Durability of a Polypropylene Geotextile in an Unpaved Road Structure

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This paper addresses select durability characteristics of a continuous-filament, nonwoven geotextile commonly used in transportation-related applications. Two samples of the geotextile were exhumed from the base of an unpaved road structure located at an industrial site in East Texas. The two samples had been in service for 12 and 13 years, respectively. The samples, together with an unused reference sample manufactured at the same time as the exhumed samples, were subjected to a series of destructive mechanical tests, structural analyses, and examinations via scanning electron microscopy. The mechanical tests included measurements of grab-tensile strength and elongation, burst strength, puncture strength, trapezoid-tearing strength, as well as individual fiber strength and elongation. The exhumed samples retained in excess of 70 percent of their initial strength and elongation properties. The microstructural analyses included differential scanning calorimetry and infrared spectroscopy. The results of these tests indicated that some polymer degradation had occurred such as might be caused by oxidation. The extent of the oxidation is not considered significant because scanning-electron microscopy does not show any circumferential cracking on the fiber surface, a feature that occurs when fiber oxidation is extensive. Scanning electron microscopy did show some mechanical damage on the surface of the fibers; however, this may be ascribed more to installation damage than to degradation during service.

To date, the majority of geosynthetic tests for civil or geotechnical engineering applications are used to determine whether the geosynthetic has properties appropriate for service only at the moment of installation. Be they geotextiles for highways, geogrids for embankment reinforcement, or geomembranes for landfill liners, little interest has been expressed in the long-term durability of the product. This is partially due to the fact that appropriate tests to evaluate durability are not routinely performed and standardized. However, recently, significant interest in the long-term degradation of geotextiles and the polymeric fibers from which they are manufactured has been expressed by the International Organization for Standardization, the American Society for Testing and Materials (*1*), the Strategic Highway Research Program, the Geosynthetic Research Institute (*2*), and others (*3–7*). The new test methods are mainly performed on the fibers that constitute the geotextile rather than on the geotextile itself and are employed to assess their long-term durability.

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BACKGROUND

The geotextile examined in this program was a continuous-filament, thermally bonded, nonwoven polypropylene material with a nominal mass per unit area of 136 g/m^2 (4 oz/yd^2). The individual fibers had linear densities of approximately 1.1 tex (10 denier) in both machine and cross directions.

Definitions

The geotextile for examination was exhumed from a site in East Texas. The site was chosen from one of seven sites used in a previous complementary study (*7*) of the survivability and durability characteristics of the same geotextile. In the previous study, survivability was defined as a geotextile's resistance to destruction during construction and initial operation. Durability was defined as the resistance of a buried geotextile to long-term degradation. These definitions are maintained in this paper. However, contrary to the previous study, which was concerned with geotextile survivability, this study is more concerned with geotextile durability and has been partially directed to compare the bulk geotextile properties with those of the individual fibers.

Site Description

The study site was previously described by Bonaparte et al. (*7*) as being located in a flat, wet, low-lying area near the Gulf Coast in East Texas. The site has poor drainage and a water table near the surface. The subgrade soil is a black organic, high-plasticity clay with undrained shear strengths in the range of 30 to 45 kPa (570 to 940 psf) in the first meter below the surface. Geotextiles were used to construct access roads and drill pads at the site in 1975 for oil and gas exploration and production.

The geotextile samples exhumed during the present study had been installed in an area where subgrade preparation prior to road construction was limited to the clearing of small trees and shrubs. The geotextiles were unrolled directly on the cleared, relatively flat subgrade. The fill material used to construct the roads and pads was a well-graded, crushed (angular) limestone aggregate with a maximum particle size of about 60 mm (2.5 in.), with about 15 to 20 percent fines (15 to 20 percent passing a No. 200 U.S. standard sieve). The fill was brought to the site in 225-kN (25-ton), 10-wheel dump trucks that back-dumped onto previously constructed portions of the road or pad. The fill was spread in a single lift using track-mounted Caterpillar D6 and Case 1450 bulldozers. Ground pressures exerted by the dump trucks were on the order of 500 kPa (5 tsf), whereas the bulldozers exerted ground pressures in the range of 70 kPa (1500 psf). Fill thicknesses ranged from about 225 mm (9 in.) to 300 mm (12 in.).

Test Specimens

In December 1986, a 0.5-m^2 (5-ft^2) sample of geotextile was retrieved from the Texas site. The sample had been in service approximately 12 years and is identified here as No. 12. The sample retrieval procedure has been described in detail by Bonaparte et al. (*7*), who also described the site, which has a moderate to high geotextile survivability rating based on the FHWA *Geotextile Engineering Manual* (*8*). At the Texas site, the geotextile was found to have performed adequately and to have been in good condition (*7*). On the basis of the observed good condition of the geotextile, it was concluded that the material had adequate physical and mechanical properties for use at a site with a moderate-to-high survivability rating.

The study by Bonaparte et al. (*7*) provided only limited information on geotextile durability. Therefore, in April 1988, a second 0.5-m^2 sample of geotextile was retrieved from the Texas site for the purpose of conducting additional durability studies. This second sample had been in service approximately 13 years and is identified here as No. 13. The remainder of this paper describes the additional studies carried out using geotextile samples 12 and 13.

LABORATORY EXAMINATION

After retrieval from the Texas site, the geotextile samples were delivered to the laboratory in tightly sealed polyethylene bags. After removal from the bags, the samples were gently shaken to remove loose dirt and cleaned of easily removed dirt by rinsing in deionized water. The samples were allowed to dry naturally in a standard laboratory atmosphere (temperature 21 ± 2°C, relative humidity 45 to 65 percent). The geotextile samples were then subjected to a series of tests as follows; however, both samples were not subjected to all the tests.

Mechanical Property Tests

Mechanical property testing included the following standard geotextile index tests:

- Mullen burst strength (ASTM D 3786),
- Puncture strength (ASTM D 3787),
- Grab-tensile strength (ASTM D 1682), and
- Trapezoid-tearing strength (ASTM D 4533).

Sample 13 was subjected to the Mullen burst-strength test only, because the emphasis of testing on this sample was to be the individual fiber and analyses of the fiber structure.

Hydraulic Property Test

Sample 12 was subjected to permittivity testing according to ASTM D 4491 at a hydraulic head of 50 mm (2 in.). Because permittivity data were not available in 1975, reference data were obtained from 1987 literature for the equivalent product.

Fiber Linear Density and Strength Tests

Individual fibers were carefully removed from sample 13 and the 1975 reference material. Fiber tests were not performed on sample 12. Each fiber was gently pulled out of the geotextile with the assistance of a stereomicroscope. The linear density of the fibers was measured on a Vibromat tester according to ASTM D 1577. The peak tensile strength (tenacity) and strain at rupture were determined using specimens with a 25-mm (1-in.) long gage length at an elongation rate of 25 mm/min (1 in./min) according to ASTM D 3822.

Scanning Electron Microscopy

Scanning electron microscopy (SEM) was used to examine the outside surfaces and fracture surfaces of individual geotextile fibers in both samples 12 and 13. In an attempt to detect whether the fibers had become more or less brittle during exposure, small samples of the geotextile were pulled in tension so that the microscopic features of the fiber fracture faces could be examined. One of the prime objectives of the SEM analysis was to identify any circumferential cracking, which, if present, is evidence of the degradation of the surface layers of the polypropylene. Reference data were generated by examining 1975 reference samples that had been stored indoors.

Chemical Structural Analyses

Both samples 12 and 13 were subjected to two types of analytical tests: differential scanning calorimetry (DSC) and infrared spectroscopy (IR). Reference data were generated by performing the same tests on the 1975 archive samples.

The analytical tests were used to assess the effects of long-term environmental exposure on the microstructure of the geotextile. The degrees of crystallinity and oxidative induction temperatures were measured using DSC. Structural characteristics were evaluated using IR.

Differential Scanning Calorimetry

A DSC analysis involves monitoring of the thermal energy required to maintain a test specimen at the same temperature as a reference specimen heated at a constant rate of increasing temperature. This energy is exhibited as a function of the reference temperature in a thermogram. The thermogram may display endotherms (Figure 1), corresponding to energy absorbed in the specimen, and exotherms (Figure 2), corresponding to energy emitted. From endotherms, melting point ranges and degree of crystallinity may be derived. Exotherms provide data for the assessment of the oxidative stability of

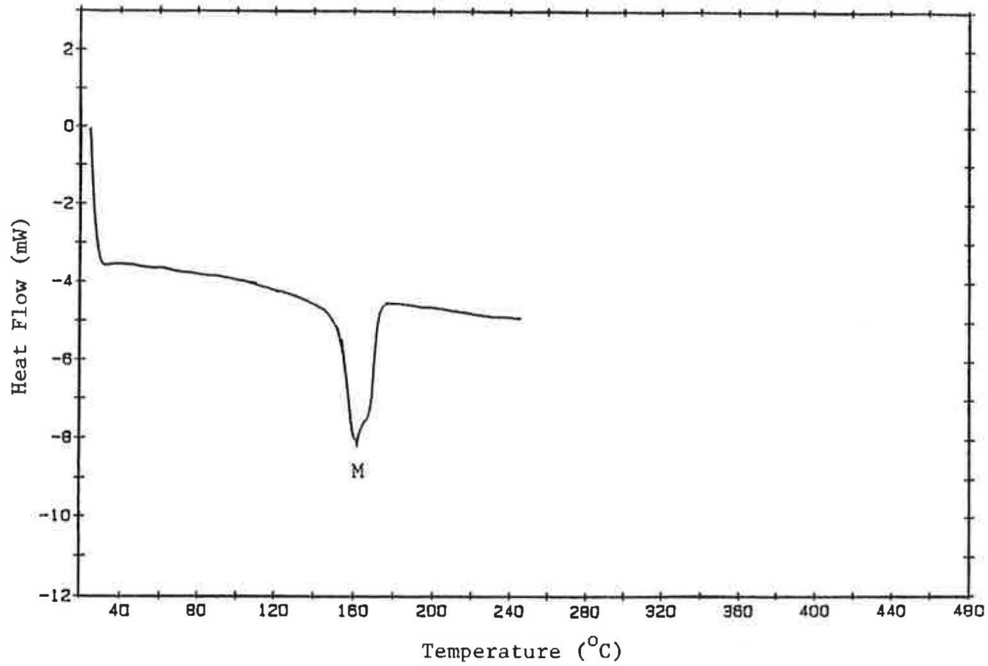

FIGURE 1 Melting endotherm (*M*) for archive polypropylene geotextile.

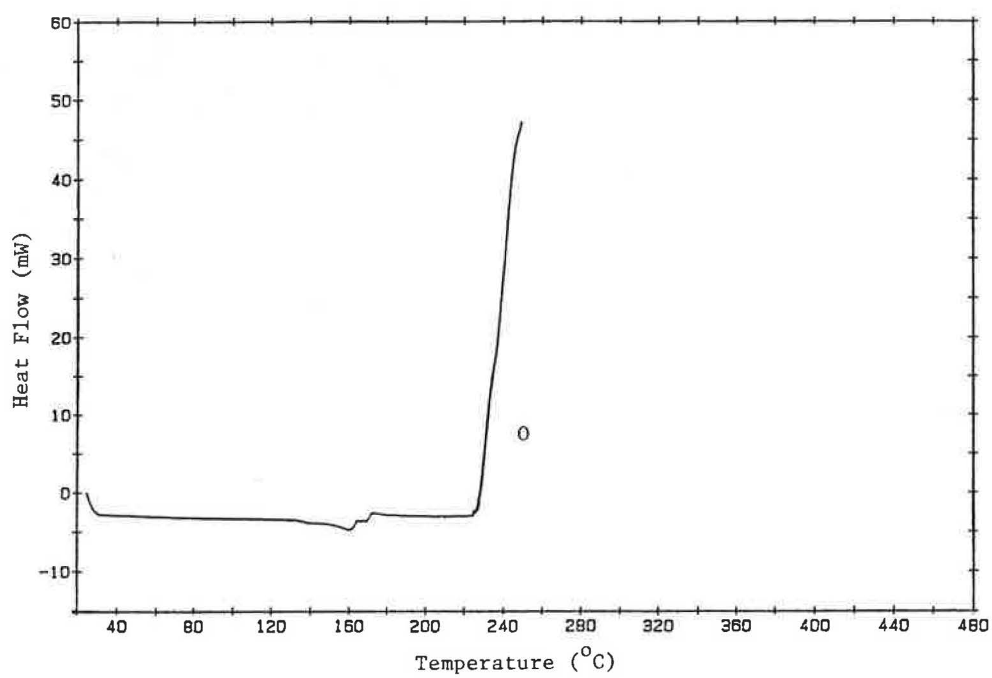

FIGURE 2 Oxidation exotherm (*O*) for archive polypropylene geotextile.

the material based on either the oxidative induction time or oxidative induction temperature, which is the time or temperature at which the specimen is completely degraded. The oxidative induction temperature tests were conducted in an air atmosphere at a heating rate of 20°C/min. The degree-of-crystallinity tests were performed in a nitrogen atmosphere at a heating rate of 20°C/min.

Polypropylene is a semicrystalline polymer. By comparing the area within the melting endotherm (the heat of fusion) to the heat of fusion of a fully crystalline material such as indium, the degree of crystallinity of the microstructure can be determined.

The oxidative induction temperature is the temperature at which reaction of a material with oxygen occurs. The DSC analysis is conducted with the specimen in a reactive atmosphere (air or oxygen), and the oxidative induction temperature value is the temperature at the onset of the exotherm, approximately 232°C in Figure 2. This parameter gives an indication of the oxidative stability of a material (i.e., the effectiveness of the antioxidant package).

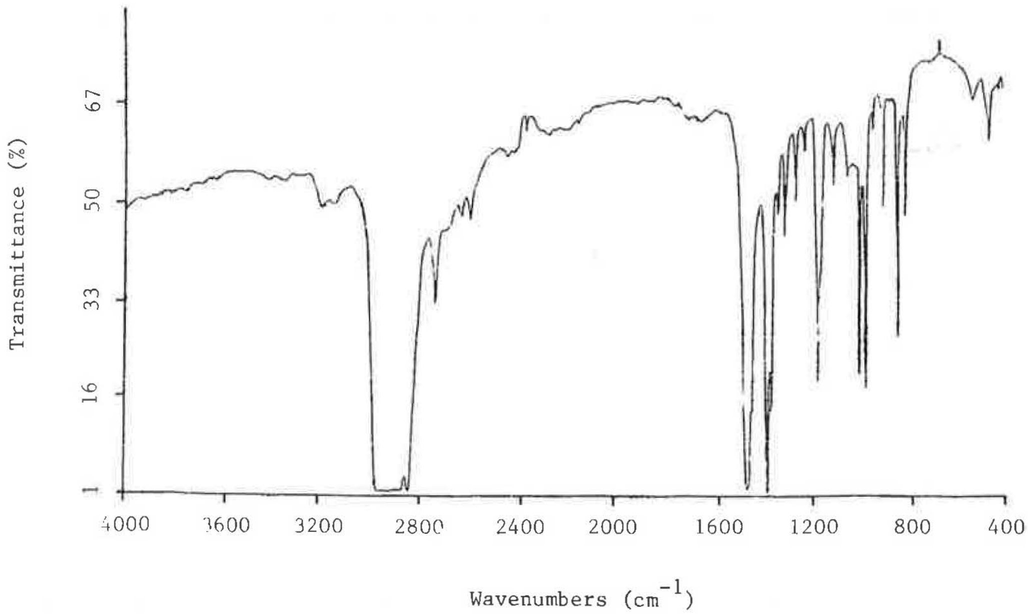

FIGURE 3 Typical IR spectrum for polypropylene geotextile.

Infrared Spectrometry

IR spectra provide information on the structural characteristics of a material. This analytical technique involves exposing the material to infrared radiation at decreasing frequencies. This radiation scan generates a spectrum of bands (Figure 3), each corresponding to a particular frequency or range of frequencies in which infrared radiation is absorbed by the specimen. The molecular components of any given material display a characteristic "spectrum of bands," thus allowing correlations or comparisons with spectra from other materials.

IR can be used to identify a specific degradative process in a geotextile through the identification of new spectral bands generated by the products of the degradative process.

TEST RESULTS

Before any laboratory tests were performed, the as-received samples were examined carefully. Sample 13 contained only one hole, which had been caused by the pickaxe when the soil cover was being removed during field exhumation. The condition of sample 12 appeared to be undamaged. Sample 13 showed no signs of severe distress, although deformations and indentations from the limestone aggregate base that covered the geotextile were evident. A close-up view of a typical area of the sample is shown in Figure 4. The geotextile has retained its original morphology without significant evidence of "fraying" or loosened fibers.

Figure 5 shows a direct comparison of the exhumed sample 13 and the 1975 reference sample. Except for the dirt in the exhumed sample, there is very little difference in the appearance of the two materials.

In general, the exhumed sample 13 does not appear to have suffered significant degradation on a macro scale.

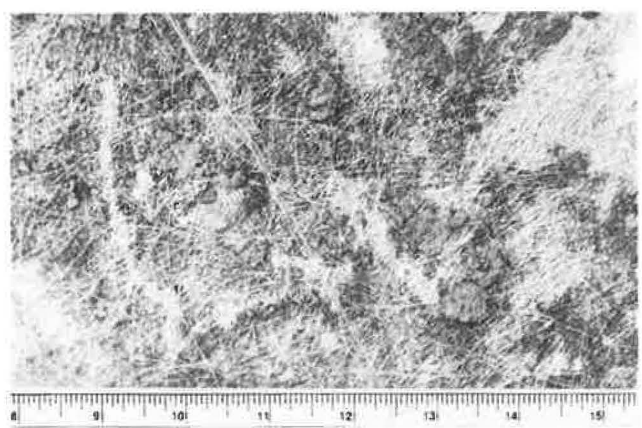

FIGURE 4 Close-up view of the surface of the as-received sample.

Mechanical Property Test Results

The mechanical property test results, including those from sample 12, are shown in Table 1. Because it was difficult to identify the machine and cross directions of the samples removed from the field, the reference parameter is presented as the arithmetic mean of the two (machine and cross direction) values published in the 1975 product brochure.

Although some general loss-of-strength properties are indicated in Table 1 for sample 13, it is notable that at the 95 percent confidence limits (approximately two standard deviations), the data for the exhumed samples overlap the ranges of values for the 1975 reference samples. The Mullen burst strength for sample 13 shows virtually no loss when compared with the reference data.

(a)

(b)

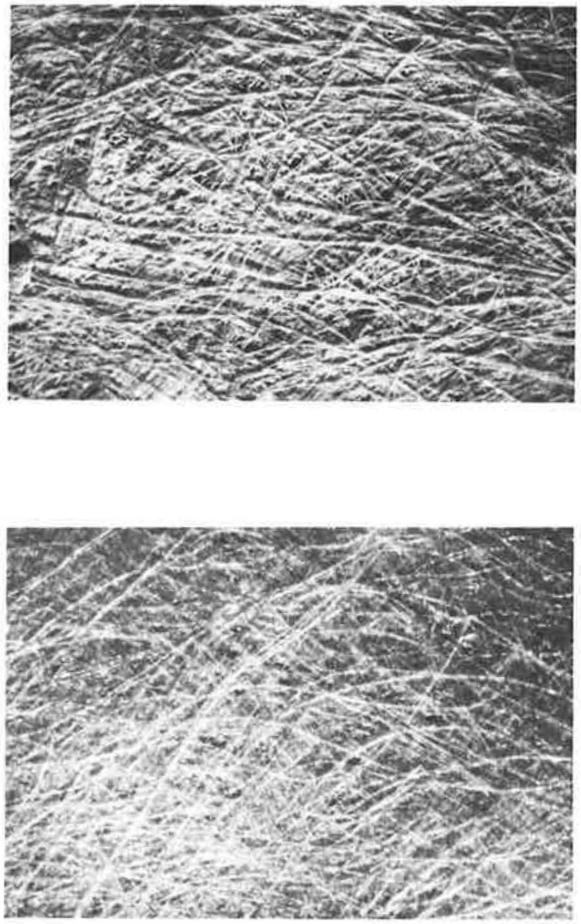

FIGURE 5 Comparison of the surfaces of (a) sample 13 and (b) the 1975 reference sample (×3).

The residual property values after exposure of the geotextile to the environment are of major interest to geotechnical and transportation engineers. These data are given in Table 2.

The exhumed geotextile has retained in excess of 70 percent of its original mechanical properties after construction and 12 to 13 years of burial. It appears in addition that the strength retention could be dependent upon the location of the specimen within the exhumed sample as shown in sample 13 (exposed for the longer period), which has a higher burst strength than sample 12. This suggests that a major contributor to the loss could be mechanical damage incurred during installation rather than the overall degradation of the geotextile during service. A similar conclusion was reached by Bonaparte et al. in the previous study (7) of this geotextile.

Hydraulic Property Test Results

The results of the permittivity testing are as follows: field sample 12, 0.48 s^{-1}; brochure reference (1987), 0.55 s^{-1}. The geotextile has retained 87 percent of its original permittivity. However, this loss is not due to aging processes but primarily to the retention of soil particles within the pore structure of the geotextile. All of the soil particles were not removed by the preparatory wash in deionized water. The geotextile clearly had not become clogged with soil and still allowed passage of water.

Fiber Linear Density and Strength Test Results

The individual fiber test results are summarized in Table 3. Nine fibers from the 1975 reference sample and six sample 13 fibers were tested. The exhumed fibers show a 5 percent loss in linear density and an equivalent loss in peak tensile

TABLE 1 MECHANICAL PROPERTY TEST DATA

Parameter	Field Sample #12	Field Sample #13	Brochure Reference (1975) (Mean of MD and XD)
Grab Strength (N)	481 ± 62[a]	-	614 ± 40[a]
Grab Elongation (%)	53	-	74
Burst Strength (kPa)	837 ± 186[a]	1200 ± 15[a]	1200 ± 140[a]
Puncture Strength (N)	209 ± 22[a]	-	220 ± 18[a]
Tear Strength (N)	245 ± 62[a]	-	310 ± 45[a]

[a] Standard deviation

MD = Machine direction

XD = Cross-machine direction

TABLE 2 RESIDUAL MECHANICAL PROPERTIES

		Residual Value	
Parameter	Brochure Reference Value	Field Sample #12 (%)	Field Sample #13 (%)
Grab Strength (N)	614	78	-
Grab Elongation (%)	74	71	-
Burst Strength (kPa)	1200	70	100
Puncture Strength (N)	220	94	-
Tear Strength (N)	310	79	-

TABLE 3 FIBER TEST RESULTS

Parameter	Field Sample #12	Field Sample #13	Reference Fibers (1975)
Linear Density (D)	-	10.1 (95)[a]	10.6
Tenacity (g/D)	-	3.2 (94)[a]	3.4
Break Strain (%)	-	123 (86)[a]	143

[a] Residual Value

strength or tenacity. To produce a decrease in linear density, material must be lost from the surfaces of the fibers. The scanning electron microscopy results that follow show that the loss may be due to scraping or gouging of the fibers during the construction operation. This process produces stress-concentrating notch defects on the surface of the fiber, which cause a reduction in tenacity and strain at rupture. Similar observations have been noted in polyethylene geomembranes (*9*, *10*) in which break strength may be reduced by approximately 50 percent and break elongation by approximately 95 percent due to surface defects. In comparison with these reductions for polyethylene, the polypropylene fibers have suffered relatively little loss of mechanical properties.

In sample 13 fibers, there were two specimens of average linear density that did in fact show low peak-tenacity values of 2.44 and 2.91 g/D and rupture strains of 42 and 90 percent, both well below the average reference values. These individual specimens had apparently suffered major surface damage. However, two of the reference geotextile fiber specimens also showed similar mechanical characteristics: peak tenacities of only 2.64 and 3.02 g/D and rupture strains of 47 and 93 percent. It therefore appears that some of the as-manufactured fibers contain surface features that affect the mechanical properties of the fibers. Therefore, excessive damage may not have occurred during installation.

The test data from sample 13 indicate that little degradation of the geotextile fibers has occurred over the 13-year period that the geotextile has been in service.

SEM Test Results

The original as-manufactured geotextile (the 1975 reference sample) and the individual fiber surfaces (from sample 13) are shown in Figure 6. The individual fibers (occasionally a few are bonded together in a parallel fashion) are distributed more or less randomly to produce a planar isotropic structure. The surfaces of the individual fibers are generally very smooth,

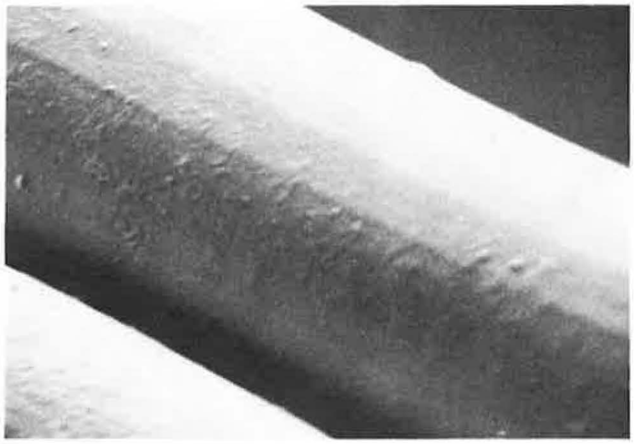

FIGURE 6 Surface of reference geotextile fiber (×975).

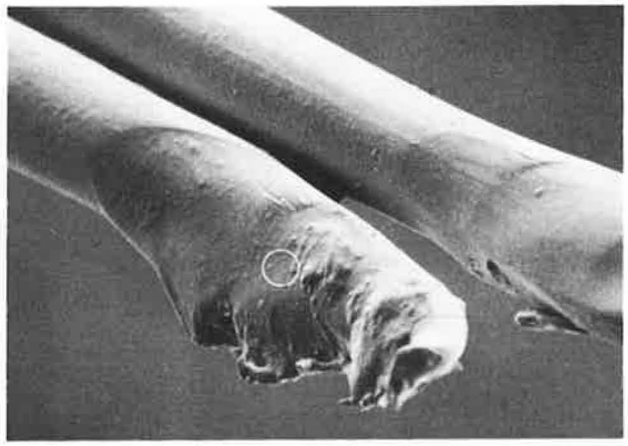

FIGURE 8 End of fractured reference geotextile fiber (×325).

with only occasional surface blemishes (Figure 7). These blemishes, particularly those with the geometrical profile of a notch, were probably responsible for the few low tenacity and rupture strain values obtained in the fiber-testing component of the program.

Fibers that had failed in tension showed a significant amount of elongation with a characteristically ductile final fracture. The surface of the fiber adjacent to the final fracture region was smooth, as seen in Figures 8 and 9.

In comparison, Figure 10 shows the surfaces of fibers removed from samples 12 and 13. In general, the fibers from sample 12 are more severely damaged than those from either the sample 13 fibers or the reference sample. The damage appears to be more of a ductile "smearing" than a brittle chipping. In other words, the fiber material is not lost but is just redistributed, probably as a result of spreading of the limestone aggregate over the geotextile during installation.

The fracture features of fibers in sample 12 (Figures 11 and 12) show more brittle characteristics in that there is little reduction in the cross section of the fibers. However, the nature of the fracture face itself shows the rounded, coarse surface features of a progressive ductile failure.

The fiber fracture in sample 13, shown in Figures 13 and 14, is essentially a replicate of the fiber fracture in the reference material shown in Figures 8 and 9. The only difference is the presence of the soil particles that have contributed to the roughness of the polypropylene surface adjacent to the fracture.

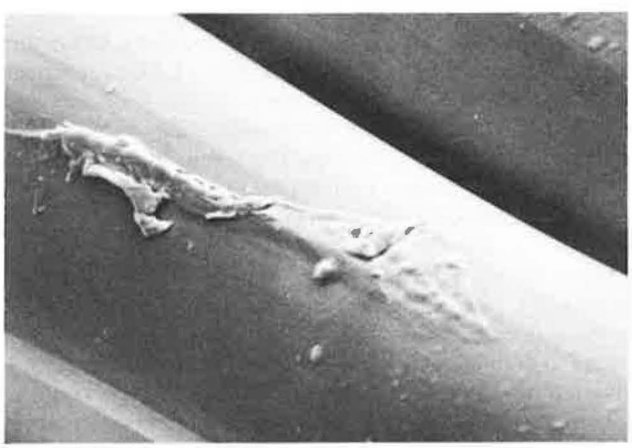

FIGURE 7 Blemish on surface of reference geotextile fiber (×975).

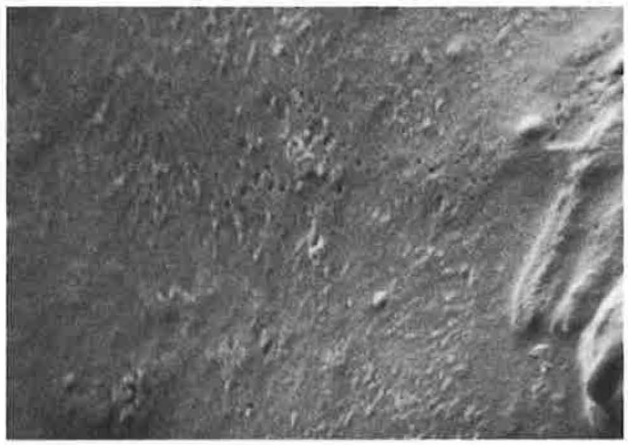

FIGURE 9 Surface of fiber in area circled in Figure 8 (×1950).

It appears that the fibers from sample 12 have been damaged more severely than those from sample 13. In fact, the fibers from sample 13 appear to have received very little damage or not to have suffered any damage at all. This may explain the observation that the Mullen burst strength of the geotextile in sample 13 shows no loss when compared with the reference data, whereas the burst strength of sample 12 does.

Many fibers were examined in the electron microscope for this project and the project reported earlier (*7*), but at no time was any evidence of circumferential surface cracking found. Such cracking occurs in highly oriented fibers when they degrade because of oxidation initiated by ultraviolet radiation. An example of degradation after 3 months of exposure to sunlight in a geotextile manufactured from a polypropylene resin similar to the one used in the present study is shown in Figure 15. Quite clearly, the individual fibers of the geotextile break up into short lengths at points where they are stressed.

The circumferential nature of the cracking in the oxidized fibers is clearly shown in Figure 16.

(a)

(b)

(c)

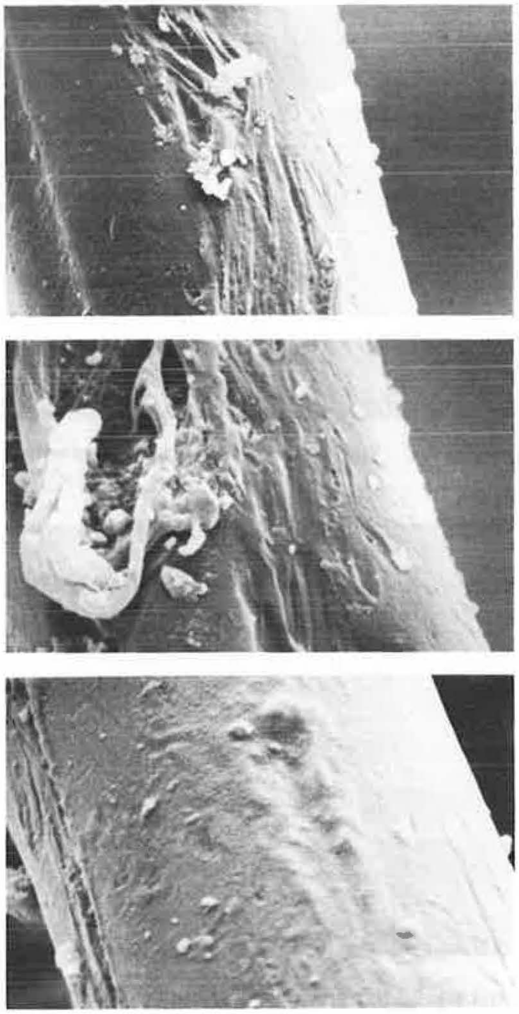

FIGURE 10 Surfaces of fibers from (a,b) sample 12 and (c) sample 13 (×975).

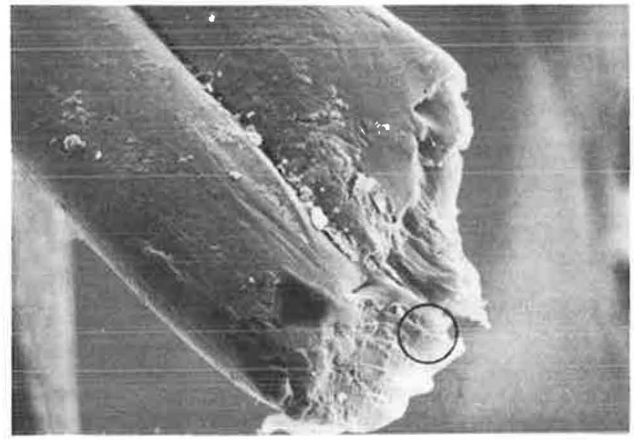

FIGURE 11 Fracture characteristics of fibers in sample 12 (×423).

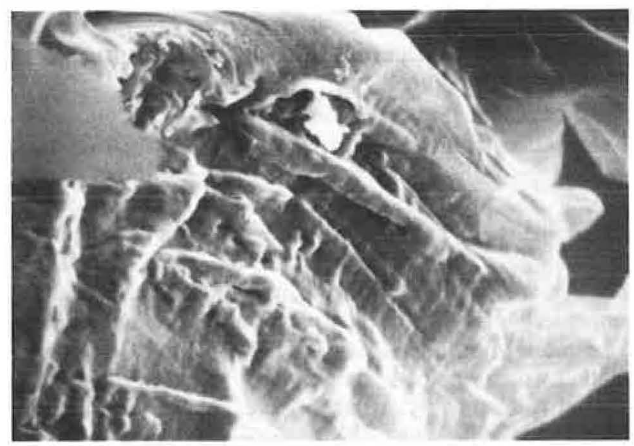

FIGURE 12 Fracture characteristics of fibers in area circled in Figure 11 (×1950).

Chemical Structural Analytical Test Results

The data from both DSC and IR studies indicate that only minor amounts of polypropylene chemical structural degradation have occurred since 1975.

Degree of Crystallinity

The crystallinity values and melting ranges of the reference geotextile and the exposed sample 13 geotextile are shown in Table 4. Five specimens from different areas of each were analyzed to take into account material variability.

The results are consistent, as indicated by the low standard deviations. The degree-of-crystallinity values for the exhumed samples are lower than for the reference samples, although the magnitude of the difference is not significant (within one standard deviation of the reference value). The average melting range for the exhumed material is lower and wider than the corresponding reference melting range. This is not unexpected, because retention of minute quantities of impurities within the polypropylene microstructure may have occurred in the exhumed sample. (Impurities lower and widen melting ranges through modification of the cohesive forces.)

Oxidative Induction Temperature

Table 5 presents oxidative induction temperature values for the reference sample and exhumed sample 13. Five specimens were measured from different areas of the reference and exhumed samples. The tests were conducted in an air atmosphere at a scan rate of 20°C/min. The results of the oxidative induction temperature analysis for the reference and exhumed samples are consistent, as shown by the low standard deviation for both sets of data.

The oxidative induction temperature of the exhumed sample was 20°C lower than the oxidative induction temperature for the reference sample, which is consistent with a reduction in oxidative stability. Such a reduction in oxidative induction temperature demonstrates the decreased effectiveness of the stabilizer package after long-term environmental exposure, through consumption or some other factor. Partial consumption of the stabilizer package may have occurred during initial installation of the geotextile. Buried geotextiles would not

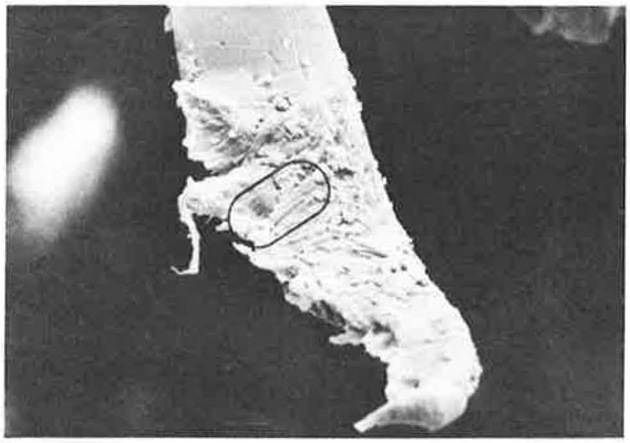

FIGURE 13 Fracture characteristics of fibers in sample 13 (×325).

FIGURE 14 Fracture characteristics of fibers in area circled in Figure 13 (×1950).

likely encounter sufficient quantities of heat or ultraviolet radiation to initiate significant degradation. Also, the initial concentration of the stabilizer package in the exhumed geotextile may have been lower than that in the reference sample because of variability in processing. The 20°C reduction in oxidative induction temperature appears significant. However, the effect of such a reduction on the overall durability of the geotextiles is difficult to quantify.

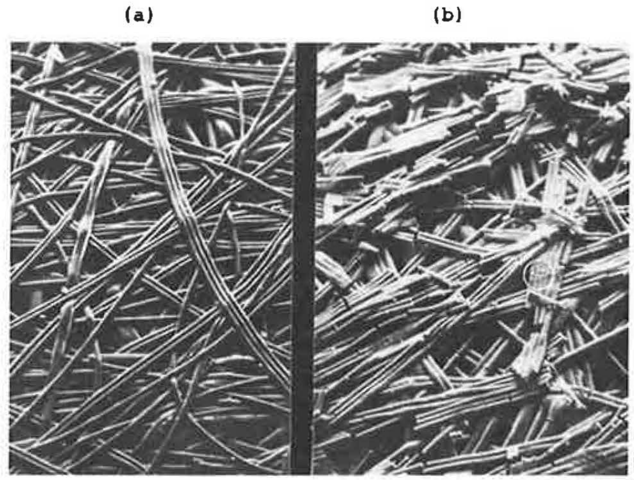

FIGURE 15 Comparison of a polypropylene geotextile structure (a) before and (b) after exposure to natural weather conditions for 3 months (×18).

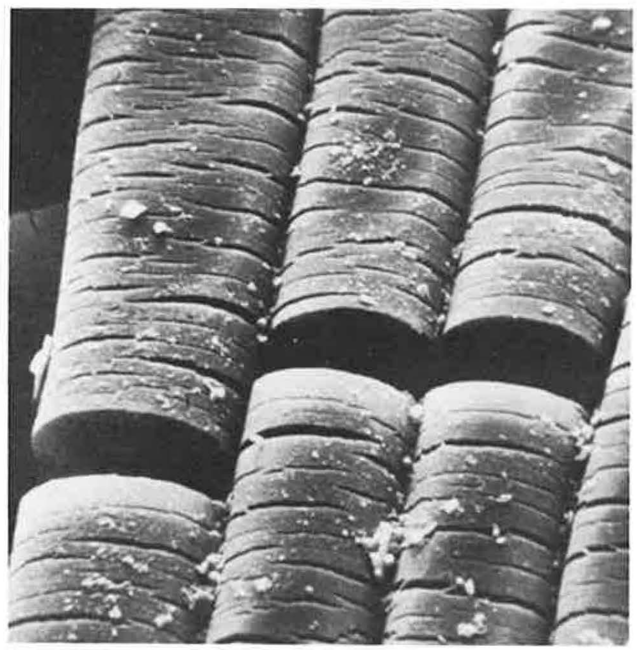

FIGURE 16 Area circled in Figure 15: circumferential cracking after 3 months of exposure to the weather could initiate fiber fracture at any stressed location (×455)

Infrared Spectrometry

Table 6 lists the characteristic spectral bands of the reference sample and exhumed sample 13 obtained from the IR analysis. Figures 17 and 18 show infrared spectra for the reference and exhumed geotextiles, respectively. Five specimens from each of the reference and exhumed samples were analyzed.

Each spectrum displays bands at 3000 to 2780 cm^{-1} and 1480 to 800 cm^{-1}, which are those bands attributable to polypropylene. The absence of bands in the 1775- to 1750 cm^{-1} region for the exhumed geotextile sample indicates that oxidative attack on the polymer molecules was minimal. Bands appearing in this region are typically observed when oxidation has occurred in polypropylene. Additional IR spectra were obtained for both the reference sample and sample 12 by Bonaparte et al. (*7*).

DISCUSSION OF RESULTS

The data generated by this study and the related earlier one (*7*) indicate that residual strength values exceeding 70 percent have been achieved by the polypropylene geotextile in this unpaved road application, which according to the FHWA *Geotextile Engineering Manual* (*8*), required use of "moderate-to-high" survivability materials. Bonaparte et al. (*7*)

TABLE 4 DEGREE OF CRYSTALLINITY AND MELTING RANGE

Sample Number	Reference		Exhumed Sample #13	
	Crystallinity (%)	Melting Range (°C)	Crystallinity (%)	Melting Range (°C)
1	28.58	127.30-180.81	22.99	119.13-182.89
2	24.31	119.12-179.96	29.27	119.50-190.67
3	25.71	122.83-182.33	20.48	128.48-180.81
4	27.22	133.95-178.29	33.00	129.82-181.59
5	26.06	125.35-176.91	21.82	119.50-186.97
Average	26.38	125.71-179.66	23.51	123.29-184.59
σ_{n-1}[a]	1.61	5.53- 2.12	5.37	5.38- 4.15

[a] Standard deviation is σ_{n-1}

TABLE 5 OXIDATIVE INDUCTION TEMPERATURE

Sample Number	Reference Sample	Exhumed Sample #13
1	240.97°C	228.87°C
2	238.84°C	202.86°C
3	238.97°C	227.94°C
4	237.09°C	208.42°C
5	239.52°C	231.29°C
Average	239.10°C	219.88°C
σ_{n-1}[a]	1.40°C	13.20°C

[a] Standard deviation is σ_{n-1}

examined similar polypropylene geotextiles from other sites and found that residual strength values may decrease to approximately 50 percent in sites with a material survivability rating that is "very high."

Thus, there is an expected relationship between the survivability rating of a site and the damage sustained by the geotextile during its installation. It might, in turn, be expected that the extent of damage to the geotextile during its installation is reflected in its durability, or its performance characteristics over the period of intended service. Despite the fact that both samples 12 and 13 show different degrees of installation damage, they appear to have performed their designed separation function as intended. There are no signs of accelerated aging processes that might have been initiated at the areas of surface damage on the fibers in sample 12 over the 12-year service period. Such effects can be of major importance in polyolefin products, as shown by the slow-crack-growth, brittle-fracture phenomenon initiated at surface defects in natural gas distribution pipe manufactured from different polyethylene resins (*11–13*). In these products, fractures have occurred after as little as 2 years of service. Apparently, the polypropylene geotextile examined in this project is not subject to these phenomena and appears to be, thus far, quite durable.

There are two components to the durability (and survivability) of geotextiles that have been compared in this examination. The first is the durability and aging performance of the polypropylene fiber. The second is the performance of the composite geotextile, which is mostly related to the geometric way in which the individual fibers are oriented and the chemical and mechanical ways in which they interact at their crossover points.

If the fibers are degraded, the geotextile will lose its durability, as shown by the circumferential cracking fractures. However, if the fibers are durable, it does not automatically follow that the geotextile will also be durable. If the chemical and mechanical bonding between fibers is destroyed with time, the geotextile may not be considered durable. Therefore, in order to assess whether a geotextile is durable in a specific environment, a two-step approach is necessary. Specifically, the two steps are to

TABLE 6 INFRARED ANALYSIS DATA

Spectral Bands	Reference Sample					Exhumed Sample #13				
	1	2	3	4	5	1	2	3	4	5
3000 - 2780 cm^{-1}	+	+	+	+	+	+	+	+	+	+
1480 - 800 cm^{-1}	+	+	+	+	+	+	+	+	+	+
New Bands	o	o	o	o	o	o	o	o	o	o

+ = Bands appearing in same region

o = No band(s) appearing

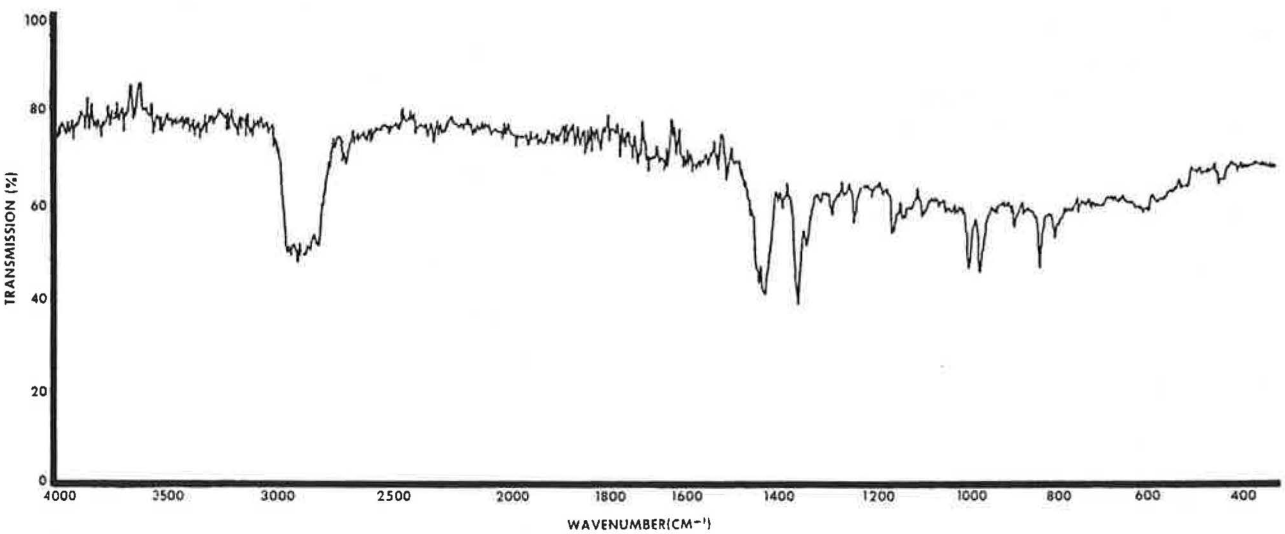

FIGURE 17 IR spectrum for the reference polypropylene geotextile.

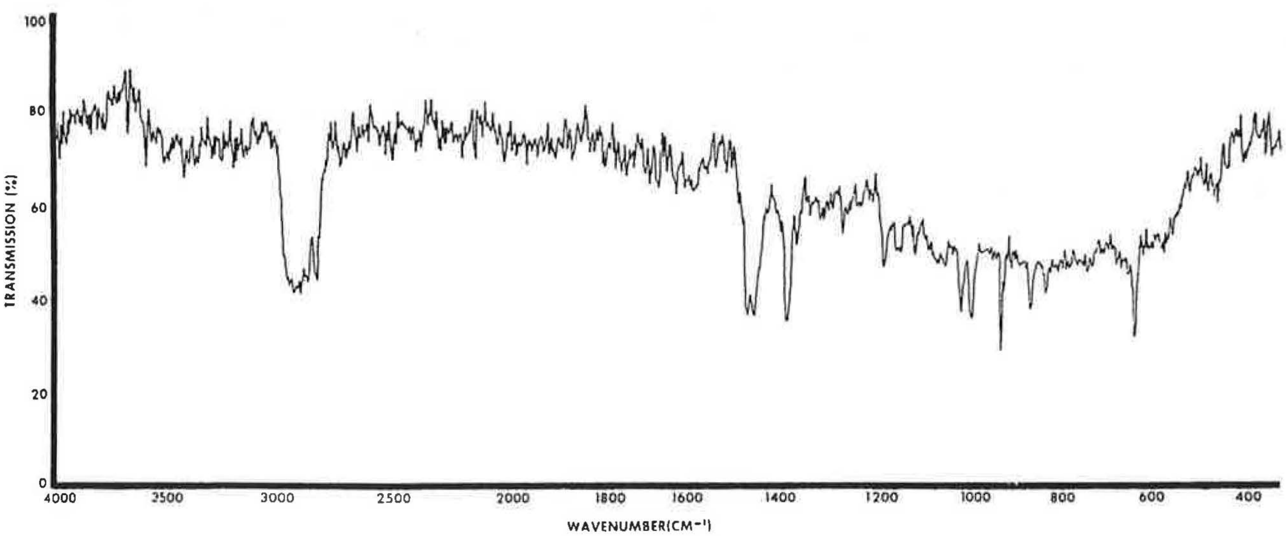

FIGURE 18 IR spectrum for the exposed polypropylene geotextile.

- Assess the degradation of the fibers from which the geotextile is manufactured. Structural analytical tests will constitute the key component in this examination. If the fiber degrades, no further steps are necessary. If the fiber does not degrade, it will be necessary to proceed to the next step.
- Assess a property of the composite geotextile related to the intended service function. This step will determine whether the integrity of the composite geotextile has been compromised.

In examining a relatively new technological field, like the durability of geosynthetics, which is not yet thoroughly understood, there is yet another overriding caution. A material or product may show some degradation or some lack of chemical compatibility, but if critical design parameters are not exceeded, the degradation may be immaterial. A product need not be discarded just because it is degraded. For instance, as discussed by Bonaparte et al. (*7*), specific minimum criteria have been established for the survivability ratings of geotextiles in specific applications. The purpose is to provide adequate survivability so that when the product is installed it will function continuously as designed. There are, however, exceptions. Some materials that do not meet the survivability ratings and have suffered some damage during installation may still provide adequate service when installed and continue to provide adequate service. Moreover, some materials that meet the survivability criteria and consequently receive very little damage during installation may not provide adequate survivability because of damage of a type that seriously reduces the durability of the product.

CONCLUSIONS

This examination of a thermally bonded, nonwoven polypropylene geotextile exhumed after 12 and 13 years of service in an unpaved road structure indicates that although a minor amount of oxidation has occurred in the polypropylene fibers, there has been little apparent degradation of the mechanical properties of the geotextile since its installation. The microstructural changes identified in the individual fibers are reflected by the mechanical property changes in the bulk geotextile, thus confirming the appropriateness of the fiber tests.

The properties of the exhumed geotextile are predominantly determined by the amount of local mechanical damage suffered by the fiber and the geotextile during installation.

The geotextile examined has adequate survivability and durability characteristics to perform satisfactorily in its intended role at the site investigated in this study.

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