Functional longevity of exposed geosynthetics

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Abstract. The time at which a geosynthetic's performance falls below established functional thresholds is known as the geosynthetic's functional longevity. As opposed to "durability" which commonly refers to an individual exposure environment such as UV exposure or a specific chemical exposure preceded and followed by an index test to quantify physical changes, functional longevity is the result of the synergistic effects of one or more exposure environments happening simultaneously or sequentially preceded and followed by a performance test. Therefore, functional longevity is characterized by a "suite" of durability tests and an accompanying performance test. Exposed geosynthetics, such as rolled erosion control products (RECPs) and engineered turf are the most common candidates for functional longevity characterization. In each case, exposures can include ultraviolet radiation, biodegradation, and damaging mechanical forces. These exposures inevitably degrade the geosynthetic over time. Yet, the important question is, when do the synergistic effects of the simultaneous or sequential exposures degrade the geosynthetic to the point where its performance falls below established thresholds? This question can only be answered by putting the candidate product through a relevant series of durability and performance tests. This paper describes a series of durability and performance tests being used to characterize the functional longevity of RECPs.

1 Functional Longevity vs. Durability

"How long will a material last?", or its durability, may be a very different question than "How long will a material perform?" This is especially true if there is no clear relationship between a specific material property and the material's actual performance in the "real world". The length of time a geosynthetic system can adequately perform its expected function is commonly referred to as its "functional longevity". While its performance may diminish over time as it is exposed to the application environment, it will still be performing "adequately" until its system performance falls below an established, sometimes arbitrary, threshold. "Durability" on the other hand, commonly refers to the adequate retention of one or more physical properties of the geosynthetic material itself when exposed to a specific environment. Durability can be much easier and less costly to determine, since it is typically based on exposing multiple pre-cut small specimens or coupons to a standard exposure, say ultraviolet radiation or chemical submergence, and then running an index test such as mass/area or tensile strength on a fraction of those small

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specimens at a range of exposure times. The retained mass or tensile strength versus exposure time is a description of the "durability" of the material. Functional longevity characterization relies on larger-scale system performance tests which typically incorporate larger samples installed in "real world" simulations, and use complex and repeated exposure events over time. This testing characterizes geosynthetic system performance rather than simply the durability of the geosynthetic material; thus it can be more costly, time consuming, and require more expansive facilities than durability testing.

Thankfully, the durability of most geosynthetics has been shown to be substantial, owing to the fact that geosynthetics are typically buried in moderate soil environments. Through both laboratory testing and field exposures these environments have not been shown to degrade geosynthetic materials, i.e. there is no loss of physical properties over years of both accelerated and real-time exposures. Thus, it is reasonable to assume that if there is no change to the material, there should be no related change in functional performance over time. But what about those cases where the geosynthetic is expected to degrade over time, such as surface applications that expose the geosynthetic to sunlight or aggressive microbes for extended periods?

1.1 Functional Longevity of Surface Exposed Geosynthetics

1.1.1 Exposed Geosynthetics

The durability and functional longevity of geosynthetics is known to be adversely affected by exposure to ultraviolet radiation, mechanical damage, and other conditions typical of surface exposures. Of course, geosynthetics can be formulated to provide more or less durability and functional longevity depending on the demands of the application.

For example, rolled erosion control products (RECPs), such as turf reinforcement mats (TRMs) and erosion control blankets (ECBs), may need to function for an indefinite time or they may need to "disappear" in a relatively short time. Specifically, TRMs are commonly used for channel lining and scour protection and are expected to remain intact for an extended period of time to first nurture vegetation growth and then reinforce mature vegetation against high water flows in channels. Thus, TRMs must be formulated for extended functional longevity. Conversely, ECBs - light-weight plastic nettings sandwiched around organic fibrous materials such as straw or coconut - are used to prevent slopes from eroding from raindrop impact and sheet-flow runoff and are only needed to help nurture germination and initial growth of vegetation until the vegetation alone can protect the slope. Thus, ECBs may be designed and manufactured to provide much shorter periods of functional longevity. In fact, a very short functional longevity may be important in the selection of ECBs so that the nettings don't interfere with the mowing of mature vegetation or contribute to wildlife entanglement.

1.1.2 The Need for Functional Longevity Testing

As noted earlier, it is important to remember that characterizing a geosynthetic's durability, i.e. how long it retains certain properties, is not the same as knowing how long it will adequately function in the "real world" – it's functional longevity. To-date, designers generally rely on experiential evidence – most often provided by product suppliers – to "estimate" functional longevity for the purpose of deciding what geosynthetic to use in a given exposed application. This system of estimated functional longevity is inadequate for designers, specifiers, and end users.

Generally, exposed geosynthetics that provide greater functional longevity are heavier, stronger, and/or incorporate more chemical stabilizers. It often costs more to provide greater functional longevity, and functional longevity can theoretically be sacrificed when economics dictate that those products be made lighter, weaker, or with less chemical stabilizers. This is why it is important that functional longevity be quantifiable through accepted laboratory testing protocols that can be implemented as part of product specification or periodic quality assurance testing.

1.2 Functional Longevity Testing Strategies for Exposed Geosynthetics

1.2.1 Rolled Erosion Control Products (RECPs)

Recently, the American Association of State Highway and Transportation Officials (AASHTO) has developed a draft specification for temporary RECPs, aka ECBs, and intends to follow-up with a specification for permanent RECPs, aka TRMs. The draft temporary ECP specification, however, does not currently address the required functional longevity of the various classifications of products. This is because there is no established testing protocol for functional longevity – for either ECBs or TRMs. This has prompted a renewed interest in defining and characterizing functional longevity of all RECPs in a way that combines durability testing with performance testing.

1.2.2 Characterizing Functional Longevity of TRMs

Permanent rolled erosion control products are more often referred to as Turf Reinforcement Mats. They are relatively permanent in-situ because they are 100% composed of synthetic polymeric components. Many years of use of these materials - and considerable research and testing – has concluded that the primary degradation mechanism of these materials is chain scission caused by UV radiation, or sunlight. Thus, it has proven more straight-forward to estimate the functional longevity of turf reinforcement mats via material durability by exposing them to UV radiation in test chambers and then measuring residual strength and/or mass/area. These chambers can either use Xenon arc lamps or fluorescent lights to generate the UV radiation, and they commonly include intermittent water spray to continually "wash" degraded materials from the component surfaces, exposing "fresh" material. The exposed specimens are typically tested for retained strength in accordance with ASTM D 6818. The test methods available for TRM functional longevity characterization via accelerated UV stability testing include:

- ASTM D4355, "Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus".
- ASTM D7238, "Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus".
- Since accelerated tests have not shown a consistent correlation to outdoor exposures, ASTM D5970, "Standard Test Method for Deterioration of Geotextiles from Outdoor Exposure" is also used, but does not accelerate the weathering process.

While the above referenced test methods were developed for exposed geotextiles and geomembranes, they have proven appropriate for TRM characterization. Additionally, ASTM Committee D35 has a standard of practice under development (based on GRI GS20) that will provide a methodology for converting the results of accelerated UV testing to an actual lifetime prediction for exposed high-performance turf reinforcement mats

(HPTRMs). Thus, the objective characterization of the functional longevity of turf reinforcement mats is on its way to becoming a generally accepted procedure and easily incorporated into a standard generic specification.

1.2.3 Characterizing Functional Longevity of ECBs

Conversely, the objective characterization of the functional longevity of temporary rolled erosion control products – primarily ECBs – is virtually nonexistent. This is primarily because the products are composites – made of a combination of synthetic and organic materials – some or all of which degrade at different rates. Additionally, the products continue to perform as they degrade so its not clear at what point they have degraded too much to continue to adequately perform – or function. Thus, the functional longevity question for temporary erosion control products involves answering at least two questions: 1) How fast does the product degrade under multiple, and potentially simultaneous, degredation methods? and 2) When has the product degraded too much to perform above the allowable threshold? This suggests that an appropriate single test protocol would have to monitor degradation AND performance over time – perhaps over extended time periods. An alternative procedure has been suggested that, like with TRMs, measurements of the rate of degradation in a relevent environment could correlate to associated performance tests – either field tests monitored over time or lab tests performed on specimens representing different degrees of degradation.

A very promising protocol has been developed that combines durability testing of the plastic nettings via UV exposures as with TRMs and the organic fiber filling via (aerobic) biodegradation exposures commonly used with composting studies. The results of these tests provide the product’s percent degradation over time. This information is then combined with performance versus percent degradation obtained from bench-scale performance tests run on a range of samples of the composite product having different percentages of fiber remaining between the nettings, such as 100%, 75%, and 50% of the as-received fiber. This would simulate 0%, 25%, and 50% fiber degradation. This is accomplished by randomly picking fibers out of the samples until the target percentage of simulated degredation is achieved.

Durability testing is done on the components of the ECB. The nettings are subject to UV exposures as discussed in the previous section. The organic fibers are subject to biodegradation testing. The biodegradation protocol simply measures the CO_2 generated from aerobic biodegradation of the fibers. Total carbon content of a specific quantity of the organic fiber used in the ECB is determined using a gravimetric technique. The specific quantity of organic fiber is taken from the ECB and exposed to an inoculum which causes biodegradation and associated CO_2 generation to take place. Flasks containing the organic fiber and inoculum are monitored periodically for CO_2 generation and compared to the theoretical total carbon content. This pure-culture method provides a test that is reproducible in almost any laboratory.

The composite ECB is then subject to bench-scale performance testing in accordance with ASTM D7101, “Standard Index Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Soil from Rain Splash and Associated Runoff under Bench-Scale Conditions”. By combining the UV and biodegradation results that provide a product’s percent degradation over time, with the product’s performance versus percent degradation relationship obtained from the bench-scale performance tests, the product performance over time, or functional longevity, can be reasonably characterized.

1.3 Functional Longevity Programs

1.3.1 Temporary RECP: Straw Erosion Control Blanket

A typical double net straw temporary erosion control blanket will have a mass per unit area of approximately 7 oz/sy (240 g/m^2). Its primary components are two polypropylene nets and agricultural straw.

1.3.1.1 UV Testing: UV testing in accordance with ASTM D4355 (Xenon Arc Weatherometer) is a very straight forward approach to characterize the durability, or loss of strength or mass over time. An example of test results from this component testing is presented in Table 1, included is the conversion of time to actual outdoor exposure time based on Standard Practice GRI-GS20, "Exposed Lifetime Prediction of Geosynthetics Using Laboratory Weathering Devices".

Table 1. UV Testing of the Netting Component of an ECB.

Accelerated Exposure Time, hrs	Converted Outdoor Exposure Time, yrs	Retained Strength, %	Retained Mass/Area, %
0	0	100	100
300	0.5	70	90
500	1.5	50	70
1000	2.5	30	50

1.3.1.2 Biodegradability Testing: Biodegradability testing in accordance with draft procedure ECTC #4 exposes the organic fiber component of an ECB to an inoculum in a sealed flask and monitors the head gas periodically for CO_2 generation and then compares the evolved carbon to the theoretical original total carbon content of the exposed sample. An example of biodegradability results is shown in Table 2 and the data is used to project the half life, or time associated with 50% degradation, as shown in Figure 1.

Table 2. Biodegradability Testing of the Fiber Component of an ECB.

Exposure Time, hrs	Exposure Time, yrs	Add'l Evolved C, mg	Biodegradation, %
500	0.057	72	3
1000	0.114	120	8
1500	0.171	144	14

1.3.1.3 Bench-scale Slope Performance Testing: ASTM D7101 is commonly used to quantify an ECB's "indexed" performance. "Indexed" means that only a specific soil – sand – is used and installation variables like staple spacing are not simulated. The C-Factor is a common measure of performance as it is a variable in the Universal Soil Loss Equation. Table 3 gives an example of C-Factor data typical of testing a straw ECB.

Table 3. Indexed Performance of ECB in Slope Protection.

Rainfall Event	% of Original Mass		
4 in/hr (100 mm/h)	100%	75%	50%
Control Soil Loss (g)	114	114	114
ECB Soil Loss (g)	14	18	23
C-Factor	0.12	0.16	0.20

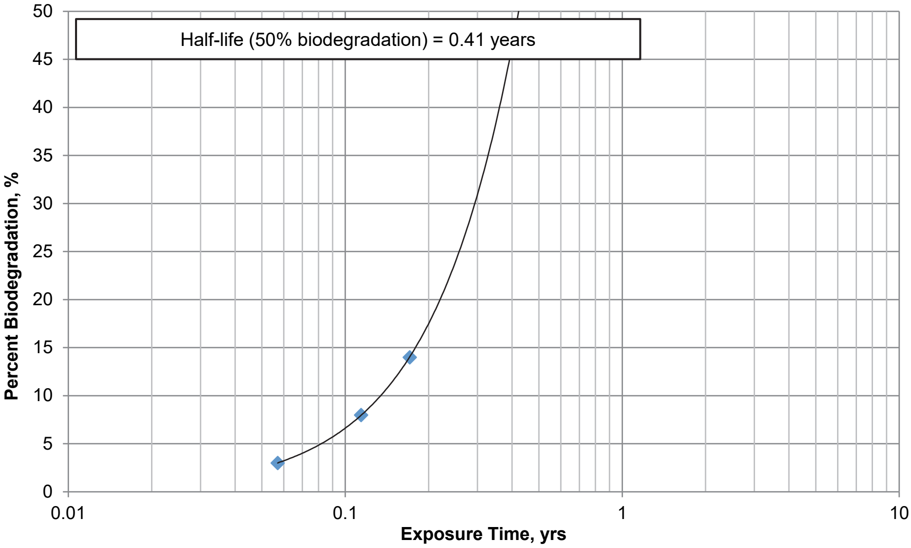

Figure 1. Projection of Biodegradation Data using Power function and log scale.

1.3.1.4 Synthesis of Functional Longevity: Functional longevity can be determined by combining durability and performance data gained from the testing described in 1.3.1.1 thru 1.3.1.3. Initially the user or specifier must decide what level of performance is adequate. Then, on the percent of original mass that provides this minimum adequate performance from Table 3, the lesser time from Table 1 and Figure 1 that equates to that percent of material degradation defines the functional longevity of the product. For the example shown here, if a C-Factor no higher than 0.20 was determined to be adequate, then Table 3 shows that this level of performance equates to 50% of the original mass of the product still being intact. Thus, the functional longevity would be 0.41 years – the lesser time associated with 50% degradation from Table 2 and Figure 1.

2 Conclusion

Surface exposed geosynthetics, such as rolled erosion control products (RECPs) have a unique need for functional longevity characterization. Surface exposures can include simultaneous ultraviolet radiation, biodegradation, and damaging mechanical forces. These exposures inevitably degrade a surface exposed geosynthetic over time. So, an important question arises: When do the synergistic effects of the simultaneous or sequential exposures degrade the geosynthetic to the point where its performance falls below established functional thresholds. This question can only be answered by putting the candidate product through a relevant series of durability and performance tests. Such a series of durability and performance tests has been proposed and demonstrated for the characterization of the functional longevity of RECPs.

3 References

1. ASTM D4355 “Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture, and Heat in a Xenon Arc-Type Apparatus”. ASTM, Conshohocken, PA.

2. ASTM D7238 “Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus”. ASTM, Conshohocken, PA.
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