Performance of Nonwoven Geotextiles Exposed to a Semi-Tropical Environment

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ABSTRACT: The performance of two needlepunched nonwoven geotextiles exposed to sunlight in a semi-tropical climate is discussed. Both geotextiles had the same mass per unit area; one was made with polypropylene, the other with polyester. Mechanical tests were conducted periodically to evaluate the deterioration of the geotextiles. During the first six months, the polypropylene geotextile deteriorated less quickly than the polyester geotextile, but shortly after 6 months of exposure, the polypropylene geotextile underwent a sharp decrease in properties and large holes appeared in the geotextile. After approximately 6 months, the rate of decrease of the properties of the polyester geotextile slowed down, and, after 14.5 months of exposure, the polyester geotextile still had mechanical properties that far exceeded the requirements of the project specifications.

1 INTRODUCTION

Two nonwoven geotextiles, one made of polypropylene, the other of polyester, were used as filters on a geonet leachate collection layer in a landfill located in a semi-tropical area. Both geotextiles were exposed to sunlight during the construction of the landfill. Although the geotextiles were not exposed at the same times, they were exposed to approximately the same conditions.

The polypropylene geotextile was installed in December 1990 and the polyester geotextile in September 1991. In both cases, the geotextiles were left uncovered until placement of a protective layer of sand. The polypropylene geotextile was left uncovered for approximately 7 months, and the polyester geotextile was left uncovered for approximately 14.5 months.

At the design stage, it was anticipated that the geotextiles would be exposed for two to three months. Because it was recognized that exposure could lead to deterioration of the properties of the geotextiles, geotextiles were used that had properties exceeding project specifications.

During construction, it appeared that the geotextiles would be exposed for approximately six months or longer. To check that the geotextiles would still meet project specifications at the time of sand placement, they were tested periodically during exposure.

After approximately 6.7 months of exposure, holes developed in the polypropylene geotextile, indicating that exposure had caused it to deteriorate (Tisinger et al., 1993). Visual examination of the polyester geotexfile during its 14.5 months of exposure did not reveal any significant deterioration. Measurement of mechanical properties indicated that both geotextiles lost some strength during the exposure period. The purpose of this paper is to show how exposed geotextiles perform in the field, to compare the field performance of two commercially available geotextiles made from different polymers, and to discuss the mechanisms of deterioration of the geotextiles.

2 DESCRIPTION OF SITE CONDITIONS

2.1 Composition of Lining System

The landfill lining system, from top to bottom, consisted of the following:

- protective sand layer;
- geotextile filter (540 g/m^2);
- geonet drainage layer;
- HDPE textured geomembrane (2.0 mm);
- geocomposite drainage layer; and
- HDPE textured geomembrane (2.0 mm).

2.2 Exposure conditions

The site is located in a semi-tropical area in the northern hemisphere where the geotextiles were exposed to high temperatures (Fig. 1), humidity, sun, wind, and rain.

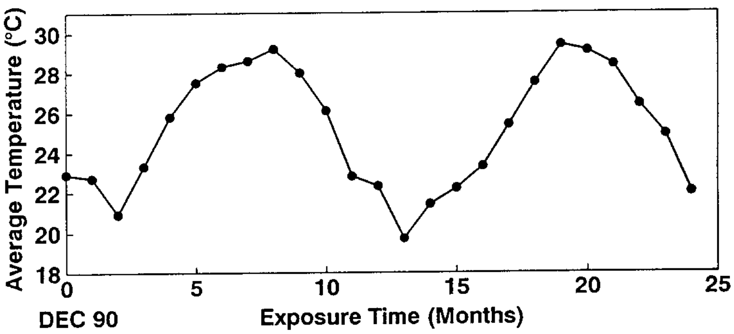

Fig. 1 Average monthly temperatures

3 THE GEOTEXTILES

3.1 Description

Both geotextiles were continuous filament needlepunched nonwovens with a nominal mass per unit area of 540 g/m^2. The polypropylene geotextile was made with filaments stabilized against ultraviolet (UV) radiation with hindered amine light stabilizers. This geotextile did not contain carbon black, but contained a light brown pigment. The polyester geotextile was made with polyethylene terephthalate filaments and did not contain stabilizers. This geotextile was, however, pigmented with approximately 0.12% to 0.16% of carbon black and was light gray.

3.2 Specifications

The following survivability requirements were in the project specifications:

Grab Strength	>	800 N (180 lbs)
Tear Strength	>	220 N (50 lbs)
Puncture Strength	>	355 N (80 lbs)
Burst Strength	>	2000 kPa (290 psi)

While the above requirements could have been met by needlepunched nonwoven geotextiles with a mass per unit area of 270 g/m^2, geotextiles with a nominal mass per unit area of 540 g/m^2 were selected. These geotextiles far exceeded the above requirements, and it was anticipated that they would still retain enough strength to meet the project specifications after the exposure period (i.e., 2-3 months) foreseen at the design stage.

3.3 Conformance testing

Conformance testing was performed on samples taken at random from the geotextile rolls delivered to the site. The results are reported in Table 1.

Table 1. Pre-exposure properties

Property	Unit	PP	PET
Mass/area	g/m^2	589	582
Grab Strength	N	2358	3137
Tear Strength	N	811	844
Puncture Strength	N	954	1094
Burst Strength	kPa	4206	5705

Table 1 shows that the mechanical property values of the polyester (PET) geotextile exceeded the corresponding values of the polypropylene (PP) geotextile, due possibly to either the polyester fibers having a higher tenacity than the polypropylene fibers or the polyester geotextile being more tightly needlepunched.

4 PERFORMANCE OF THE GEOTEXTILES

At the construction stage, when it was recognized that the geotextiles would be exposed longer than originally anticipated, the decision was made to monitor periodically the mechanical properties of the geotextiles to check that they still meet project specifications at the time of sand placement.

Tables 2 and 3 present the post-exposure properties of the geotextiles at different periods of exposure.

Table 2. Post-exposure[(1)] properties of the polypropylene geotextile

Property (Unit)	4.5 Months Strength Value	4.5 Months Change (%)	6.5 Months Strength Value	6.5 Months Change (%)	6.7 Months Strength Value	6.7 Months Change (%)
Grab (N)	2140	-9.2	1818	-22.9	882	-62.6
Tear (N)	890	9.7	535	-34.0	285	-64.9
Puncture (N)	867	-9.1	724	-24.1	494	-48.2
Burst (kPa)	4600	9.4	4076	-3.0	1793	-57.4

Note (1) The pre-exposure values are provided in Table 1.

Table 2 shows that the polypropylene geotextile experienced a reduction in grab strength and in puncture strength after 4.5 months of exposure. However, tear strength and burst strength both increased, owing to either testing errors or physical changes in the geotextile (possibly shrinkage, induced by heat from sunlight, which would cause the geotextile mass per unit area to increase) (Tisinger et al., 1993). The results might also indicate that grab and puncture strengths are more sensitive than other properties to the effects of exposure. After 6.5 months of exposure, all properties were reduced, but still met project specifications. However, after 6.7 months of exposure, visual inspection revealed the development of large holes in the geotextile (Tisinger et al., 1993), and, as shown in Table 2, the mechanical properties decreased significantly.

Table 3. Post-exposure properties of the polyester geotextile

Property (Unit)	Pre-Exposure Strength Value	6.0 Months Strength Value	6.0 Months Change (%)	14.5 Months Strength Value	14.5 Months Change (%)
Grab (N)	3137	2382	-24.1	2188	-30.3
Tear (N)	844	1142	35.3	1048	24.2
Puncture (N)	1094	877	-19.8	874	-20.1
Burst (kPa)	5705	4918	-13.8	4964	-13.0

Examination of Table 3 reveals that the mechanical properties of the polyester geotextile, with the exception of the tear strength, were reduced. However, the rate of reduction was slow after 6.5 months.

5 COMPARISON OF THE PERFORMANCE OF THE GEOTEXTILES

The mechanical properties of the geotextiles are plotted in Fig. 2, which shows that both geotextiles underwent reduction in some mechanical properties within the first 6 months. During that period, the rate of reduction appears to be slightly lower for the polypropylene than for the polyester geotextile. A similar trend was reported in a study by Brand and Pang (1991), in which polypropylene and polyester nonwoven continuous filament geotextiles were exposed for up to nine months. As was observed in this study, Brand and Pang (1991) show the strength of the polyester geotextile reaching a plateau after approximately 6 months of exposure, while the polypropylene geotextile continued deteriorating. The results of this study and the study by Brand and Pang (1991) suggest that the mechanisms of deterioration for polypropylene and polyester geotextiles may be different.

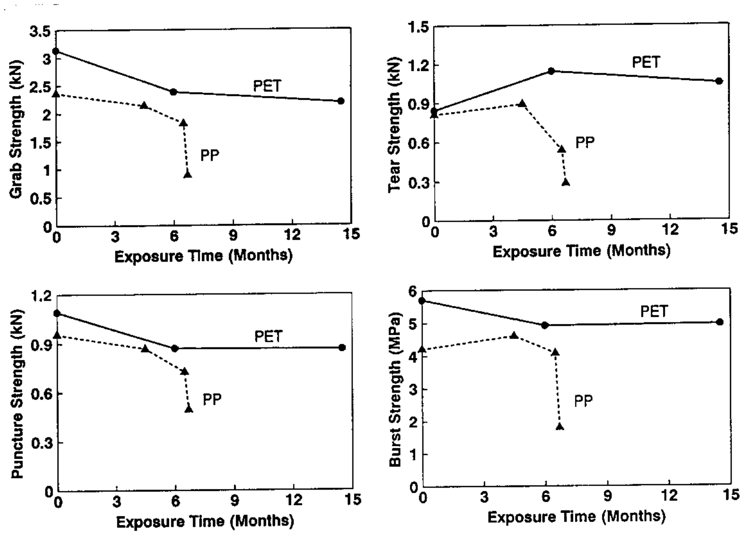

Fig. 2 Mechanical properties of the geotextiles

6 MECHANISMS OF DETERIORATION

6.1 Overview

As shown in Fig. 2, the polypropylene geotextile exhibited a deterioration behavior different from the behavior of the polyester geotextile. This may be due to molecular structure differences between polypropylene and polyester, as well as to other factors. Because the geotextiles were exposed outside, a number of different modes of deterioration, which are discussed below, may have affected the geotextiles.

6.2 UV radiation

Exposed outside, where the conditions were fairly extreme, the geotextiles were subjected to UV radiation-induced oxidation. It has been suggested by Sotton (1984) and by Carlsson and Wiles (1976) that UV-radiation induced oxidation is a surface phenomenon, and, therefore, only the fibers exposed on the surface can oxidize. Oxidation can weaken and embrittle fibers, leading to their fracture. As a result, the geotextile may undergo an initial loss of strength due to deterioration of the surface fibers, but further strength losses, due to UV radiation, may occur at a significantly reduced rate, because the surface fibers screen the UV radiation. (In this study, a contributing factor to the polyester geotextile reaching a plateau after approximately 6 months of exposure might be that its surface, at 14.5 months, was partially covered with bird droppings and landfill residue, possibly screening some UV radiation from the fibers. However, after 6.7 months, the months, the polypropylene geotextile had a small amount of bird droppings and landfill residue on its surface.)

6.3 Heat

Heat, like UV radiation, induces oxidation. However, the effect of heat is not limited to fibers on the surface of geotextiles, and fibers beneath the surface may undergo oxidation. Oxidation induced by heat can occur on both polypropylene and polyester geotextiles, and, like oxidation induced by UV radiation, can weaken and embrittle fibers, leading to their fracture.

Heat has an additional effect that has been observed only in polypropylene geotextiles. Heat relaxes the internal stresses of polypropylene fibers, causing the fibers to shrink (Schneider, 1989; Tisinger et al., 1993). The mechanism of degradation of polypropylene fibers may therefore be as follows: (i) exposed polypropylene fibers are first embrittled by UV radiation- and heat-induced oxidation; then (ii) if exposure to heat is prolonged, shrinkage of the fibers occurs and the resulting tension in the fibers, combined with fiber embrittlement, develops holes in the geotextile. Similar behavior was reported previously by Tisinger et al. (1990) and Tisinger et al. (1993).

6.4 Hydrolysis

Polyester can undergo hydrolysis, which is a chemical reaction of water with polyester, resulting in the breakdown of polyester molecules (Risseeuw and Schmidt, 1990). (In contrast, polypropylene, by virtue of the absence of a reactive site on its molecular structure, can not undergo hydrolysis.) As discussed by Risseeuw and Schmidt (1990) and by Schneider and Groh (1987), hydrolysis accelerates with increasing temperature and increasing relative humidity. Therefore, under extreme climatological conditions (i.e., high ambient temperature and high relative humidity), the polyester geotextile may have experienced hydrolysis in addition to oxidation.

6.5 Mechanical stresses

Finally, the geotextiles may have been subjected to significant mechanical stresses which might have contributed to the strength loss. The sources of such stresses, which were discussed in detail by Tisinger et al. (1993), might include the action of wind, abrasion from construction equipment, and abrasion from walking. In addition, the geotextiles' fibers may have been loosened by birds pulling the fibers.

7 CONCLUSIONS

Based on the findings of this study and available literature, the following conclusions have been reached:

- During the first six months of exposure, the rate of deterioration of the polypropylene geotextile was slower than that of the polyester geotextile.
- Shortly after six months of exposure, the polypropylene geotextile underwent significant deterioration, whereas the polyester geotextile still had mechanical properties that exceeded project specifications after 14.5 months of exposure.
- The mechanism(s) of deterioration of the polypropylene geotextile appeared to be due to a combination of mechanical stresses, heat, and oxidation.
- The mechanism(s) of deterioration of the polyester geotextile appeared to be due to a combination of mechanical stresses, oxidation, and hydrolysis.

REFERENCES

Brand, E.W. and Pang, E.L.R. (1991) Durability of Geotextiles to Outdoor Exposure in Hong Kong, *Journal of Geotechnical Eng.*, 117, 7: 979-1000.

Carlsson, D.J. and Wiles, D.M. (1976) Effects of UV Light on the Chemical and Mechanical Properties of Fiber-Forming Polymers, *UV Light Induced Reactions in Polymers*, ACS Symposium Series 25, Washington, D.C., USA: 321-339.

Risseeuw, P. and Schmidt, H.M. (1990) Hydrolysis of HT Polyester Yarns in Water at Moderate Temperatures, *Proc. of the 4th International Conference on Geotextiles, Geomembranes, and Related Products*, The Hague, Netherlands, 2: 691-696.

Schneider, H. and Groh, M. (1987) An Analysis of Durability Problems of Geotextiles, *Proc. of Geosynthetics '87*, New Orleans, USA, 2: 434-441.

Schneider, H. (1989) Long-Term Performance of Polypropylene Geosynthetics, *Durability and Aging of Geosynthetics*, R.M. Koerner, Ed., Elsevier: 48-64.

Sotton, M. (1984) Durability of Geotextiles, *Proc. of the 23rd International Man-Made Fibres Conference*, Dornbirn, Austria: 364-386.

Tisinger, L.G., Peggs, I.D., Dudzik, B.E., Winfree, J.P., and Carraher, C.E. (1990) Microstructural Analysis of a Polypropylene Geotextile After Long-Term Outdoor Exposure, *Geosynthetic Testing for Waste Containment Applications*, ASTM STP 1081, Philadelphia, USA, 335-351.

Tisinger, L.G., Clark, B.S., Giroud, J.P., and Christopher, B.R. (1993) Analysis of an Exposed Polypropylene Geotextile, *Proc. of Geosynthetics '93*, Vancouver, Canada, 2: 757-771.