Durability Assessment of Exhumed Polyester Geotextiles

C. J. Sprague
Sprague & Sprague Consulting Engineers, Greenville, SC, USA

R. A. Goodrum
Hoechst Celanese Corporation, Spartanburg, SC, USA

P. J. Kuck
Hoechst AG, Bobingen, Germany

ABSTRACT: The term "durability" is defined and the use of macrostructure versus microstructure tests for evaluating durability is discussed. Tensile strength (macrostructure test) results are compared to solution/intrinsic viscosity and carboxyl end group values (from microstructure tests) measured on both exhumed and baseline polyester geotextiles from two projects representing 11 years and 20 years of insitu exposure, respectively. The relationship between solution/intrinsic viscosity and carboxyl end group properties and polyester durability is explored.

1 INTRODUCTION

Maintaining satisfactory performance of geosynthetics is commonly termed, "durability." Durability can be thought of as relating to changes over time of both the polymer microstructure and the geosynthetic macrostructure. The former involves molecular polymer changes and the latter assesses geosynthetic bulk property changes. This paper focuses upon the evaluation of both micro- and macrostructural changes to polyester geotextiles which have been exhumed after 11 and 20 years of service in differing insitu conditions.

2 MACROSTRUCTURE vs. MICROSTRUCTURE TESTING

To-date, the primary means to measure durability has been the use of macrostructural laboratory strength tests on both unexposed and exposed samples. Results are plotted with the goal of identifying degradation trends. At best, these macrostructural results are "indirect" measures of durability because of the inherent variability of the textile structure. At worse, the interaction of the structure may be misinterpreted altogether. Therefore, it is generally agreed that microstructural tests hold greater promise for accurately quantifying geotextile durability.

2.1 Macrostructure Testing

Commonly used macrostructure tests which are used to characterize the bulk properties of both unexposed and exposed geotextile samples include:

- Weight
- Thickness
- Tensile Strength
- Tensile Elongation

Standard protocol has been developed for these tests by organizations such as ASTM, DIN, ISO, CEN and CGSB.

2.2 Microstructure Testing

Less familiar and, in some ways, less standardized for use with geosynthetics are microstructural tests. The most useful of these tests for characterizing polyesters are designed to provide either direct measures of or relative indications of the polymer's molecular weight. Such tests include the measurement of:

- Molecular Weight
- Solution/Intrinsic Viscosity
- Carboxyl End Groups

Molecular weight is a measure of the number and corresponding length of molecular chains comprising a polymer.

Degradation of a polymer normally involves chain scission which reduces the length and increases the number of chains - reducing the molecular weight.

Solution/intrinsic viscosity is an indicator of the degree of polymerization; the longer the polymer chain the more viscous the solution. In this test the polyester is dissolved in a solvent and a defined volume of this solution is run through a viscosimeter in a certain amount of time. The flow time is transformed into a characteristic value. As a result of polymer degradation, i.e. hydrolysis, shorter polymer chains and lower viscosities are measured.

The number of carboxyl end groups characterizes the length of the polyester molecule and indicates the extent of any hydrolytic degradation of the molecule; the greater the hydrolytic degradation, the shorter the molecule chains and the greater the number of carboxyl end groups.

In all of these tests, the protocol is less "standard" because the running of the tests is either dictated by the equipment or is dependent on the solvent(s) used, neither of which is "standard". Therefore, reporting of the equipment and solvent along with the results is imperative.

3 GLENWOOD CANYON WALL

3.1 Overview

The Colorado Department of Highways has investigated the durability of geotextiles buried for up to 11 years in an experimental geotextile reinforced soil retaining wall constructed in 1982 in Glenwood Canyon Colorado. Geotextile samples were excavated from the wall in 1984 and again in 1993. Durability of the polyester geotextiles was evaluated by the Department of Highways using macrostructure testing and subsequently by Hoechst Celanese Corporation using microstructure testing. Results from the excavated samples were compared to those measured from testing samples of the same geotextile lots before construction. This allowed for differentiating between "survivability", which relates to construction damage, and "durability", which relates to post-construction changes in the geotextiles.

3.1 Macrostructure Testing

Wide-width tensile strengths from testing in accordance with ASTM D 4595 were measured on 8 specimens from each exhumed sample. The sample mean was computed and compared to before construction strengths. The average results of the three sets of tests are given in Table 1 and show that no degradation occurred between the first and second sampling for 1127. No comparable samples of 1115 were exhumed in 1993. Clearly, construction damage accounted for nearly all degradation.

Table 1: Glenwood Canyon Durability Testing - Macrostructure

TREVIRA Geotextile	Wide-Width Strength @ Strain (kN/m @ %) 1982	1984	1993
1115	9.8 @ 80	7.0 @ 59	Not Avail
1127	23.8 @ 75	13.1 @ 57	14.5 @ 60

1 lb/ft = .021 kN/m

3.2 Microstructure Testing

Intrinsic viscosity and carboxyl end group numbers were measured on "archived" baseline samples and on samples exhumed in 1993. The results of the tests are given in Table 2 and show that little, if any, degradation occurred in the polymer itself. This appears to corroborate that construction damage accounted for nearly all degradation.

Table 2: Glenwood Canyon Durability Testing - Microstructure

TREVIRA Geotextile	Intrinsic Viscosity 1982	Intrinsic Viscosity 1993	Carboxyl End Groups 1982	Carboxyl End Groups 1993
1115	.585	.578	30.3	25.5
1127	.598	.550	27.1	24.8

3.3 Discussion

Durability data was obtained on

samples of TREVIRA Spunbond geotextiles exposed for 11 years. Using both macrostructure testing (wide-width tensile & elongation) and microstructural testing (I.V. & C.E.G.) it has been clearly demonstrated that, while there was damage to the geotextiles from construction activity in 1982, there was no loss of strength in samples obtained and tested in 1993 compared to 1984.

4 ROTHSEE RECREATION AREA BEACHES

4.1 Overview

In 1973 a recreation area / nature conservation area was built in the Bavarian Roth valley (near Augsburg). A 130,000 m^2 lake is the centerpiece of the area with beaches built over surrounding "swampy" areas. To preserve the beach, especially during and after flooding events, a TREVIRA Spunbond geotextile separator and a .3 m gravel layer were constructed beneath the beach. The geotextile has been exposed to mechanical loads, water immersion, temperatures as high as 27°C, and rooting.

4.2 Macrostructure Testing

In April/May 1993, samples of the geotextile were exhumed from the beach area and examined in the Hoechst AG laboratories in Bobingen, Germany using the following tests:

- Mass/Unit Weight (DIN 53854)
- Thickness (DIN 53855)
- Tensile Strength (DIN 53855)
- Tensile Elongation (DIN 53855)

The results of the macrostructure testing of the geotextile are presented in Table 3.

The higher mass per unit area results in 1993 are related to fine soil particles that remained trapped within the fabric even though there was no significant change in thickness. The tensile strengths showed a 34% reduction along with a reduction in elongation of 24%. Yet, it was suspected that most, if not all, of the reduction was a result of construction damage as has been reported in other case histories.
To evaluate the post-construction performance of the fabric, microstructural tests were run.

Table 3: Rothsee Recreation Area Testing - Macrostructure

Property	Original Sample 1973	Exhumed Sample 1993
Mass / Unit Area (g/m^2)	350	530
Thickness (mm)	3.30	3.37
Tensile Strength		
MD (kN/m)	19.9	13.1
CD (kN/m)	22.5	14.8
Tensile Elongation		
MD (%)	63	51
CD (%)	65	49

4.2 Microstructure Testing

The samples were also tested using the following microstructure tests:

- Solution Viscosity
- Carboxyl End Groups

The results of the microstructure testing are given in Table 4. Additionally, microscopic inspection of fiber surfaces was done using a scanning electron microscope.

Table 4: Rothsee Recreation Area Testing - Microstructure

Property	Original Sample 1973	Exhumed Sample 1993
Solution Viscosity	770	850
Carboxyl End Groups (mmol/kg)	30	40

These results are not consistent with the tensile strength results. The solution viscosity (S.V.) increased when a lower S.V. would be expected if the polymer had degraded. For example, a 50% reduction in tensile strength has been correlated to an S.V. of 400. Yet, measurement of the S.V. can be influenced by soil particles in the sample as was found in the mass/unit area testing.

Perhaps, the results of the carboxyl

end group (C.E.G.) testing can help interpret the S.V. results. Since a 50% reduction in tensile strength has also been correlated to a C.E.G. of 100mmol/kg, a C.E.G. of 40 probably indicates that less than 10% reduction occurred over the 20 year period.

4.3 Discussion

A useful tool for determining the basis for loss in tensile strength is the microscopic inspection of the filament surfaces. The surface structure gives the missing information about the reason for the loss of tensile strength.
Numerous notched and flattened passages as well as filaments with rub marks were observed. Therefore, it appears that the loss of tensile strength is primarily a result of abrasive forces from the overlying gravel during and after construction.
Hydrolytically damaged fiber surfaces characteristically show a crater structure. This was not found in the microscopic inspection.

Though macrostructural testing shows strength loss, microstructural testing and microscopic evaluation clearly demonstrates that the loss of tensile strength is due to abrasion - probably during construction - and that over a period of 20 years there has been almost no chemical degradation even though the geotextile was immersed in water at elevated temperatures.

5 LIFETIME PREDICTIONS & CONCLUSIONS

Predicting how long any material will continue to sufficiently perform its design function(s) will require continued monitoring along with some type of accelerated testing and modeling. Neither is sufficient by itself - laboratory testing and modeling must be verified by actual field data and, by necessity, a model must be found which allows actual field data to be used to accurately predict performance in specific conditions.

These case histories give solid evidence that polyester geotextiles can provide and have provided the required long-term performance for which they were designed in common, challenging insitu conditions.

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