Exposed NPNW GT Performance at a Large Surface Impoundment For Nearly One Year

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ABSTRACT

Exposed needle punched nonwoven (NPNW) Geotextiles are uncommon in Civil Engineering applications. Most specifications limit their exposure to a few weeks after installation due to the threat of UV degradation. This very unusual case history allowed us to evaluate an exposed NPNW geotextile over a long period of time (8 months). In addition, we performed laboratory UV exposure tests to counterpoint field versus lab performance and develop correlations between different methods of exposure.

INTRODUCTION

The functional requirements of the geotextile in each application will determine the properties required, and any assessment of the products durability will be based on the degradation of these properties over a given time. There are several factors that will help to determine the durability of a geotextile; the physical structure of the fabric, the nature of the polymer used, the quality and consistency of the manufacturing process, and the environment in which the product is placed. It is essential that a geotextile performs effectively for the required duration of the design life. The project was supposed to have protective soil cover installed in three weeks. Instead, it was covered in eight (8) months. This was due to a miss calculation of the available soil from the borrow site.

LOCATION OF THE SITE

Navigable waterways are essential to all inland transportation. Critical to this navigation is the maintenance of adequate depth or the waterway (which was originally regulated by the U.S. Congress in 1824!). The typical maintenance method to gain navigable depths is, and has been for centuries, that of dredging. Historically, dredge spoils have been placed in lined impoundments. This case history is a 105-ha dredge disposal site adjacent to the C & D Canal in the state of Maryland USA. The roughly triangular site was lined with a geomembrane and had a geotextile beneath and above the geomembrane. Strips of multi-linear drainage geocomposite Draintube were also placed to collect gas from the dredge spoils. This investigation concentrated on the upper geotextile used for puncture protection.

Figure 1. Map showing location of the site **Figure 2. Aerial photograph of the site**

The site is operated by the U.S. Army Corps of Engineers (USACE) and is identified as the Pearce Creek Confined Disposal Facility, which receives dredge sediment from the Chesapeake and Delaware (C & D) Canal southern approach channels. The C & D canal is shown on the map in Figure 1 and the site location is identified by a star. Figure 2 shows an aerial view of the dredge disposal facility. This facility is in the Mid-Atlantic region of the USA just outside of Willington Delaware. The site's closest town is Elk Neck, Maryland, with a longitude and latitude of 39.4848° N, 75.9848° W.

Climate conditions include summers that are warm, humid, and wet; winters are very cold and snowy; and it is partly cloudy year-round. Over the course of the year, the temperature typically varies from 26°F to 86°F and is rarely falls below 13°F or above 93°F. The exposure test period was conducted in 2017, from January to August. This was advantageous because the solar radiation at the site was lower during the winter months. In addition, the containment facility was often covered with snow or water during the winter months.

THE GEOTEXTILE

The geotextile used at this site was a 350 g/m2 black needle-punched nonwoven made of polypropylene staple fibers. The geotextile was intended to serve as puncture protection for the underling geomembrane. Unexpectedly, the upper geotextile was left exposed to ultraviolet degradation for eight months prior to soil covering at the Pierce Creek dredge disposal facility. As a result of this miscalculation, this case history was made possible. Originally the geotextile conformed to the following minimum properties as they appear in Table 1.

Table 1– Properties of Geotextile Used at Pearce Creek as Geomembrane Protection (or Cushioning) Materials

Property	Test Method ASTM	Unit	Result	Unit	Result
Grab tensile strength	D4632	lb.	250	N	1112
Grab tensile elongation	D4632	%	50-105	%	50-105
Trap. tear strength	D4533	lb.	100	N	445
Puncture (CBR) strength	D6241	lb.	700	N	3114
UV resistance [(1)]	D7238	%	70	%	70

Notes: (1) Evaluation to be on 2.0-inch (50 mm) strip tensile specimens per ASTM D5035 after 500 lt. hrs. exposure.

The geotextiles are a non-woven needle-punched fabric manufactured from 100% short polypropylene fibers. The fibers size is 3-6 denier, length is 3-4 in. (76-102 mm). The rolls were 17.2 ft. (5.25m) width and 300 ft. (91.44 m) long.

FIELD INVESTIGATION

The most important conditions affecting the seasonal variability of exposure conditions are the quantity and quality of sunlight, the amount of humidity, time of wetness, and the average maximum specimen temperature. Seasonal variability can vary greatly from year to year and must be accounted for in our test.

While laboratory weatherability and light stability tests are important for many geotextiles, the best way to test geotextiles is through natural exposure. Natural exposure testing has many advantages in that it is realistic, in-expensive, and easy to perform. However, most manufacturers do not have several years to wait to see if a “new and improved” product formulation is feasible.

Geotextile samples were taken in the field at the beginning of the project after 85 days of exposure and then finally after 252 days of exposure. A site photograph of the geotextile being deployed is shown in Figure 3. Figure 4 shows geotextile samples being taken at 85 days.

Figure 3. Site photo of deployed geotextile

Figure 4. Photo of geotextile being sampled

The results of the field study are shown in Figure 5. Although the data is sparse for this site during this time increment, (only three points), the half-life of the geotextile is 200 days via a linear regression of the data. We were pleasantly surprised by this finding.

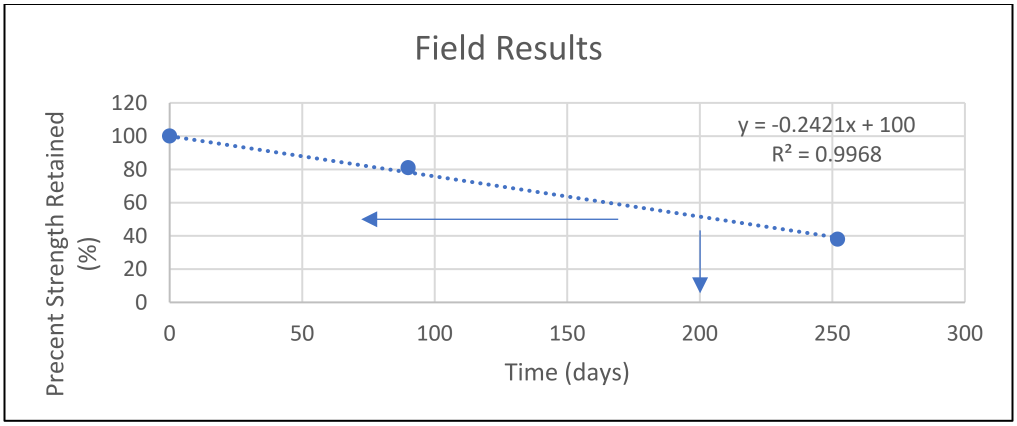

Figure 5. Field results of percent strength retained versus time plot for the NPNW protection geotextile at the Pearce Creek Disposal Facility

Figure 6 shows an aerial photograph of the completed project.

Figure 6. Aerial photograph of the Pearce Creek Disposal Facility

LABORATORY INVESTIGATION

Durability issues with exposed geotextiles are caused by three factors: light, high temperature, and moisture. Any one of these factors may cause deterioration. Together, they often work synergistically to cause more damage than any one factor would cause alone.

Light spectral sensitivity varies for each polymer type. For durable materials, like geosynthetics, short-wave UV is the cause of most polymer degradation. The destructive effects of light exposure are typically accelerated when temperature is increased.

Although temperature alone does not affect the primary photochemical reaction, it does affect secondary reactions involving the by-products (Hsuan, Lord and Koerner 2002). A laboratory weathering test must therefore provide accurate control of temperature.

Moisture Dew, rain, and high humidity are the main causes of moisture damage. Objects stay wet outdoors for several hours each day (on average 8-12 hours daily) and condensation in the form of dew is responsible for most outdoor wetness. Dew is more damaging than rain because it remains on the material for a long time, allowing significant moisture absorption. Rain can cause thermal shock over the course of a hot summer day and can be rapidly dissipated by a sudden shower. Mechanical erosion caused by the scrubbing action of rain can also degrade materials because it wears away the surface, continually exposing fresh material to the damaging effects of sunlight.

The xenon arc and UV accelerated weathering testers are the most commonly used accelerated testers. The equipment cross-sections are shown in Figures 7 and 8 respectively. GSI's UV exposure room is shown in the photograph of Figure 9.

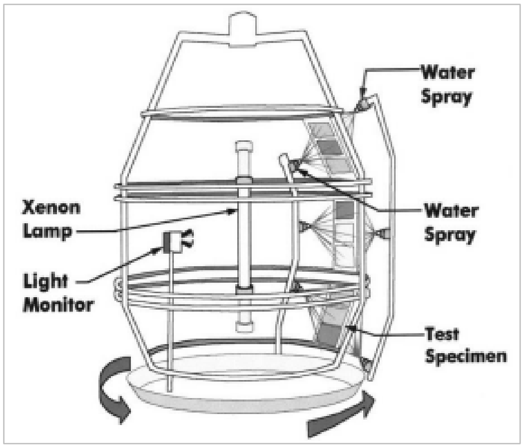

Figure 7. Cross-section of Xenon Apparatus

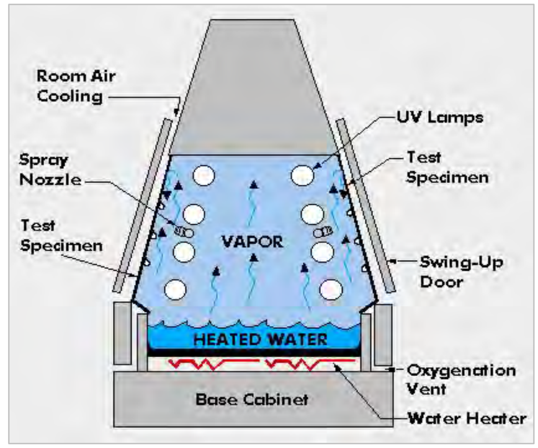

Figure 8. Cross-section of UV accelerated weathering Apparatus

Figure 9. Photograph of the weathering durability lab at the Geosynthetic Institute (GSI). Note, four UV accelerated weathering apparatuses on the left and a single Xenon apparatus on the right

Each apparatus reproduces light, temperature, and moisture in different ways. The xenon test chamber reproduces the entire spectrum of sunlight, including ultraviolet (UV), visible light, and infrared (IR). The xenon arc is essentially an attempt to replicate sunlight itself, from 295 nm - 800 nm. The UV weathering test chamber does not attempt to reproduce sunlight, just the damaging effects of sunlight that occur from wavelengths between 295 nm and 400 nm. It is based on the concept that, for durable materials (geosynthetic polymers) exposed outdoors, short-wave UV causes the most weathering damage.

Which is the better way to test? There is no simple answer to this question. Depending on the application, either approach can be quite effective. Your choice of tester should depend on the product or material you are testing, the end-use application, the degradation mode with which you are concerned, and your budgetary restrictions, (UV accelerated weathering devices are much more economical to maintain and operate than Xenon devices).

The UV accelerated weathering tester is designed to reproduce the damaging effects of sunlight. We used UVA-340 lamps for this experiment and the procedure described by ASTM D7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus. Control of irradiance was achieved with the Q-Lab Corporation SOLAR EYE feedback-loop system. The calibration of this UV accelerated weathering apparatus is traceable to the National Institute of Standards and Technology (NIST) for ISO 9000 compliance.

Xenon arc testers are considered to be the best simulation of full-spectrum sunlight because they produce energy in the UV, visible, and infrared regions. To simulate natural sunlight, the xenon arc spectrum must be filtered. The filters reduce unwanted radiation and/or heat. Two boron filters were used in our experiment as described in procedure ASTM D4355 Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus). The results of the laboratory study undertaken on the NWNP geotextile samples taken in the field at the beginning of the Pearce Creek Disposal facility project are shown in Figure 10.

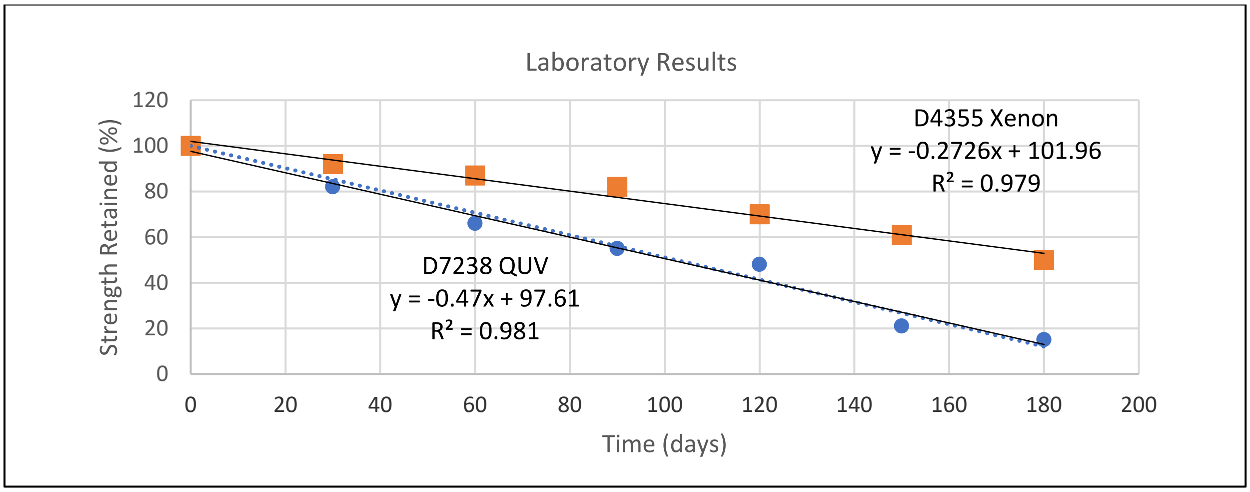

Figure 10. Laboratory results of percent strength retained versus time plot for the NPNW protection geotextile at Pearce Creek Disposal facility. Note that both the ASTM D4355 Xenon and ASTM D7238 UV accelerated weathering results are shown on the same plot

From these results we can determine the half-life for the NPNW geotextile from both the ASTM D4355 Xenon and ASTM D7238 UV accelerated weathering experiments. They are 175 and 100 days respectively. Again we were pleasantly surprised by these findings.

SUMMARY AND CONCLUSIONS

Weathering testing is a tool to mitigate risks. This can be done when introducing new products, qualifying new vendors, or forensic work. Accelerated testing is used because market forces require rapid decisions, but the use of accelerated methods presents challenges. Our investigation had optimal conditions which incorporated a field case history to calibrate-normalize the findings.

A test program has the best ability to predict performance of materials used in a real-world application by combining outdoor and accelerated test results. The main objective of this work was to study the effect of aging by UV radiation on the tensile properties of a polypropylene-based non-woven geotextile and compare them to long term field exposure. The results obtained show that the mechanical properties, such as the tensile strength, held up better than anticipated for both the field and laboratory investigations. Half-lives for the three tests are as follows:

1. Field Exposure = 200 days
2. Xenon = 175 days
3. UV accelerated weathering = 100 days

It should be noted that most specifications suggest that geotextiles should have 70% strength retained after 500 hours (21 days) of exposure. This work shows that we are currently making NPNW polypropylene geotextiles that are less sensitive to ultraviolet radiation because of better antioxidant packages (HALS) and stabilizers. Hence, they will easily meet current durability specifications and have exceeded expectation.

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