

Durability of polypropylene geotextiles exposed to several degradation agents – Importance of the incorporation of a chemical stabilizer on the geotextiles formulation

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ABSTRACT: Geotextiles applied in civil engineering structures can suffer changes on their resistance caused by an extended exposure to many physical and/or chemical agents. As geotextiles must perform specific functions for a long period of time, it is very important to evaluate their resistance against such degradation agents. This paper studies the resistance of non-woven polypropylene geotextiles (specially manufactured with different amounts of the additive chimassorb 944) against immersion in acid and alkaline solutions, hydrolysis, thermo-oxidation and artificial weathering. The tensile behaviour of the geotextiles exposed to the degradation agents was analysed and compared with those obtained for unexposed materials. Microscopic changes on the polypropylene fibres caused by exposure to the degrading agents were characterised by scanning electron microscopy. An analytical methodology was developed for the analysis of chimassorb 944 on geotextiles and used to monitor the consumption and/or loss of this additive during the different durability tests.

1 INTRODUCTION

The degradation that geotextiles (GTXs) will suffer during their service lifetime is a major concern for the right application of these materials in civil engineering structures. Agents of degradation are many and include: weathering, oxidation, thermal degradation, direct attack by chemical substances like acids and alkalis, hydrolysis and biological degradation. An extended exposure to such degradation agents can cause a negative impact on the physical, chemical, mechanic and hydraulic properties of the GTXs, affecting their durability and, consequently, their useful lifetime.

Thermal degradation is induced by the energy supplied by heat and involves the dissociation of molecular bonds along the polymeric chains of the GTXs. However, it is almost impossible to have pure thermal degradation because oxygen is often present. So, thermal degradation usually occurs by a thermo oxidative mechanism (thermo-oxidation).

GTXs exposed to weathering conditions are damaged by sunlight (mainly due to the UV radiation), combined with the oxidative effects of atmospheric oxygen and the hydrolytic effects of water. Sunlight degradation occurs when the energy from UV radiation breaks down the chemical bonds within the polymeric structure of the GTXs. In the presence of oxygen,

this light-initiated process is called photo-oxidation.

In order to prevent or retard the damaging effects of thermo-oxidation and photo-oxidation, chemical additives (such as pigments, antioxidants and UV stabilisers) are often incorporated on the polymeric matrix of the GTXs. Chimassorb 944 (an hindered amine light stabiliser) is an example of a chemical additive used in the stabilisation of polyolefins against the damaging effects of oxygen and UV radiation.

2 EXPERIMENTAL DESCRIPTION

2.1 Geotextiles

Polypropylene (PP) fibres with different amounts of chimassorb 944, 0.2% and 0.4% (*w/w*), were specially manufactured to produce needle punched non-woven GTXs (280 g.m⁻²). A non-stabilized GTX was produced from PP fibres without any chimassorb 944 (C944).

2.2 Immersion tests

GTXs were immersed in acid (sulphuric acid) and alkaline (calcium hydroxide and sodium hydroxide) solutions at different temperatures (60°C and 90°C) during 3 or 7 days (Table 1). GTXs were also immersed in water at 95°C during 28 days.

Table 1. Experimental conditions of the immersion tests.

Immersion test	Degradation agent	Test conditions
Acid I*	H ₂ SO ₄ (0.025 mol.L ⁻¹) pH ≈ 1,6	3 days, 60°C
Acid II	H ₂ SO ₄ (0.1 mol.L ⁻¹) pH ≈ 1	7 days, 90°C
Alkaline I*	Ca(OH) ₂ (2.5 g.L ⁻¹)*** pH ≈ 12,4	3 days, 60°C
Alkaline II	NaOH (0.1 mol.L ⁻¹) pH ≈ 13	7 days, 90°C
Hydrolysis**	H ₂ O pH ≈ 7	28 days, 95°C

*according to EN 14030: 2001

**according to ENV 12447: 1997

***saturated solution; solubility [Ca(OH)_{2(25°C)}] ≈ 0.87 g.L⁻¹

After immersion, the specimens were washed (in order to remove the acid or alkaline solutions) and were dried during 7 days in the absence of light.

2.3 Thermo-oxidation tests

Oven ageing tests at 110°C (circulating air, 21% O₂) were carried out to study the resistance of the GTXs to thermo-oxidation. Stabilised GTXs were exposed during 14, 28, 42 and 56 days, while the GTX without C944 was only exposed for 4, 7, 9 and 11 days. After the test, the GTXs were conditioned at least for 24 hours in a dry place and in the absence of light.

2.4 Weathering tests

GTXs were exposed to artificial weathering conditions (UV radiation and rain) in a laboratory weatherometer (QUV/spray, Q-Panel Lab Products). Fluorescent UV lamps (UVA-340) were used to simulate the UV radiation emitted by sunlight (UV step), while rain was simulated by a direct water spray against the GTXs surface (spray step). The water used in the spray step (flow of 5 L.min⁻¹) was treated microbiologically and purified by reverse osmosis followed by deionisation on ionic exchange columns. The spray step causes a thermal shock on the GTXs (the temperature decreases rapidly from 50°C to 24°C) and can also cause mechanical erosion on the materials surface.

The GTXs were submitted during 362 hours to the following weathering cycle:

Step 1: UV exposure (50°C, 5 hours)

Step 2: Water spray (thermal shock, 10 minutes)
(Return to step 1)

During the 362-hour test, the GTXs were exposed to a total irradiance of 50 MJ.m⁻² (according to EN 12224: 2000). After the weathering test, the GTXs were dried for 7 days in a dark place.

2.5 Tensile tests

The mechanical properties (tensile strength and elongation at break) of the exposed GTXs were

Table 2. Experimental conditions used on the tensile tests.

Tensile test	EN 29073-3	EN 10319
Specimen width	50 mm	200 mm
Specimen length*	200 mm	100 mm
Number of specimens	5	5
Test velocity	100 mm.min ⁻¹	20 mm.min ⁻¹
Temperature	20 ± 2°C	20 ± 2°C
Relative humidity	65 ± 5%	65 ± 5%

*between jaws

determined (in the machine direction of production) according to EN 29073-3 (for specimens from immersion tests and weathering tests) and according to EN ISO 10319 (for specimens from the oven ageing test) and the obtained results were compared with those obtained for unexposed materials.

2.6 Analytical determination of chimassorb 944

A fast and simple analytical methodology was developed for the analysis of C944 on the GTXs. An ultrasonic extraction with chloroform at 60°C was applied for the isolation of C944 from the GTXs polymeric matrix and quantitative analysis of the additive was performed by UV spectroscopy.

3 RESULTS AND DISCUSSION

3.1 Immersion tests

After the immersion tests, no visible changes were noticed on the GTXs. Scanning electron microscopy (SEM) analysis confirmed the inexistence of major modifications on the PP fibres. The tensile strength of the GTXs remained practically unchanged after the different immersion tests (Table 3).

Although no significant changes were observed on the tensile strength of the GTXs, the additive C944 was lost and/or consumed during the immersion tests (Figure 1). So, an extended contact with liquids (acids, alkalis or water) can reduce the concentration of C944 and, consequently, reduce the protection of the GTXs against further degradation agents.

3.2 Thermo-oxidation tests

The GTX without C944 did not resist to the oven ageing test. After 9 test-days, the GTX without C944

Table 3. Retained strength of the GTXs after the immersion tests.

Immersion test	GTXs retained strength (%)		
	0% C944	0.2% C944	0.4% C944
Acid I	101	99	100
Acid II	91	97	102
Alkaline I	99	102	97
Alkaline II	94	99	102
Hydrolysis	99	102	98

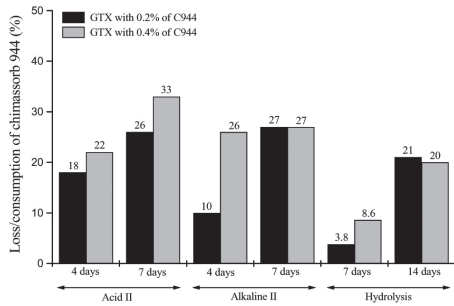


Figure 1. Loss and/or consumption of the additive C944 during the immersion tests.

was yellowish (originally it was white) and could be easily reduced into small pieces or powder (Figure 2). The degradation process was accompanied by a loss on the GTX mass (loss of 6% after 11 days) and by a reduction on the GTX dimensions (reduction of 12% after 11 days).

The tensile strength of the GTX without C944 was reduced to zero after 9 test-days, while the tensile strength of the stabilised GTXs remained practically unchanged during the 56 test-days (Figure 3). This shows the importance of C944 in the active protection of the PP fibres against the damaging effects of thermo-oxidation.

The GTXs stabilised with C944 maintained their mass and dimensions during the 56 test-days. SEM analysis of the stabilised GTXs showed the inexistence of microscopic changes on the PP fibres morphology.

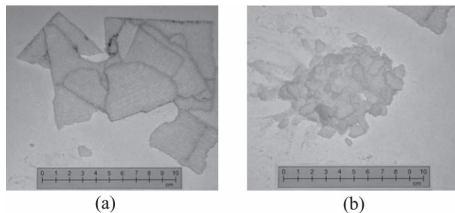


Figure 2. Small pieces (a) and powder (b) of the GTX without C944 after 11 days of thermo-oxidation.

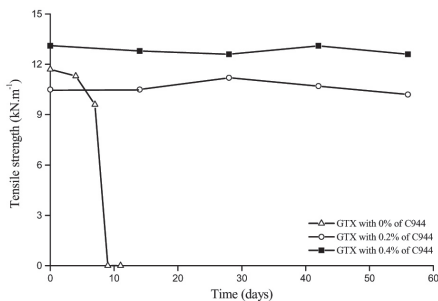


Figure 3. Evolution of the GTXs tensile strength during the thermo-oxidation test.

The oxidation of the GTXs was retarded or inhibited by the incorporation of C944 on the PP fibres. A low quantity of C944 (0.2%) was sufficient to achieve a good protection against oxidation induced by heat. As consequence of its protective function, C944 may be consumed and/or lost when preventing the oxidation of the GTXs. Indeed, the level of C944 on the PP fibres decreased during the thermo-oxidation period (Figure 4).

3.3 Weathering tests

The PP fibres without C944 depolymerised completely and the corresponding GTX was reduced into small pieces or powder during the weathering test. The GTXs stabilised with C944 (0.2% and 0.4%) were not destructed during the weathering test, which shows the importance of the incorporation of C944 on these materials. Although the stabilised GTXs did not present visible signs of degradation, a considerable reduction on the tensile strength and elongation at break of these materials was observed (Table 4). The mean curves strength-elongation obtained for the GTXs exposed to the weathering test are illustrated on Figure 5.

The decrease on the GTXs tensile strength and elongation at break shows that even stabilised GTXs are not fully protected against degradation by weathering. SEM analysis of the GTXs showed the degradation that occurred on the PP fibres stabilised

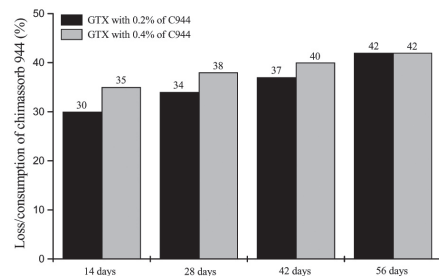


Figure 4. Loss and/or consumption of the additive C944 during the thermo-oxidation test.

Table 4. Tensile strength, elongation at break and retained strength of the GTXs before and after the weathering test.

GTX	Tensile strength (kN.m ⁻¹)	Elongation at break (%)	Retained strength (%)
Intact	12.7 (8.1%)	77.4 (8.2%)	–
0%	0.0 (0.0%)	0.0 (0.0%)	0
0,2%	6.0 (11%)	40.0 (9.1%)	47.2
0,4%	9.5 (9.0%)	40.0 (10%)	74.8

(in brackets are the obtained coefficients of variation, 5 samples)

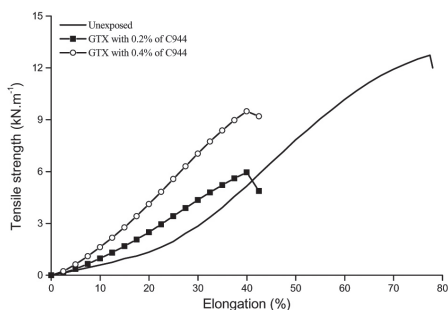


Figure 5. Mean curves strength-elongation for the GTXs exposed to the weathering test.

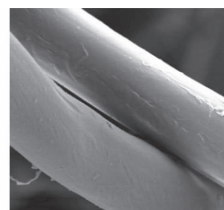
with C944 (Figure 6). The fibres stabilised with 0.4% of C944 were not as damaged as the fibres stabilised with only 0.2% of C944, what is in agreement with the previous tensile results. A higher concentration of C944 on the PP fibres resulted in a better protection against the damaging effects of weather.

4 CONCLUSIONS

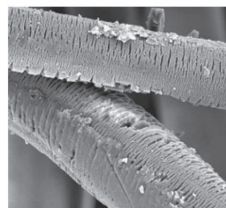
The tensile strength of the GTXs immersed in acids, alkalis and water remained practically unchanged after the tests. However, an extended contact with such liquids caused a decrease on the concentration of C944, that reduces the GTXs protection against further degradation agents.

The GTX without C944 did not resist to the oven ageing test and to the weathering test, being reduced into small pieces or powder. Contrarily to what happened after the weathering test, the tensile strength of the GTXs stabilised with C944 (0.2% and 0.4%) remained unchanged after the oven ageing test. Due to its protective function, C944 was consumed and/or lost when preventing the GTXs thermo-oxidation.

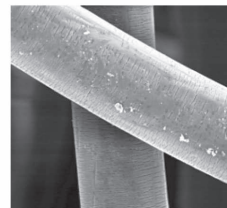
Although stabilised GTXs were not completely destructed by the weathering test, a considerable reduction on the resistance of these materials was observed. This shows that even stabilised GTXs are not fully protected against the damaging effects of weather. However, a better protection against weathering was achieved by the incorporation of a higher concentration of C944.



(a)



(b)



(c)

Figure 6. SEM photographs ($\times 1000$) of the GTXs before (a) and after weathering: (b) GTX stabilised with 0.2% of C944; (c) GTX stabilised with 0.4% of C944.

C944 proved to be extremely important in the stabilisation of the PP fibres against the deleterious effects of oxidation induced by heat and weathering (principally against photo-oxidation). Therefore, the incorporation of chemical stabilisers, such as C944, in the GTXs formulation is essential to extend the service lifetime of these materials.

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