repeated loading and abrasion with those obtained directly from the successive exposure to both degradation agents shown the existence of some differences, although not pronounced. It appears that, as found in similar works for other geosynthetics [12,13,15], the traditional method may not always be able to represent accurately (by underestimating) the combined effect of MD and abrasion, since interactions (synergisms) may occur between those agents. This was observed when the geocomposite was tested on the side with filaments, but not when tested on the side without filaments (in which the abrasion tests had a low impact on the PET filaments and, therefore, a limited influence in the tensile strength of the geocomposite). Finally, it is important to underline that the degradation tests were performed under particular conditions that might not be representative of the field conditions and, thereby, the reduction factors determined in this work should not be considered for design purposes.

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