Behavior of Partially Ultraviolet Degraded Geotextiles

Y. G. Hsuan, R. M. Koerner & T. -Y. Soong
GRI - Drexel University, Philadelphia, PA, USA

ABSTRACT: The outdoor degradation of twelve geotextiles was simulated using a UV fluorescent lamp device. It was determined that the ultraviolet rays by themselves were the major contributor to the degradation of these geotextiles. Neither heat nor moisture had a significant effect on the geotextiles, at least within the testing time used in this study. The rate of UV degradation of the geotextiles was seen to be inversely proportional to their unit weight. In addition, the rate of degradation in the weatherometer was essentially terminated once the UV source was removed. The 70% UV degraded PP and PET geotextiles exhibited similar strength retained behavior as those unexposed samples at 60°C within 3000 hours.

1 INTRODUCTION

During any type of construction that involves the use of geotextiles, there will generally be the potential for sunlight exposure. Within the sunlight spectrum, the ultraviolet (UV) portion is most harmful to polymers used in the manufacture of geotextiles, causing a photo-oxidative degradation to occur (Hirt and Searle, 1964). Thus many owners, designers and government agencies require product certifications and sometimes warranties concerning the resistance of geotextiles to weathering exposure. This is usually done by stipulating a laboratory test method and a certain strength retained after a prescribed exposure. For example, thirty-two U.S. State Departments of Transportation presently have included UV durability specifications for various types of applications. They usually follow the AASHTO/Task Force 25 recommendations which use the Xenon Arc weatherometer according to ASTM D4355. The time for minimum strength retained from 70% to 90% varies from 150 hours to 500 hours. Although the correlation between these values and outdoor site-specific exposure is still uncertain, a tentative estimation has been proposed (Hsuan and Koerner, 1994). However, there are still many unanswered questions:

- How does thickness of a given geotextile influence its UV degradation?
- How does the UV degradation compare with thermal oxidative or hydrolytic degradation?
- Will partially UV degraded geotextiles continue to degrade after they are covered with soil or other geosynthetics?

The purpose of this paper is to clarify these questions.

2 EXPERIMENTAL DESIGN

In the experimental design, there are included a total of twelve different types of geotextiles. Nine are polypropylene (PP) and three are polyester (PET). The type of geotextiles and their unit weights are listed in Table 1. They are somewhat arbitrarily separated by their color, i.e. light or black.

Table 1. The geotextiles evaluated in this study

Types of geotextile (color)	Unit weight (g/m^2)
#1-nonwoven needled PP (light)	135, 270, 540
#2-nonwoven heat bonded PP (light)	140
#3-nonwoven needled PET (light)	135, 270, 540
#4-nonwoven needled PP (black)	135, 410, 610
#5-woven - monofilament PP (black)	210
#6-woven - slit film PP (black)	190

The overall concept of the study is illustrated in Fig. 1. Three discrete experimental steps are as follows:

A - Achieve 70% UV degradation in strength for the various geotextile coupons using a laboratory weatherometer.

B - Monitor the thermal degradation of various PP geotextiles of both unexposed and 70% UV degraded coupons at temperatures of either 60°C or 70°C.

C- Monitor the hydrolytic degradation of PET geotextiles of both unexposed and 70% UV degraded coupons at a temperature of 60°C.

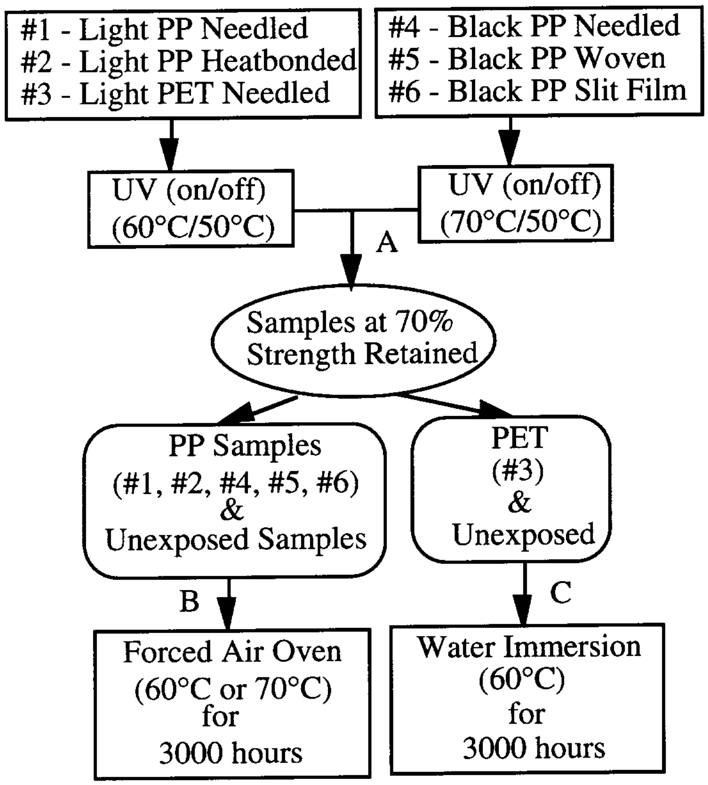

Fig. 1 Design flow chart of the complete study

3 INCUBATION AND TESTING METHODOLOGY

The type of laboratory weatherometer used in this study was a UV fluorescent lamp device equipped with UVA-340 lamps. The spectral output of this light source represents the UVA portion of sunlight with a peak intensity at a wavelength 340 nm (ASTM D 5208). The geotextiles were exposed to alternating UV and condensation cycles with durations of 5 hours and 3 hours, respectively. The temperature of the chamber was at 50°C during the condensation cycle. For the UV cycle, the temperature was at either 60°C for light color materials or 70°C for black materials. The ten degree difference was to compensate for the high heat absorption of the black materials when exposed in outdoor conditions. The coupon retrieving times were 100, 200, 500, 1000, and 2000 hours. Five replicate coupons were exposed for each time period.

For PP geotextiles, the thermal-oxidative reaction was simulated using a forced air oven at a temperature of 60°C or 70°C. Coupons were free hanging on racks with a minimum of 40 mm spacing. They were removed at predetermined time periods. Five replicate coupons were incubated for each time period.

For PET geotextiles, the hydrolytic reaction was simulated using a water bath at a temperature of 60°C. Coupons were completely immersed in the water without any confinement. They were removed at defined time periods. Five replicate coupons were incubated for each time period.

All retrieved coupons were equilibrated at room temperature for a minimum of 24 hours. A strip test specimen measuring 50 mm wide by 150 mm long was cut from each coupon, and then weighed. Tensile tests were performed using a strain rate of $8.5x10^{-4}$ m/s for nonwoven geotextiles and $1.7x10^{-4}$ m/s for woven geotextiles. The gauge length was 100 mm. The breaking strength of each specimen was normalized with respect to its weight to minimize variation in the data. The average value of the five replicate test specimens was used in the comparison studies. Breaking elongation values were not considered due to the customary emphasis on strength mentioned earlier.

4 TEST RESULTS AND DISCUSSION

The test results from this study are divided into two sections in order to illustrate the behavior of partially UV degraded geotextiles with respect to those that were unexposed. Due to the space limitations only some of the results of the complete study will be presented.

4.1 Degradation mechanisms in the UV weatherometer

Degradation of the geotextiles in the UV weatherometer is measured based on the percent retained tensile strength with respect to its original value. Some of the test data is presented in Figs. 2 , 3, and 4. From the curves shown by the solid triangles, the required exposure times to reach 70% strength retained were obtained. The values are listed in Table 2. It must be emphasized that direct comparison between different types of geotextiles requires caution and may not even be appropriate. This is due to the nature of the exposure test method. The intensity distribution of the UVA 340 nm light spectrum is probably more severe to PET than to PP. Rather than cross comparison, the intention is to evaluate each geotextile separately within its own data set.

For nonwoven needled geotextiles, the degradation is inversely proportional to its unit weight. This is because the degradation of the geotextiles takes place first from the exposed surface and then gradually migrates into the thickness of the material. This was determined by separate measurements of high pressure oxidative induction time (HP-OIT). The exposed surface of geotextile #4 with unit weight of 410 g/m^2 had 40% lower values than the inner material after 70% UV degradation. Thus the percentage of degraded mass is lower in a thick (i.e., heavier) geotextile than it is in a thin (i.e. lighter) geotextile.

The second issue can now be addressed which has to do with distinguishing UV degradation from thermal-oxidation (for PP) and hydrolysis (for PET). In order to separate each mode of the degradation, a set of original unexposed PP and PET geotextile coupons were placed in a forced air oven and a water bath, respectively. The incubation temperature was the same as the UV tests at either 60°C or 70°C.

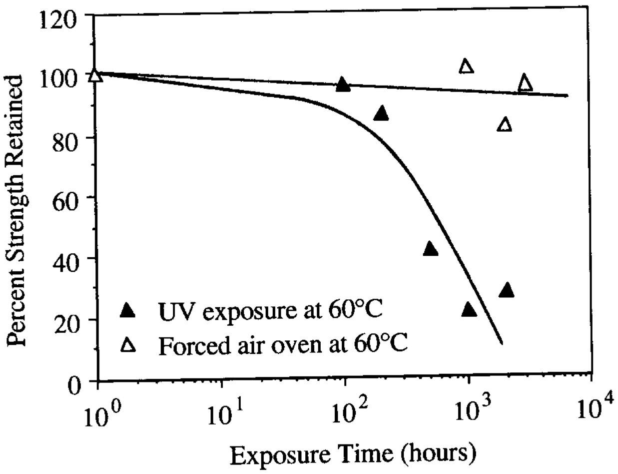

Fig. 2 Strength retained curves of geotextile #1 with unit weight of 270 g/m^2.

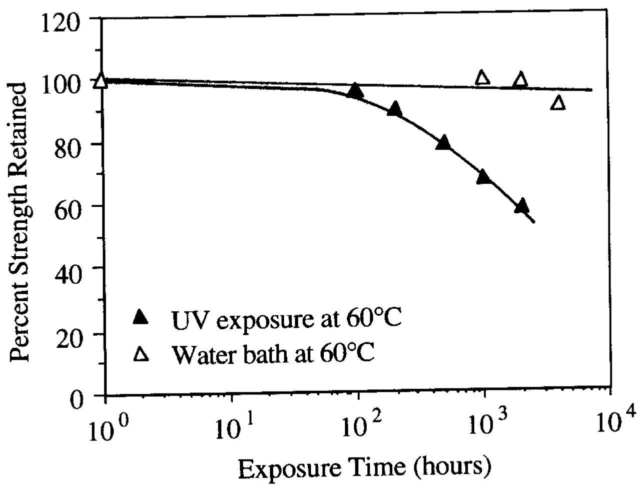

Fig. 3 Strength retained curves of geotextile #3 with unit weight of 270 g/m^2.

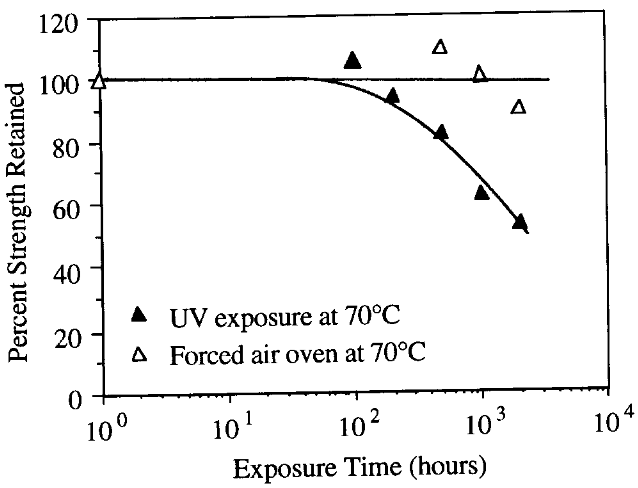

Fig. 4 Strength retained curves of geotextile #4 with unit weight of 410 g/m^2.

The percent strength retained for each geotextile was monitored up to 3000 hours. The results were superimposed with their corresponding UV degradation curve in Figs. 2, 3 and 4. They are showed by the open triangles. By comparing the set of curves it can be seen that the heat and moisture in the weatherometer do not contribute a significant amount to the degradation of geotextiles. This suggests that UV light is the primary factor causing outdoor degradation in geotextiles. The other geotextiles not shown here behave similarly.

Table 2. Time to reach 70% UV degradation

Geotextile	Time (hours)/ Unit Weight (g/m^2)
#1	350/135, 400/270, 500/540
#2	400/140
#3	350/135, 800/270, > 2000/540
#4	300/135, 800/410, > 2000/610
#5	2000/210
#6	>2000/190

Note: Due to the limited testing time, all tests were terminated at 2000 hours.

4.2 Degradation behavior of partially UV degraded geotextiles after UV light is removed

The third question raised with respect to partially UV degraded geotextiles is the uncertainty of the degradation rate after being covered. This part of the study is designed to provide insight into this issue.

Geotextiles #1 and #3 were used in this experiment. They were exposed in a UV weatherometer to achieve approximately 70% strength retained as described previously. After reaching this level of degradation the degraded samples were incubated in either a forced air oven for geotextile #1 (PP) or a water bath for geotextile #3 (PET). Both incubations were conducted at a temperature of 60°C. The strength retained was monitored up to 3000 hours. The results of geotextiles #1 and #3 with unit weights of 270 g/m^2 are presented in Figs. 5 and 6, respectively. In each figure, three curves are included. The open circles are the UV degradation response. The open triangles represent the thermal-oxidative (for PP) and hydrolytic (for PET) reactions without UV exposure. These two sets of curves have been shown earlier in Figs. 2 and 3, but now they are on an arithmetic plot. The solid triangles represent the thermal-oxidative (for PP) and hydrolytic (for PET) reactions after 70% UV degradation. The contrast between curves consisting the open circles and solid triangles indicate that the continuous UV degradation is essentially eliminated once the UV source is removed. The overall changes of strength retained in the 3000 hour incubation are very similar to those of unexposed geotextiles. Table 3 is prepared by comparing the slope of the lines with the open and solid triangle symbols in Figs 5 and 6.

Geotextiles #1 and #3 at other unit weights were also evaluated and they all exhibit similar behavior. It seems that the degradation behavior of the partially UV degraded geotextiles are very similar to their unexposed materials, at least within 3000 hours at 60°C.

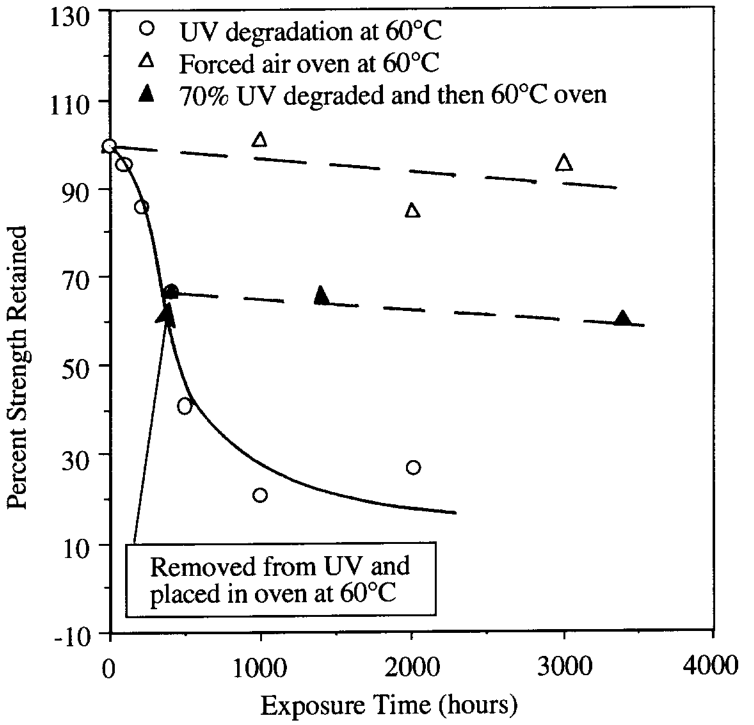

Fig. 5 Strength retained behavior of geotextile #1 under three different test conditions.

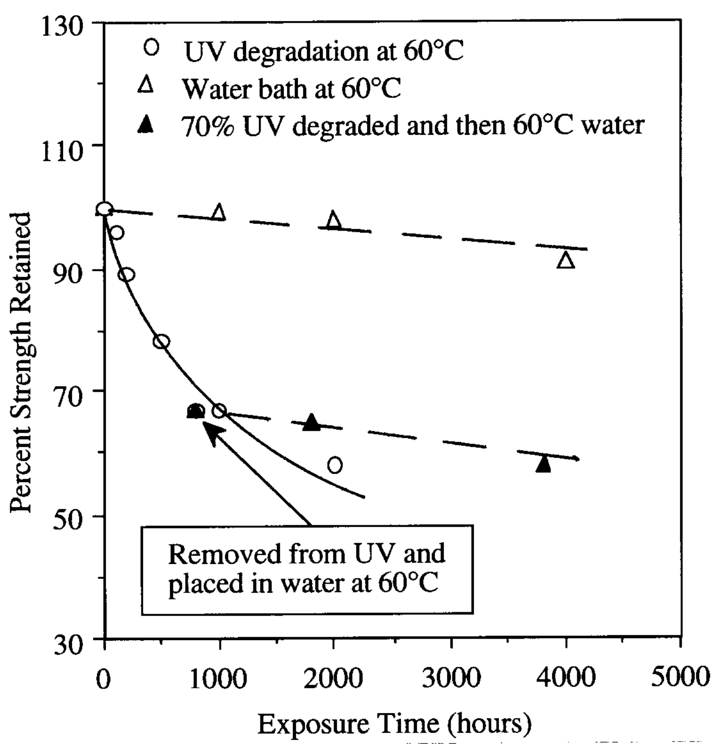

Fig. 6 Strength retained behavior of geotextile #1 under three different test conditions.

Table 3 The rate of strength retained for the 70% UV degraded and unexposed geotextiles from Figs. 5 and 6

Geotextile	Unexposed (%/hour)	70% UV degraded (%/hour)
#1 (Fig. 5)	-0.0031	-0.0042
#3 (Fig. 6)	-0.0017	-0.0028

Note that caution must be applied to interpolating the results of the PP geotextiles. The behavior of one type of PP geotextile does not represent the others due to the difference in their anti-oxidant package which is the primary protection for PP from outdoor weathering.

5 SUMMARY AND CONCLUSIONS

The behavior of partially UV degraded geotextiles is the focus of this paper. Twelve different geotextiles were evaluated. The results can be summarized as follows :

- UV exposure is the major contributor to the laboratory weatherometer degradation of geotextiles used in this study. (as opposed to thermal-oxidative or hydrolytic degradations)
- The rate of strength reduction is inversely proportional to the unit weight of the geotextiles. This is due to the degradation starting from the exposed surface and then moving progressively inwards.
- The rapid photo-oxidative degradation rates of geotextiles caused by UV exposure are essentially eliminated once the UV source is removed.
- The 70% UV degraded geotextiles show a similar behavior as those unexposed geotextiles regarding the strength retained property within 3000 hours at 60°C.

The obvious next phase of this study is to evaluate the behavior at three, or more, temperatures in order to predict the long term behavior via Arrhenius modeling.

6 ACKNOWLEDGEMENTS

The funding for this study was provided by the Geosynthetic Research Institute Consortium of member organizations and the U.S. EPA under cooperative agreement CR-821448 with Robert E. Landreth as Project Officer.

7 REFERENCES

Hirt, R. C. and Searle, N.A. (1964) Wavelength sensitivity or activation spectra of polymer, Society of Plastics Engineers, Regional Technical Conference, Washington, DC, pp. 286-302.

Hsuan, Y. and Koerner, R.M. (1993) Can outdoor degradation be predicted by laboratory acceleration weathering? Geotechnical Fabrics Report, Vol. 11 No. 8, pp. 12-17.