Review of accelerated aging methods for geotextiles

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Abstract. Accelerated aging methods are becoming increasingly common to evaluate geotextile properties in long-term behavior. Due to this, various manufacturers of these materials are asked to guarantee the useful life of the product, especially for components that cannot be easily inspected or may fail in service. Although the durability of geotextiles in non-demanding applications has traditionally been predicted from previous in-service experience, design for harsh environments or the long term requires a much better understanding of degradation mechanisms and the use of accelerated aging conditions to allow reliable useful life predictions to be made. Therefore, this paper aims to review accelerated aging methods according to the geotextile application environment that is commonly experienced in service and some techniques that have been developed for lifetime prediction in geotextiles according to different applications in engineering projects. The results of the review of the different papers analyzed show a clear division between conventional and non-conventional aging procedures. Moreover, characterization is defined according to the type of application of the geotextile. The review in this study, for geosynthetic design, provides general knowledge about accelerated aging methods using the main articles from the literature to evaluate the durability of geotextiles.

1 Introduction

From the first projects in the 1950s to the present day, there are few studies that have raised doubts about geotextile behavior in terms of their durability. Under certain circumstances (exposure to ultraviolet (UV) rays, hydrolysis and chemical and/or biological attack) and over time (due to mechanical damage, fatigue and creep), geotextile properties can change unfavorably. In fact, much of the uncertainty regarding geotextiles in engineering is generally related to durability and in-service performance. It is a well-known fact that geotextiles are very susceptible to inclement weather and must be protected from UV radiation. There is also a real concern with geotextiles, which is linked to fragility in the face of mechanical impact and vandalism [1-3].

Decreased strength due to mechanical damage, weathering, as well as chemical and biological degradation can result in poorer performance as a consequence of a loss of strength

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and function. Differences between geotextile materials are often related to the durability properties of the materials. However, due to the fact that some of the test results cannot be interpreted as a guarantee under normal operating conditions, but rather as a tool to select a suitable product with the proper service life, it is essential to evaluate products based on their performance in situ.

The extent to which the material loses performance determines its durability, which is also influenced by degradation processes during handling and in service. The term durability is also applied to refer to the capacity of the work to continue in operation at an acceptable level even after some of the materials used in its construction are in the process of degradation. During installation, there is a high probability that the material will suffer mechanical damage. In addition, storage and transport require special attention. Depending on location, there is also a risk of vandalism. All these factors can lead to a reduction in tensile strength, component failures and/or due to their effect on loss of functionality.

Thus, the origin of actions that affect the durability of geotextiles can be classified as anthropic or natural. While human actions can be minimized by greater control and materials management, natural actions require greater care regarding choosing the main base polymers, as well as their connection with project applications. Therefore, this paper reviews accelerated aging methods for geotextiles and provides a guide to methodologies that can help durability analyses in materials already applied in works or new materials available on the market.

2 Material and methods

2.1 Material

Geotextiles are produced from thermoplastic polymers, which include polyolefins, vinyls, polyesters and polyamides. According to [4], polypropylene (PP) is the most used polymer in the manufacture of geotextiles (85%), while polyester (PET) is the second most used polymer with a 12% mark. Based on this, Table 1 presents the main characteristics of PP and PET according to the properties required in the project.

Table 1. Properties required for equal weight (adapted from [5]).

Property	Polymers	
	PP	PET
Tensile strength	***	*
Elongation at rupture	**	***
Creep	*	***
UV resistance (not stabilized)	***	**
UV resistance	***	***
Resistance to base	*	***
Resistance to microorganisms	**	**

***high, **medium, *low

Among the main intrinsic characteristics that interfere with in the durability of geosynthetics, which are presented in Table 1, are its formulation and possible additives. The extrinsic characteristics are related to the environment to which this material will be exposed, subject to local weather and other possible exogenous actions. These factors directly interfere in the ability of geosynthetics to maintain their properties in design for the desired time. However, analyzing the durability of geosynthetics is an important aspect to be considered according to each project considering the prolonged contact with exogenous agents, which can cause premature aging.

2.2 Methods

2.2.1 Fundamental concepts

Durability is related to the ability to maintain properties throughout a geotextile's useful life. During this period, geotextiles are subject to exogenous agents, and in turn, this leads to the degradation of these materials and their response to degradation mechanisms characterizes their alterability. It should be mentioned that alterability is related to the ease with which material degradation occurs: susceptibility to degradation. When a certain analyzed property reaches the threshold value of interest, which defines an acceptable condition for the work, there is a threshold value for use. Exceeding this characteristic, design performance can drop dramatically or material collapse may occur.

2.2.2 Degradation in geotextiles

Despite the characteristics of the raw material, which are normally non-degradable in the short term, geosynthetics may be subject to rapid alteration, especially in works whose environment characteristics are aggressive, such as sanitary landfills, industrial tailing dams and containment of coastal and river erosion. It is noteworthy that degradation causes an irreversible change in the properties of polymeric materials, observed by the progressive deterioration of their properties, including their visual appearance.

The degradation of a geotextile can be caused by the action of one or more exogenous agents that are classified as physical, chemical and biological. Physical agents can be solar radiation or α, β and γ radiation, temperature, abrasion and mechanical damage. Chemical agents are water, acids, bases, solvents and other chemical agents, oxygen, ozone and atmospheric pollutants. As biological agents, they have actions of microorganisms, such as fungi and bacteria.

The accelerated degradation of geosynthetics normally occurs by the combination of different degradation agents, involving different degradation mechanisms such as oxygen and UV light, ultraviolet and temperature, temperature and oxygen, among others.

Thus, it is essential to study the transformations of geosynthetics due to degradation. These transformations can cause problems in the works and even make the use of certain types of materials unfeasible. Furthermore, the study of alterability can define the best way to use geo-synthetic materials and their susceptibility to degradation.

2.2.3 Characterization tests

The purpose of characterization tests is to obtain important parameters for design. There are conventional test methods (on intact materials, degraded in the field and degraded in the laboratory) and non-conventional test methods (tests in which parameters are obtained simultaneously with the degradation procedure). All of them can be classified into groups that analyze physical, mechanical, hydraulic and performance properties of geosynthetics.

The tests that characterize the physical properties most used in geotextiles are weight [6] and thickness [7]. In addition to these, optical microscopy is used to qualitatively analyze the texture, structure or biological activities through images, as well as spectrophotometry, which quantitatively analyzes the degradation through the breaking of bonds. It is also important to note that the tests use a small amount of sample.

Mechanical properties are obtained through a wide variety of destructive tests. Among them are the traditional tensile strength [8], the strip method [9] (ASTM D5035-11), multidirectional [10], punching [11], compressibility [12], tear propagation [13], burst [14], creep in traction [15] and compression [16].

The characterization in relation to the hydraulic properties are permittivity [17] and transmissivity [18], which evaluate the flow of water through the geotextile (perpendicularly) and in-plane without causing physical changes to the samples. On the other hand, in the filtration opening test [19] the characteristic diameter of the material is obtained, in which the geotextile ends the test with a little clogging due to the granular material used.

Finally, performance tests, which expose geotextiles to recurring situations in field applications, include exposure to agents of exogenous origin such as ultraviolet radiation [20], chemical [21] and biological [22], as well as anthropogenic sources such as shear [23], abrasion [24] and installation damage [25].

3 Results

Based on the different articles and standards, to show the review of accelerated aging methods for geotextiles (conventional and non-conventional), Figure 1 shows the five phases involved in predicting long-term behavior.

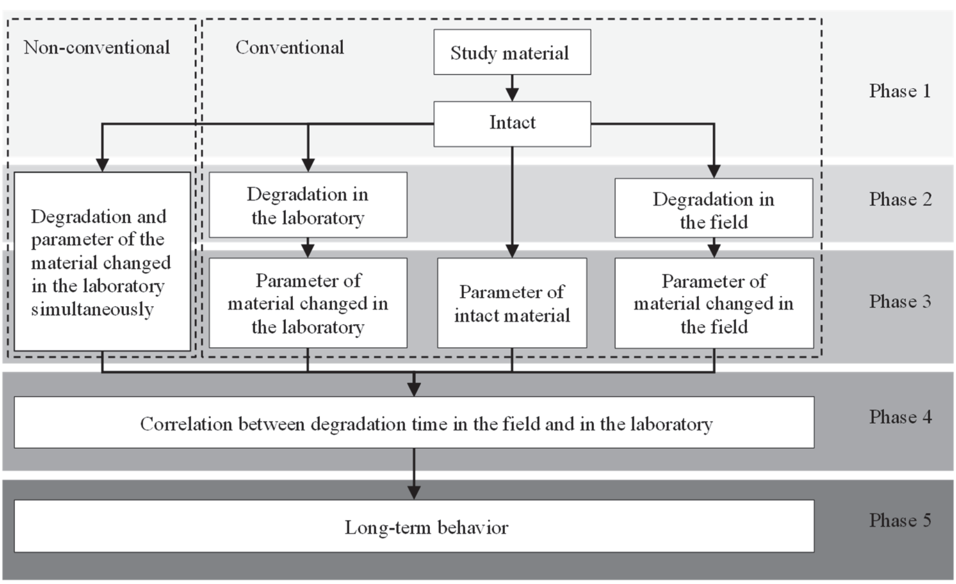

Fig. 1. Methodology to predict the long-term behavior of the geotextile [26]

Briefly, materials in intact (phase 1) and de-graded (phase 2) conditions are studied. A portion of the intact material is aimed at producing naturally altered samples in the field and another is for accelerated conditions in the laboratory (phase 3). Degraded materials are then used to determine the characteristic parameters (phase 4) and, consequently, the determination of durability (phase 5). The way in which the methods are used and their analyses can be divided between conventional or non-conventional methodologies and are presented below. While conventional methods stand out for traditional tests and the parameters are usually obtained after performing some degradation procedure, in non-conventional methods the parameters are obtained with a combination of effects between degradation procedures or simultaneously with the test used. The main characteristics of these methods are presented below with the main standards and papers in which the techniques are used, highlighting accelerated aging methods for geotextiles.

3.1 Conventional methods

Conventional methods use characterization tests to evaluate changes in geotextile properties after a degradation procedure, which can be natural or accelerated.

Natural degradation in the field refers to international references [27] and [28]. The method presents the necessary procedures for natural exposure to geosynthetics. The intention is to provide the user with a standard to assess weather degradation focusing on ultraviolet radiation from natural exposure in the field. Thus, due to the variability of the climate in the world, making direct comparisons between test data obtained from different exposure locations is difficult. In order to carry out any kind of comparison, the total and accumulated daily solar ultraviolet radiant energy during the natural exposure time in the field must be analyzed during the exposure period. It is worth mentioning that [29] describes the standard practice for accelerated outdoor weathering using concentrator equipment. This causes the sample to be exposed to an intensity approximately equal to eight times the radiation of natural sunlight.

Both [30] and [27] specify laboratory methods for accelerated degradation. The degradation procedures can change the properties of materials that are affected by some degradation agents or synergy between them more quickly and in less time. These include biodegradation [31], chemical degradation [32], creep by conventional [33] or stepped isotherm - SIM [34], mechanical damage [35], photodegradation [36] and thermal degradation [37]. It should be emphasized that there is a protocol for performing and analyzing the results of each laboratory procedure based on the main degradation mechanisms associated with the application of geotextiles in engineering projects.

3.2 Non-conventional methods

Some researchers have analyzed the interaction between standardized methods for long-term analysis based on conventional methods to analyze the synergy to more than one degradation mechanism of exposing geotextiles. There are various combinations of degradation mechanisms. Some examples of this study include studies involving thermal oxidation and UV radiation [36, 38], natural exposure and immersion in acid at different temperatures [39, 40], creep and natural exposure [41], installation damage [42] or immersion in acid and caustic solutions [43].

The choice of method will vary depending on the application of the geotextile in the project, which will often be affected by more than one degradation mechanism. The specific circumstances of the authors' study above created a need for testing and helped to better understand how synergies could contribute to material durability studies. It is important to emphasize that when designing structures using geotextiles, the effects of installation damage, creep and durability can be considered to evaluate their long-term performance.

4 Conclusions

This paper presented a review of accelerated aging methods for geotextiles presenting some studies and standards that allow for a durability analysis of the main geotextiles used.

Considering the main raw materials used for geotextiles, there is a greater use of PP and PET. Regardless of the base polymer, it is important to know its main characteristics to better target its application. Durability studies always evaluate the variation of geotextile properties according to the parameters of interest.

Regarding characterization, choosing the main test methods depends on the application of the material. Standards referring to physical, mechanical, hydraulic and performance properties are presented. There will always be a need to characterize geotextiles, whether for their design or alterability study.

The methodologies to predict the long-term behavior of geotextile presented the ways of evaluating the durability in a conventional and non-conventional way. The standards and main articles show that conventional tests continue to be widely used. However, it is worth highlighting that current studies, which adapt the methodology according to the application of geotextiles in projects, are a more appropriate form of characterization to evaluate durability.

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