CORRELATION OF CHANGE IN PERFORMANCE PROPERTIES TO LONGER-TERM ACCELERATED WEATHERING TO YEARS OF NATURAL WEATHERING FOR GEOGRIDS

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ABSTRACT
Geosynthetic products used in aboveground geotechnical applications maybe exposed to the effects of natural weathering potentially impacting their long-term performance. Due to continuous climatic variations in weathering, several years of continuous exposure and monitoring are required to quantify the impact of natural weathering. However, much shorter-term exposure tests, via accelerated weathering, can provide an indication of performance relative to other construction materials. A generic specification stipulates at least 70% retention of strength after 500 hours exposure to accelerated weathering. However, the significance of this specification in relation to actual long-term field performance is unknown. This study evaluates retained strength of a geosynthetic reinforcement material (a biaxial geogrid) through ≤10,000 hours of exposure to accelerated weathering. These results are compared to the retained strength of similar geogrid products after nine and eleven years of natural weathering at two locations. Results indicate no significant impact on retained strength by either accelerated or natural weathering conditions. Thus, under normal service, these geogrids would not likely suffer any significant change in properties during the design life of a civil engineering structure (75 to 100 years).

RESUME
Les produits géosynthétiques utilisés dans les applications géotechniques de surface pourraient perdre éventuellement de leur capacité de rendement lorsqu'exposés durant de longues durées au processus naturel de décomposition des sols. En raison des variations climatiques intervenant au cours de ce processus de dégradation, il est essentiel de tenir compte de plusieurs années d'exposition continue et d'effectuer un control de qualité régulier lorsque l'on quantifie l'effet de ce processus naturel sur les produits géosynthétiques. Il reste néanmoins possible d'évaluer l'efficacité de ces produits et de les comparer à d'autres produits de construction grâce à des tests d'exposition de courte durée à un processus accéléré de décomposition. Une spécification à titre indicatif recommande la conservation d'au moins 70% de la performance après 500 heures d'exposition à un processus accéléré de décomposition. Néanmoins la signification de cette spécification en relation avec une capacité de rendement réelle à long terme et en milieu naturel n'a pas été établie. L'analyse ci-jointe évalue le degré de force retenu par un matériau de renforcement géosynthétique (une géogrille biaxiale) après 10,000 heures d'exposition à un processus accéléré de décomposition. Les résultats obtenus sont comparés à la capacité de rendement conservée par des géogrilles biaxiales de type similaire excavées à deux emplacements différents après neuf et onze ans d'exposition continue au processus naturel de dégradation. Les résultats indiquent que la performance des géogrilles n'est pas affectée par le processus artificiel ou naturel de dégradation. On peut en déduire que sous conditions normales d'utilisation, les propriétés des géogrilles restent constantes pour toute structure conçue pour une durée de service de 75 à 100 ans.

1. INTRODUCTION

Geotechnical applications involving geosynthetic products in wrap-faced structures, such as Mechanical Stabilized Earth (MSE) walls and slopes, expose these products to natural weathering. Moreover, the principal elements (viz., ultraviolet radiation, oxygen, relative humidity, precipitation, temperature, and atmospheric pollutants) are constantly fluctuating. Thus, these elements have an ever-changing impact on the long-term performance of geosynthetics used in wrap-faced structures.

Due to year-to-year climatic variations in weathering at a given location, or between different geographical locations, a single year of continuous outdoor exposure should not be used to predict the absolute rate at which a property will change. And, the rate of change determined from continuous exposure for less than a 12-month duration will depend upon the particular portion of the season in which exposure occurred. Thus, several years of continuous exposure and monitoring are required to quantify the impact of natural weathering on the long-term performance of a geosynthetic product at a particular geographic location.

Much shorter-term exposure tests, via accelerated weathering, can provide an indication of performance relative to other construction materials, but quantification of an absolute rate of change for a particular property is not practical due to the ever-changing conditions.

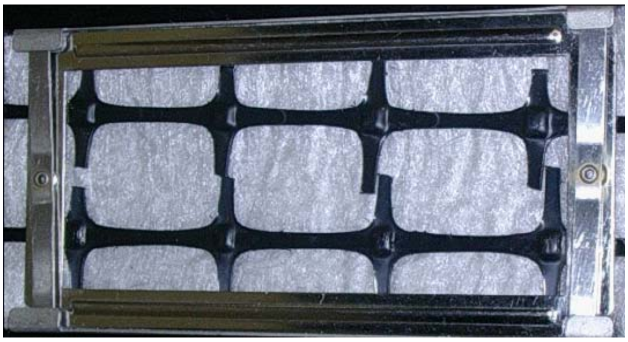
Currently, a generic specification for the acceptance of geosynthetics stipulates at least a 70% retention of tensile strength after an arbitrary, short-term exposure of 500 hours to accelerated weathering induced by a xenon arc source according to American Society for Testing and Materials (ASTM) Test Method D 4355. Although xenon arc replicates the harsh spectra of natural sunlight, the significance of 500 hours of exposure relative to long-term field performance is not known.

2. PROGRAM

A laboratory study was initiated to evaluate retained tensile strength of a biaxial geogrid after as much as 10,000 hours exposure to accelerated weathering induced by a xenon arc source in accordance with ASTM D 4355. Multiple test specimens were exposed for specific time intervals: zero (baseline), 500, 1250, 2500, 5000, 7500, and 10,000 hours. Specimens were mounted within a metallic plate, rectangular frame and backed with a white geotextile, as shown in Figure 1, to prevent background reflection thus avoiding excessive UV irradiance and temperature, and to replicate, more accurately, field exposure conditions.

All specimens were taken from the same product sample. All specimens were cut five (5) apertures long in the cross machine direction (CMD). The CMD is the principal loading bearing direction in wrap-faced structures.

Figure 1. Mounted test specimens.



After each exposure time interval, specimens were evaluated for single rib tensile strength, melt index (MI), and high-pressure oxidative induction time (HPOIT). The corresponding ASTM standards and properties listed in Table 1.

Table 1. Property and corresponding ASTM test standard.

Test	ASTM Standard	Material Property Change by Test
Melt Index	D 1238	Molecular weight
Tensile Strength	D 6637	Tensile strength
High-pressure Oxidative Induction Time	D 5885	Antioxidant package

These results were compared to similar results after 9 and 11 years of continuous field exposure to natural weathering of similar biaxial geogrid products at two locations: one near the east coast of the United States and the other near the west coast. At each location, geogrid products were aligned at 45° to the sun with a southern exposure.

3. EQUIPMENT AND TEST CONDITIONS

The accelerating weathering device was an Atlas Ci-65 Weatherometer. The light source emulating sunlight was a xenon arc; the irradiation level was 0.35 $W/m^2/nm$ @ 340 nm. The exposure cycle for all specimens was 90 minutes of light only, followed by 30 minutes of water spray and light.. The temperature inside the weatherometer was held at 65 ± 2.5° C with a relative humidity of 50 ± 5%.

4. EVALUATED GEOSYNTHETIC PRODUCTS

The geogrid exposed to accelerated and natural weathering was an extruded, punched, and drawn biaxial polypropylene geogrid compounded with fine carbon black (CB) particulate. This geogrid is commonly used in wrapped face MSE wall and slope applications to enhance surficial stability. Carbon black is compounded into polypropylene to protect the long-term performance properties of the geogrid during exposure to weathering. The base resin was the same grade of polypropylene for all three geogrids. At their respective time of manufacture, all three geogrids met their minimum physical and mechanical property specifications. However, the CB loading varied by exposure location for the three geogrids as shown in Table 2.

Table 2. Carbon black loading, weathering mode and duration, and location by geogrid.

Biaxial	Carbon Black (% wt)		Weathering		Location
Geogrid	Specification	Actual	Type	Duration (Yrs)	
1	≥ 2	2.7	Accelerated	≤ 1.142	Laboratory Weatherometer
2	≥ 0.75	2.5	Natural	9	Atlanta, Georgia
3	≥ 0.75	1.0	Natural	11	La Jolla, California

5. RESULTS

Tables 3, 4, and 5 show results for this study on the performance of biaxial geogrids 1, 2, and 3 respectively. In Table 3, test results for tensile strengths are the average of 5 specimens; and MI values are the average of 3 specimens. Test results for HPOIT are from a single test. For HPOIT testing, the temperature was 150° C with a pressure of 500 pounds per square inch.

Table 3. Summary of test results for accelerated weathering on geogrid 1 in the laboratory study.

Time Line (Hours) (Years)	0 0	500* 0.057	1250* 0.143	2500 0.285	5000* 0.571	7500* 0.856	10,000* 1.142
Melt Index (gm/10 min.)	1.310			1.355			
CMD Tensile Strength (lbf)							
@ 2% Strain	65.7			64.1			
@ 5% Strain	112.4			122.5			
@ Ultimate	154.4			157.8			
Strain @ Ultimate (%)	10.5			10.1			
HPOIT (min) @ node	125			113			

Note: * denotes exposure tests in progress at the time of writing

In early 1985, a biaxial geogrid product was mounted on outdoor weathering racks located southeast of Atlanta, Georgia. Samples were retrieved annually for evaluating residual tensile strength in the machine direction (MD) according to Geosynthetic Research Institute (GRI) Test Method GG1, the forerunner of the current ASTM Test Method D 6637. After 9 years, MI and OIT testing were conducted on the original control and exposed sample. In 1994, the OIT test was an industrial procedure that evolved into the OIT test method (ASTM D 3895) as the HPOIT test method (ASTM 5885) standard did not exist at that time. Although OIT and HPOIT test results are not directly comparable for a given time, changes in value for a given exposure time interval are relatively comparable. Test results after 9 years of natural weathering are given in Table 4 (Cassady et al. 1995). Machine direction tensile strength is reported as the average of 10 specimens while MI and OIT are single test results. The OIT test was conducted at 200° C.

Table 4. Summary of test results over nine years of natural weathering on geogrid 2 in Georgia.

Time Line (Year Sequence) (Year)	0 1985	1 1986	2 1987	3 1988	5 1990	7 1993	9 1994
Melt Index (gm/10 min.)	> 1						1.460
CMD Ultimate Tensile Strength (lbf)	134	139	140	140	134	132	137
Strain @ Ultimate (mm)	7.9	5.8	6.6	6.7	6.0	5.9	6.7
OIT (min) @ node	6.7						7.0

In 1986, a reinforced soil slope was constructed in La Jolla, California as part of a land development project for future home sites. Biaxial geogrid 3 provided surficial stability and secondary reinforcement. The site was revisited in 1997 to monitor instrumentation. Excess geogrid was found fully exposed to natural weathering for 11 years due to the lack of sufficient vegetative growth. There was no evidence of soil erosion around the exposed geogrid. Samples were retrieved for testing and comparison to 1997 production of the same product. Tensile strength was evaluated according to GRI test method GG1 in both the MD and CMD. Melt index and tensile strength test results for geogrid 3 are given in Table 5 (Bright et al. 2001).

Table 5. Summary of test results for eleven years of natural weathering on geogrid 3 in California.

Time Line (Year)	1997 Production		1986 Production / Weathered	
Melt Index (gm/10 min.)	2.043		2.100	
Tensile Strength (lbf)	MD	CMD	MD	CMD
@ 2% Strain	43.2	50.4	49.0	53.0
@ 5% Strain	83.2	100.7	92.9	106.5
@ Ultimate	115.5	135.6	123.8	137.1
Strain @ Ultimate (%)	12.0	-	11.6	8.6

6. DISCUSSION OF RESULTS

After 2500 hours of exposure to a xenon arc light source, melt indices indicate no significant change in molecular properties of biaxial geogrid 1. Slight increases in tensile strength and corresponding decreases in strain with time does suggest the occurrence of some molecular cross linking. At the time of this writing, there is insufficient data for predicting a time frame when the HPOIT will approach zero (i.e., a depleted antioxidant package). However, based upon results to date and experience, the testing laboratory believes that a significant amount of time remains before complete depletion of the antioxidant package.

Nine years of natural weathering in Georgia had no impact on the tensile strength, strain, and OIT properties of biaxial geogrid 2. Likewise, eleven years of natural weathering in southern California on geogrid 3 showed similar results to those from the Georgia location. Increases in tensile strength and corresponding decreases in strain with time again suggest the occurrence of some molecular cross-linking. Moreover, MI and OIT results indicate no significant change in molecular properties and that the antioxidant package has not been depleted, respectively.

7. CONCLUSIONS

Through 2500 hours exposure to accelerated weathering, changes in melt index, tensile strength and strain for geogrid 1 do not surpass respective changes for geogrids 2 and 3 through approximately 10 years of exposure to natural weathering. This would suggest that an exposure time for accelerated weathering equivalent to approximately 10 years of natural weathering is well beyond 2500 hours.

Based on the results of long-term exposure to natural weathering, similar biaxial geogrid products 2 and 3, it may be concluded that these geogrids, with at least 1% by weight carbon black, are not significantly affected by long-term (approximately 10 years) exposure to harsh weathering conditions. Under normal service conditions (not directly exposed to the elements for long periods), these results indicate that these geogrids would not likely suffer any significant change inproperties of the normal design life of a civil engineering structure (75 to 100 years.

8. RECOMMENDATIONS

The laboratory study should be continued until the changes recorded in melt index, and tensile strength and strain for accelerated weathering, with concurrent monitoring of HPOIT, are approximately equivalent to the changes recorded for approximately 10 years of natural weathering. Then access the additional time to depletion of the antioxidant package, and the equivalent years of natural weathering and residual property values of geogrids 2 and 3. These results could be compared to the results of other ongoing studies at the time of their publication.

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