Procedure to determination of durability parameter in geosynthetics

Procédure de détermination du paramètre de durabilité dans les géosynthétiques

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ABSTRACT: This research aimed to analyze geosynthetics in terms of durability. Four samples of polypropylene and polyester woven geotextiles were obtained and separated into two lots. One lot was exposed to natural degradation in the field, whereas the other was exposed to accelerated degradation in the laboratory. After degradation, the materials were submitted to mechanical properties by the wide-width strip method. The tensile results for the materials degraded until 100 days in the laboratory and those degraded for 2 years in the field were found an exponentially behavior. During this time, the resistance decreased until stabilize the value. This paper presents a model that defines the variation of tensile strength over time. For this, two durability parameters were introduced that reflect the characteristics of durability and alterability. The proposed model allows prediction the long-term behavior and was constructed by simulation of the accelerated degradation process in the laboratory. The results indicate the application potential of the model for predicting the lifetime of geosynthetics. It is noteworthy that this model was applied in rock materials by Dias Filho *et al.* (2016), showing good correlations.

RÉSUMÉ: Cette recherche visait à analyser les géosynthétiques en termes de durabilité. Quatre échantillons de polypropylène et de géotextiles tissés en polyester ont été obtenus et séparés en deux lots. Un lot a été exposé à une dégradation naturelle dans le champ, tandis que l'autre a été exposé à une dégradation accélérée en laboratoire. Après dégradation, les matériaux ont été soumis à des propriétés mécaniques par le procédé à bande large. Les résultats de la traction pour les matériaux dégradés jusqu'à 100 jours en laboratoire et ceux dégradé pendant 2 ans dans le domaine ont été trouvés un comportement exponentielle. Pendant ce temps, la résistance a diminué jusqu'à stabiliser la valeur. Cet article présente un modèle qui définit la variation de la résistance à la traction dans le temps. Pour cela, deux paramètres de durabilité ont été introduits qui reflètent les caractéristiques de durabilité et d'altérité. Le modèle proposé permet de prédire le comportement à long terme et a été construit par simulation du processus de dégradation accélérée en laboratoire. Les résultats indiquent le potentiel d'application du modèle pour prédire la durée de vie des géosynthétiques. Il est à noter que ce modèle a été appliqué dans des matériaux de roche par Dias Filho *et al.* (2016), montrant de bonnes corrélations.

KEYWORDS: Durability parameter, accelerated UV test, outdoor exposure, weathering, geosynthetic, woven geotextile.

1 INTRODUCTION

The main intrinsic characteristics that affect the durability of polymeric geosynthetics are their formulation, possible additives, the geometry of the fibers and the quality of bonds. Already extrinsic characteristics are associated to the environment that this material will be exposed subject to local weather and other possible exogenous actions. These factors directly affect the ability of geosynthetics to maintain its properties in design for the desired time. However, the analysis of geosynthetics durability is an important aspect to be considered according to each project, especially as the prolonged contact with change agents, which can cause premature aging. Figure 1 shows the steps involved in the geosynthetic design implementation and analysis where durability or lifetime is initiate.

1.1 *Laboratory testing procedures*

The procedures for durability studies permit to analyze the variation of the long-term behavior of the properties of the materials exposed to degradation agents.
The tests to evaluate durability are chosen in accordance with the research objective and the type of material. Experience and research determine the proper testing procedures.

1.2 *Objectives*

This paper aims a critical analysis of laboratory testing procedures to define the properties of woven geotextile by UVB radiation exposure. and apply a model created by Dias Filho *et al.* (2016a), applied in rock materials, for analysis of index durability.

2 METHODS

2 .1 *Standard tests*

The standardized methods ISO/TS 13434 (2008) and ASTM D5970 (2009) treat the subject with the necessary procedures for natural exposure geosynthetic samples. The objective of the method is to provide the user with a standard by which to evaluate the degradation of the weather with emphasis on solar energy from a location in terms of geotextile lifetime, not in terms of incident radiation from the exposure. Thus, due to the climate variability in the world, a direct comparison between test data obtained from different exposure sites is difficult. In order to perform any type of comparison, the total daily solar ultraviolet radiant energy and accumulated during the time of natural exposure in the field, must be measured during the exposure period. However, the effects of temperature and humidity can't be incorporated in the comparison.

2.2 *Distinct tests*

From the standard methods, some authors analyze the interaction of more than one standardized procedure for the evaluation of durability. These methods make analysis of geosynthetic display synergy in more than one degradation mechanism as present work Gijsman and Sampers (1997) with thermo oxidation and ultraviolet Diesing *et al.* (1999) with natural exposure and immersion in acid at different temperatures, Benjamin et al (2008) with damage of installation and natural exposure, Guimarães et al (2015a) with fluency and natural exposure, Guimarães et al (2014) and Guimarães et al (2015b) with ultraviolet and immersion in acidic and basic solution. Dias Filho *et al.* (2016b) shows a methodology associating tests dedicated to the preparation of degraded or altered samples and tests devoted to determining the properties of durability and Dias Filho *et al.* (2016a) demonstrate a model for evaluating durability.

3 WEATHERING TEST

3.1 *Outdoor exposure*

The samples were exposed to the natural climatic conditions in Campos dos Goytacazes/RJ from August 2013 to August 2015 (Figure 2). The samples were installed on the support which has an inclination of 21°48' degrees in relation of the horizontal which correspond to the local latitude, 21° 48′ 14″ S and 41° 19′ 26″ W. This procedure ensures a higher incidence and, consequently, greater absorption of solar radiation by the material.

The degradation times in the field to be subjected to the tests set out in the experimental program were 90, 180, 270, 360 and 720 days.

Figure 1. Outdoor exposure.

The climatic characteristics of region during the tests of natural exposition were: maximum average temperature 33oC, the minimum average temperature 20oC, the altitude 14 m, 292 days of precipitation with a value accumulated of 1487,8 mm, relative humidity of 81%, the largest irradiation of solar energy accumulated by month was 847,7 MJ/m2 and 13,44 GJ/m² for the total irradiation of solar energy to two year of analysis.

3.2 *Accelerated UV test*

In the laboratory, the samples were degraded by condensation and ultraviolet radiation, which simulates the natural changes throughout the temperature variation between day and night; precipitation and UV radiation by the sun. The conditions replicate well the natural degradation process because they simulate with greater intensity the main mechanism of degradation in geosynthetics used in geotechnical design.

The degradation times accelerated in the laboratory to be subjected to the tests set out in the experimental program were 8, 16, 24, 32, 40, 80, 200, 400, 800, 1040, 2160 e 4800 hours.

3.3 *Durability parameter*

The creation of durability parameters was completed with the publication of Dias Filho *et al.* (2006a) showing the ways to characterize the material through the index, curve and model.

3.3.1 *Index*

The index is a comparison between the intact material and the degraded samples considering any property used in characterization. The calculation applies Equation 1, where I0 is a parameter of the intact material, and Id is a parameter of the degraded material. The index value I can vary from zero for the intact material to a maximum value, which is always less than 1 for the degraded material.

$$I = \frac{|I_0 - I_d|}{I_0} \quad (1)$$

3.3.2 *Curve*

Figure 2 presents the index curves over time for the samples degraded in the field and in the laboratory. The variables Iult and T_0 allow the correlation of the curves of the material behavior; $I'_{ult\ l}$ denotes the mass loss adjustment index for the laboratory samples, whereas T indicates how many times larger the ultimate degradation in the field is compared with the degradation in the laboratory (Figure 3).

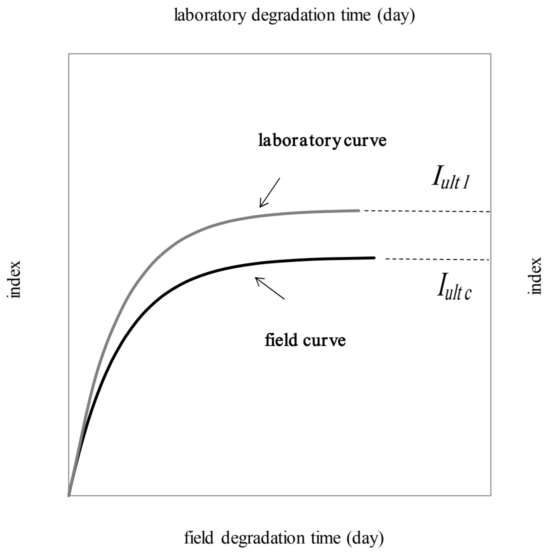

Figure 2. Mass loss index in the field and in the laboratory over time with the variables of loss mass I.

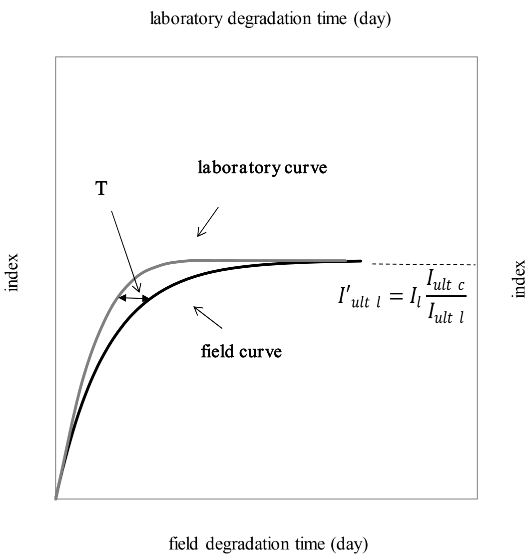

Figure 3. Adjustment and durability parameter T.

So, it is possible to determine the duration of laboratory exposure that replicates the desired exposure time in the built environment so as to predict the durability. The curve adjustment can be expressed by Equation. 2.

$$I=I_{ult}\left(1-e^{\frac{t}{T_0}}\right) \qquad (2)$$

3.3.2 *Model*

To determine the relation between the degradation time in the field and that in the laboratory (T), it is enough the inclination adjustment of the laboratory initial linear phase to the field. Then, the Ft value is determined by using Equation 3.

$$T=\frac{T_f}{T_l} \qquad (3)$$

3.4 *Test materials*

Four geotextile fabrics 2 in polypropylene monofilament and 2 Polyester multifilament, whose characteristics are shown in Table 1.

Table 1. Characterization of woven geotextiles tested.

Property	Values			
	H108	H105	C200	H200
Weight (g/m²)	340	500	740	925
Thickness (mm)	0,51	1,53	1,17	2,62
Tensile (kN/m)	52	106	149	155

4 RESULTS AND DISCUSSIONS

For the analyzes of parameters the mechanical strength data were used in the natural degradation in the field and accelerated in the laboratory. The comparison highlighted the results of stress, strain and stiffness. The following is the routine of each stage and the final characterization of durability according Dias Filho *et al.* (2016a).

4.1 *Index*

Table 2 and Table 3 shows the index values obtained for maximum tensile strength of the H108 with the parameters obtained for carrying out the curve in the field and laboratory.

4.2 *Curve*

The Figure 4 shows the variation curve of geotextile H108 resistance property with time.

Table 2. Characterization of field parameters.

Time		Tensile (kN/m)	Index	
days	hours		%	equation
0	0	52,00	0,00	0,00
90	2160	46,05	22,05	41,65
180	4320	22,09	63,12	64,24
270	6480	14,42	75,26	76,49
360	8640	6,81	79,40	83,13
720	17280	3,64	90,31	90,32
		R²	0,956	

Table 3. Characterization of laboratory parameters.

Index (hours)	Tensile (kN/m)	Index	
		%	equation
0	52,00	0,00	0,00
8	51,09	3,69	1,17
16	48,94	0,50	2,33
24	50,04	1,83	3,48
32	49,87	1,82	4,61
40	45,76	4,21	5,73
80	43,04	29,47	11,12
200	29,69	43,02	25,43
400	17,87	60,93	44,12
800	20,19	72,14	67,96
1040	10,90	82,08	76,62
2160	19,04	90,18	92,54
4800	11,32	97,11	95,94
	R²	0,985	

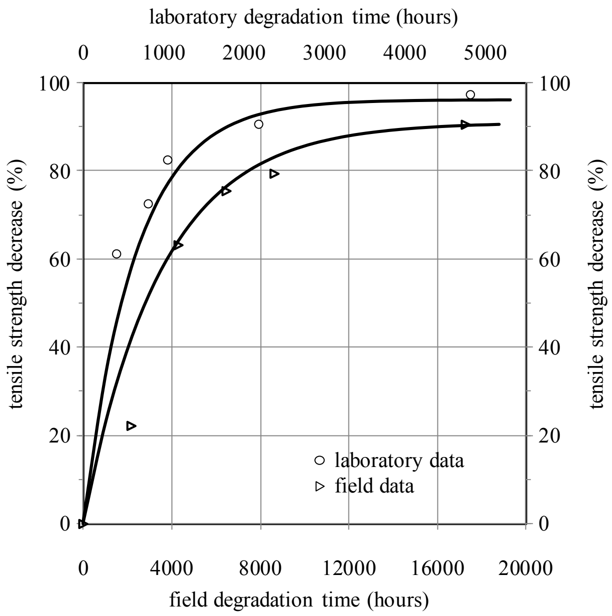

Figure 4. Relationship between the index I of the field and laboratory with time

4.3 *Model*

With the curves I_{ult} parameters, T_0 and T can be obtained according to the properties studied. From these data, it is possible to determine the prediction of material behavior. Table 4 presents the analysis of all indexes and parameters analyzed, including the durability of geotextile H108.

The parameter T tends to be the same regardless of the analyzed property. So, the durability parameters for woven geotextiles H018, H015, H200 and C200 were 5.2, 5.2, 4.2 and 6.4 respectively. From this relationship, it is possible to identify the weather service according to the design constraints, or in accordance with property limits chosen.

Table 4. Data base of indexes and parameters analyzed.

Parameter		Field			Laboratory			T
		I_{ult}	T_0	R^2	I_{ult}	T_0	R^2	
$\alpha_{máx}$	α	91	3530	0,95	96	650	0,98	5,4
	□	85	3600	0,89	88,1	700	0,86	5,1
	J_{sec}	39	2400	0,63	79	450	0,60	5,3
$\alpha_{10\%}$	□	95	4500	0,82	98	900	0,97	5,0
	J_{sec}	50	1200	0,83	87	240	0,57	5,0
	J_{tg}	60	4854	0,05	100	950	0,79	5,1
$\alpha_{50\%}$	□	97	5000	0,93	80	970	0,50	5,2
	J_{sec}	78	7052	0,58	90	1400	0,91	5,0
	J_{tg}	38	4500	0,46	100	840	0,02	5,4
						average	0,79	5,17
						standard deviation	0,17	0,16
						C.V	21,5%	3,2%

5 CONCLUSION

The methodology, which compares the behavior of the degradation material submitted in the field with the behavior of the material subjected to degradation in the laboratory, can objectively necessary parameters to predict the durability of the material studied.

This paper shows the possibility to analyze the variation of the long-term behavior with physical, chemical, chemical-physical and mechanical properties of the materials exposed to degradation agents through the correlation between the sample preparation on the field and in the laboratory. The test with parameters of mechanical properties shows values of durability indexes that allow to evaluate the durability of materials by the method with good results for each geotextile.

6 ACKNOWLEDGEMENTS

The authors thank UENF, CAPES, CNPq and HUESKER Brazil.

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