

Evaluation of the Degradation of Polypropylene Geotextiles under Real Coastal Conditions and UV Radiation Exposure

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Abstract. Geotextiles are permeable polymeric fabrics used in coastal protection to allow water flow while retaining fill material. These materials are usually minimally exposed to solar radiation (UV) and other atmospheric agents, often being covered by soil or liquids. However, exposure during installation can cause degradation. This study analyzed the impacts of weathering on a polypropylene geotextile exposed to different UV radiation conditions in Natal/RN, Brazil. The samples were exposed for 29, 58, and 90 days under four conditions: on a wooden table, on beach sand, immersed in seawater, and on beach sand submerged in seawater. After exposure, tensile strength tests were conducted. The results indicated that the transverse tensile strength of the exposed samples remained within the confidence intervals of the virgin geotextile ($50.92 \leq \mu \leq 56.46$ kN/m), suggesting no significant degradation during exposure. The samples immersed in seawater exhibited the lowest standard deviation in strength, with an average of 1.993 kN/m. On the other hand, the samples on beach sand submerged in seawater showed the lowest average strength, at 53.77 kN/m. In conclusion, exposure to coastal weathering during the studied periods did not significantly affect the geotextile's integrity.

1 Introduction

Geotextiles are permeable polymeric fabrics that allow water flow while retaining fill material [1]. For this reason, these materials offer several advantages for temporary coastal protection works, such as lower cost, reduced environmental impact compared to traditional materials like rocks, gravel aggregates, or precast concrete, as well as being easily removable in case of unforeseen adverse impacts [2].

Over the years, several authors have stated that the use of geotextiles has been growing in civil and environmental engineering projects [3,4,5,6,7], being widely applied in coastal protection structures as well as in embankments, roads, railways, lagoons, and retaining walls. Geotextiles are used to replace more traditional materials in civil engineering, as they have proven to be an excellent solution for the construction of different infrastructures [8].

According to [9], during the installation of geosynthetics, these materials are typically exposed to solar radiation (UV) and other atmospheric agents for short periods. However, the authors state that for coastal structures, geosynthetics may remain exposed to UV radiation for months. Exposure to UV radiation is one of the primary sources of degradation for

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polymeric materials, aggravated by solar radiation temperature, humidity, thermal shock, and other factors, leading to synergistic effects that degrade the polymeric chain [10].

Geotextiles are generally minimally exposed to UV radiation, as they are mostly covered by soil or liquids, being exposed only during the installation period, which can be enough to cause significant degradation. Depending on how they are applied, geotextiles can have an extended service life, lasting over 25 years [7,5]. [11] Investigated the microstructural degradation of geotextiles and geomembranes under UV radiation, concluding that the loss of strength of materials in contact with soil and water was greater than when exposed to open air. The fibers on the surface exposed to UV radiation showed disintegration, while those not exposed became denser.

There are two ways to assess the UV resistance of geotextiles: the first is through laboratory tests, using accelerated testing, and the second is through field tests. Field tests provide more accurate and reliable data, but they are more time-consuming. In these cases, laboratory meteorometers are often used, with exposure to open air [9,5].

This research aims to analyze a woven geotextile, made from polypropylene polymer, subjected to different modes of exposure to UV radiation.

Given the need to understand the factors caused by the harsh conditions of a coastal environment on a geotextile, this study analyzed a polypropylene geotextile exposed to different UV radiation conditions for the climate of Natal/RN. Simultaneously, samples were exposed to real climatic conditions: on a wooden table, resting on sandy soil, resting on sandy soil and immersed in seawater, and submerged in seawater.

To understand the impacts of harsh weather on a geotextile in a coastal environment, this research analyzed a polypropylene geotextile subjected to different exposures to UV radiation under the climatic conditions of Natal/RN. Samples were exposed to real conditions: on a wooden table, on sandy soil, on sandy soil immersed in seawater, and submerged in seawater.

2 Materials and Methods

2.1 Geotextile Characterization and Molding

The woven geotextile used in this research was made of polypropylene, with a nominal transverse strength of 50 kN/m (NBR ISO/10319). The unit mass was 271.2 g/m² as the average value for the samples prepared before the tensile test (Table 1).

Ten specimens measuring 10 cm x 10 cm were molded for the unit mass test according to NBR ISO 9864/2013. Ten specimens measuring 5 cm x 50 cm were prepared for the nominal tensile test in the transverse direction based on ASTM 5035:11 (2019). A total of 72 geotextiles were exposed to climatic agents, with dimensions of 35 cm x 60 cm.

Table 1. Unit Mass of Geotextiles

Sample	Side measurements (cm)		Area (cm ²)	Mass (g)	Mass per unit area (g/m ²)
1	9.95	9.95	99.00	2.72	274.75
2	9.95	9.95	99.00	2.68	270.71
3	9.90	10.05	99.50	2.72	273.37
4	9.95	9.95	99.00	2.72	274.75
5	10.00	9.95	99.50	2.72	273.37
6	9.95	10.00	99.50	2.68	269.35
7	10.00	9.90	99.00	2.67	269.70
8	10.00	10.00	100.00	2.70	270.00
9	10.00	10.05	100.50	2.68	266.67
10	10.00	10.00	100.00	2.70	270.00
Mean value					270.35
Standard deviation					2.66
Coefficient of variation (C.V.)					0.98

2.2 Exposure Site

For the degradation test, the 72 geosynthetic samples were exposed at the Department of Oceanography and Limnology (DOL) at UFRN, in the city of Natal/RN, with coordinates: Latitude: 5° 47' 42" S, Longitude: 35° 12' 34" W. The location is situated at an altitude of 30 meters (Fig. 1).

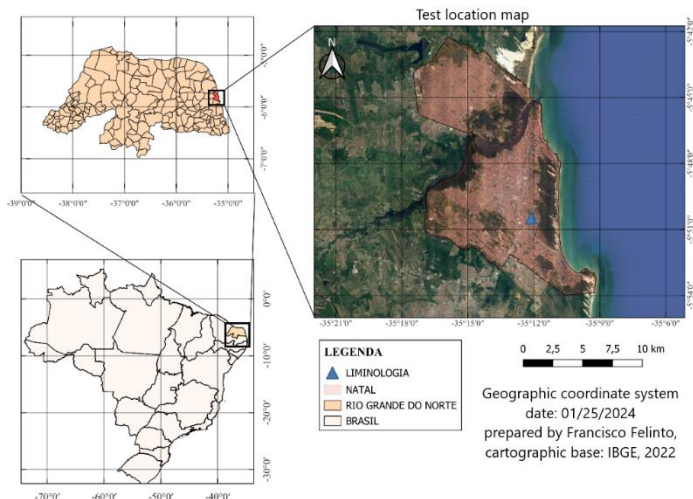


Fig. 1. Location

2.3 Material Exposure

The UV radiation exposure test was based on ASTM D5970/D5970M:16 and ASTM D1435:2013 standards. The samples were exposed for periods of 29, 58, and 90 days under

different conditions: on a wooden table inclined at 6° (GT), on beach sand (GS), immersed in seawater (GW), and on beach sand immersed in seawater (GSW) (Fig. 2). Weekly, at different times, temperature measurements were taken on the surface of the samples to compare the thermal range of the samples with that of the environment. At the end of each exposure period, residual tensile tests were performed on the samples, using the same method as for the nominal tensile test. The degradation of the specimens was assessed through statistical interference and the definition of confidence intervals.

The nomenclature used for each sample is highlighted in Table 2.



Fig. 2. Exposure location

Table 2. Indication of the sample nomenclatures

Group	Sample type	Subgroup	Exposure time (days)	N° of test specimens
G0	Intact	G0	0	10
GT	Exposure on a Wooden Table	GT1	29	6
		GT2	58	6
		GT3	90	6
GS	Exposure on Sand	GS1	29	6
		GS2	58	6
		GS3	90	6
GSW	Exposure on Sand Immersed in Seawater	GSW1	29	6
		GSW2	58	6
		GSW3	90	6
GW	Exposure Immersed in Seawater	GW1	29	6
		GW2	58	6
		GW3	90	6

2.4 Tensile Strength Test

The behavior of the intact geotextile and after field exposure was evaluated through unconfined tensile tests using the narrow strip method, according to ASTM D5035 (2019). The tensile testing speed was 300 mm/min.



Fig. 3. Tensile Test

3 Results and Discussion

3.1 Material Exposure Test

The geotextile did not show any visible signs of degradation to the naked eye under any of the conditions considered in this study. The total global radiation accumulated on the materials was 596.75 MJ/m², 1074.70 MJ/m², and 1586.00 MJ/m² for 29, 58, and 90 days, respectively (Table 3). Since it was determined that the total UV radiation accumulated was 7.5% of the total global radiation, the corresponding UV radiations were 44.76 MJ/m², 80.60 MJ/m², and 118.95 MJ/m². According to [5], in their study, visible damage to the geotextile started to appear at 138 MJ/m², while no damage was observed between 35 MJ/m² and 69 MJ/m². The authors reached the value of 138 MJ/m² in approximately 5 months, while in Natal/RN, this accumulated radiation would be reached in 3 months and 15 days.

Table 3. Indication of Sample Nomenclatures

Time (days)	Date (day/mon.)	Average relative humidity (%)	UV radiation energy (MJ/m ²)	Accumulated global solar radiation (MJ/m ²)	Accumulated rainfall (mm)
29	31/03 - 29/04	83.16	44.76	596.75	284.00
58	31/03 - 28/05	84.34	80.60	1074.70	694.60
90	31/03 - 29/06	84.25	118.95	1586.00	1018.80

3.2 Tensile Strength

The results of the tensile strength tests in the transverse direction, conducted on the samples before and after exposure, are presented in Table 4. The analysis of the confidence intervals indicates, with 95% certainty, that the mean values of the exposed material and the intact material showed no significant differences. This suggests that the exposed geotextile did not undergo significant degradation.

Since the resistance of the group G0 was considered as the resistance of the intact material, it can be observed that the samples submerged in seawater and placed on sand (GSW) showed the worst results. However, these results are close to the standard resistance presented in the G0 subgroup. For illustration, the tensile test curves are shown in Fig. 4.

The study presented in [12] addresses the degradation caused by UV radiation on polypropylene woven geotextiles, the same material used in this study. In their results, the confidence interval of the materials obtained sample values consistent with those of this study, showing no difference when compared to the virgin sample of this research. However, the virgin sample in their study had a higher resistance, ranging from 58.70 kN/m to 63.14 kN/m, highlighting a resistance reduction in their research. Their deformations were greater, with significant variations compared to those in this study, ranging from 36.06 kN/m to 39.92 kN/m for the samples after degradation.

Table 4. Transverse Tensile Strength Results of the Intact Samples

Subgrupo	Resistance (kN/m)	Standard deviation (kN/m)	Coefficient of variation (%)	Confidence interval (95 %) (kN/m)
G0	53.69	3.87	7.21	$50.92 \leq \mu \leq 56.46$
GT1	53.19	3.63	12.94	$49.38 \leq \mu \leq 57.20$
GT2	55.60	3.03	5.45	$52.42 \leq \mu \leq 58.79$
GT3	54.71	1.92	3.51	$52.70 \leq \mu \leq 56.72$
GS1	55.02	1.64	2.98	$53.30 \leq \mu \leq 56.74$
GS2	54.31	2.90	5.34	$51.26 \leq \mu \leq 57.35$
GS3	55.43	2.66	4.81	$52.63 \leq \mu \leq 58.22$
GSW1	55.29	1.82	3.30	$53.38 \leq \mu \leq 57.20$
GSW2	54.13	3.01	5.56	$50.97 \leq \mu \leq 57.29$
GSW3	51.89	2.44	4.70	$49.33 \leq \mu \leq 54.45$
GW1	56.05	2.44	4.35	$53.49 \leq \mu \leq 58.61$
GW2	56.05	1.55	2.76	$54.43 \leq \mu \leq 57.67$
GW3	54.76	1.99	3.63	$52.67 \leq \mu \leq 56.84$

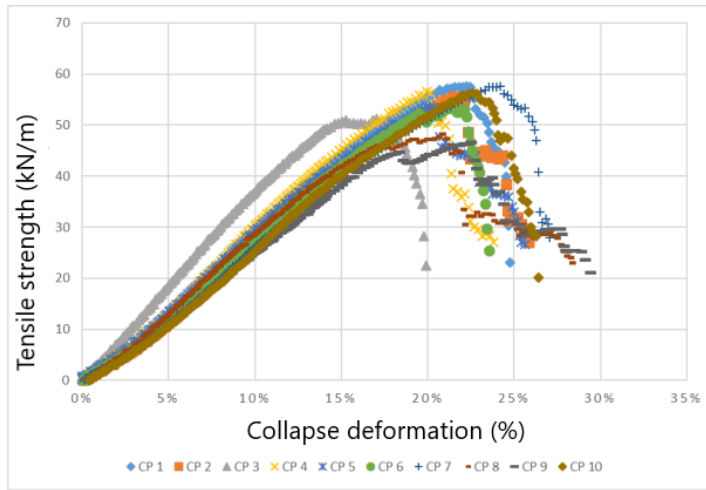


Fig. 4. Transverse Tensile Strength

Table 5 presents the deformation results at failure for the samples after the transverse tensile test. Figure 5 shows the confidence intervals discussed in Table 5. It confirms that the samples exposed to seawater and beach sand experienced greater deformations, although these were very small when compared to the intact geosynthetic.

Table 5. Deformation Results of the Samples

Subgroup	Deformation at collapse (%)	Standard deviation (kN/m)	Coefficient of variation (%)	Confidence interval (95 %) (kN/m)
G0	21.26	1.94	9.13	$19.87 \leq \mu \leq 22.65$
GT1	21.25	2.75	12.94	$18.37 \leq \mu \leq 24.14$
GT2	22.56	1.96	8.70	$20.50 \leq \mu \leq 24.62$
GT3	23.23	1.59	6.83	$21.56 \leq \mu \leq 24.90$
GS1	20.85	1.42	6.80	$19.36 \leq \mu \leq 22.34$
GS2	22.69	2.90	6.52	$21.14 \leq \mu \leq 24.25$
GS3	24.16	1.89	7.82	$22.18 \leq \mu \leq 26.14$
GSW1	20.81	2.00	9.62	$18.71 \leq \mu \leq 22.91$
GSW2	21.57	2.15	9.98	$19.31 \leq \mu \leq 23.83$
GSW3	21.63	1.38	6.38	$20.18 \leq \mu \leq 23.08$
GW1	21.65	2.70	12.46	$18.82 \leq \mu \leq 24.48$
GW2	24.58	1.82	7.39	$22.67 \leq \mu \leq 24.14$
GW3	23.81	1.00	4,21	$22,75 \leq \mu \leq 24.86$

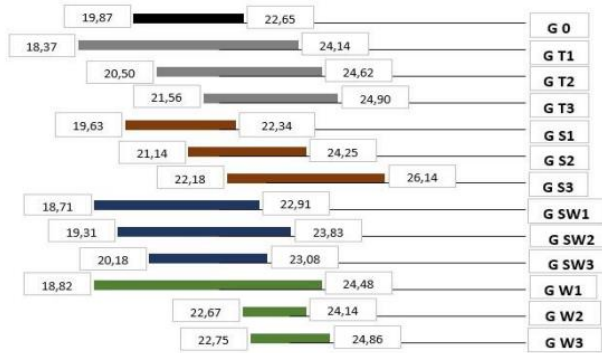


Fig. 5. Transverse Tensile Strength

4 Conclusions

The short-term aging tests for degradation did not result in significant changes in the physical properties or tensile strength of a polypropylene geotextile. This outcome is likely associated with the limited exposure period to environmental conditions. It is anticipated that visible deterioration would occur after approximately 3 months and 15 days of exposure.

Tensile strength and elongation at maximum load did not decrease over time, even under exposure. However, samples exposed to seawater or a combination of seawater and beach sand showed greater variation in tensile strength. In contrast, samples in contact with beach sand alone or placed on a wooden table exhibited minimal variations, maintaining values within the range of the intact geotextile. Similar findings have been reported in other studies using the same material, corroborating the results observed in this research.

The analyses conducted to evaluate the impact of weathering on a geotextile exposed to a coastal environment yielded conclusive results. During short exposure periods, contact with seawater and beach sand does not significantly affect the material's tensile strength, at least within a maximum duration of 3 months, which is typically the exposure time in earth-moving projects.

Although it is possible to estimate the time required for the material to start deteriorating, further results from long-term field applications are essential. Alternatively, these effects can be simulated in laboratory conditions. While it is not feasible to fully replicate certain external factors that influence the degradation process, laboratory studies have already proven effective in providing relevant insights for this type of research.

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