Durability Study of Typar 3401 Twenty Years After Installation: The Smyrna Road Project

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In 1972 a test section was initiated as part of an evaluation of the newly emerging geotextile industry. The purpose was to determine which of the family of spunbonded products best fit the end use, performing the required functions. Several materials were installed and evaluated in different locations. One location still in operation is Smyrna, Delaware. In June 1992 this original site was located and samples were exhumed. Installation conditions, field performance, and current status are reviewed for this test section, one of the oldest accessible geotextile separation applications in this country. Through evaluation of physical properties, the geotextile's survivability and durability are evaluated and compared with what is experienced today. Electron microscope results are compared, and the evolution of ultraviolet stabilizers is highlighted. Results show property retention after this extended period.

In 1972, the nonwoven fabrics "Cambrelle" from ICI and "Bidim" from Rhone-Ponlenc were being used in Europe in road support applications on soft soils and construction sites. The results were better roads. Recognizing this, DuPont, already a nonwoven fabric producer, established a program to develop a product for use in these applications. Today these permeable separation materials are commonly known as geotextiles.

As part of that program several fabrics were evaluated under roads at four different locations:

- A plant road in Delaware,
- A local school road in Delaware,
- A farm road in Wisconsin, and
- A private road in Smyrna, Delaware.

As a result, a 4-oz/yd^2 thermally spunbonded polypropylene fabric was selected as the preferred geotextile: Typar 3401.

As part of the DuPont Company's 20th anniversary in the geotextile industry and as a result of increasing interest in durability, the authors located one of the original sites, the road in Smyrna, Delaware. Pictures of the site were taken, samples of geotextile and core samples were obtained for later testing, and a general evaluation was made of the field performance of the test section.

The source of most of the historical information is the original test evaluation report and discussions with its author, Dick Hutchins (*1*). Mr. Hutchins was present when the geotextile was installed in the Smyrna road over 20 years ago, and was also present in June 1992 when the site was revisited and samples exhumed.

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1972 INSTALLATION DESIGN

In the early 1970s the DuPont Company ran various tests on its thermally spunbonded fabrics to determine their ability to enhance road performance. The Smyrna test section used a Delaware farm road over a sandy clay soil with a load bearing capacity of 1 CBR (California bearing ratio) when wet (6 CBR when dry). This road has been used actively over the past 20 years. The original road design using a geotextile as a design enhancement is one of the first of its kind in the United States.

Unlike the other test sections run by DuPont, the Smyrna road was completely controlled by the designers. During the test the Smyrna road was not subject to repair. The DuPont test program focused on providing useful information for predicting performance of potential geotextile materials placed under the base course. The Smyrna test used a 3.7- × 310-m section of road that was intentionally underdesigned. Using 40-kN wheel loads above the low-load-bearing soil calls for a 38-cm gravel base; however, only 15 cm of gravel base (40 percent of design) was used (*1*). The idea was to encourage or accelerate failure so that the test geotextiles could be evaluated. The tests were run in two stages: a dry run, in which the loaded vehicle traverses while the road is dry, then the samples are excavated; and a wet test, in which loaded vehicles are run after a heavy rain, then samples are excavated.

Normal road construction techniques were used, and a control section was installed where no fabric was placed under the 15-cm gravel base (*1*).

The dry run (142 passes of loaded vehicles) produced no noticeable differences between the section where fabric was used and the control section. After a 6.5-cm rain deluge, the wet test was carried out. Results were as follows:

- Soft spots only occured after 120 passes in the Typar 3401 section, and
- Complete failure occurred after 20 passes in the control section.

After the wet test, Typar 3401 was excavated. The fabric maintained sheet integrity, and it was concluded that Typar 3401 provided the best permeable separation and stabilization of all products used at the Smyrna road project. The relative strength loss after excavation was 50 percent for trapezoid tear and 35 percent for puncture. It was also concluded that, for heavy-duty construction stresses, fabric weights less than 135 g/m^2 should not be used due to lack of survivability. The ability of a fabric to resist tearing was noted as highly desirable (*1*).

EXHUMATIONS

In June 1992 a team returned to the Smyrna road project site to determine the performance status of the road and the condition of the geotextile and to retrieve a representative sample of the 20-year-old geotextile for evaluation.

Upon arrival at the site the various test plots were located, specifically the Typar 3401 plot. Several photographs were taken to characterize the general area conditions as well as the specific plot.

Sample exhumation followed. Pick and shovel were required to break up the unpaved road surface, which was well compacted considering that the exhumation was done in the most critical area; the tire tracks. After locating the geotextile elevation about 15 cm down, where it was initially placed, careful removal of the fill by hand and brush proceeded over an area of 2 m^2. More photos were taken and the sample was removed and stored in a plastic bag and paper tube.

Later the site was revisited and the team used Shelby tubes to take core samples. Fill was removed down to 4 or 5 in., leaving approximately 1 in. of fill. Core samples of two controls (with no geotextile) and six samples with geotextile were taken with 3 to 5 cm of fill above and 3 to 5 cm of subgrade below. It was not possible to get totally undisturbed core samples because of the rocky nature of the fill and the inability of the Shelby tube to cut cleanly through the geotextile.

The core samples were encased in plastic for observation and possible analysis. In general it was possible to reconstruct the cross-section to demonstrate the separation.

TECHNICAL EVALUATION

Site Evaluation

Photographs confirm that even though the geotextile was installed 20 years ago and the project was grossly underdesigned, the geotextile has survived and endured to effectively perform its primary function as a permeable separator. At the site it was obvious where the geotextile was used: there is no significant rutting at those locations. It was equally obvious where no geotextile was used, as indicated by the rutted areas.

Shelby Tube Evaluation

Eight Shelby tube samples of subgrade, geotextile, and fill were taken from the site. The tubes are separated into two groups: two without geotextile and six with geotextile. Although analysis continues, preliminary results indicate the following:

- Most of the geotextile samples were disturbed because the tube was inserted by impact. When the tube reached the geotextile, it did not cut cleanly. The fill and soil next to the geotextile were disturbed, making it difficult to observe the exact soil structure next to the geotextile. It was clear in all cases that there was effective separation of subgrade.
- The sample with no geotextile showed significant intermixing resulting in ruts and potholes (poor road performance).

Physical Characteristics

The geotextile samples were brought to the lab to compare their current physical characteristics with those of 1972. Grab tensile was not tested in 1972; however, curent results show a 50 percent strength retention and a 35 percent elongation retention compared with historical production data on first-quality Typar 3401 produced in 1972. Current trapezoid tear stength retention was approximately 40 percent, which compares favorably with the 50 percent strength retention observed after exhumation 20 years ago. The permeability values of the recovered soil-impregnated geotextile samples are above the range of values of the soils present (sandy clay, .00005 cm/sec). Overall the physical characteristics of the geotextile remained stable over a 20-year period in this underdesigned roadway.

Photomicrographs of Exhumed Geotextile

Exhumed geotextile samples were returned to the lab in plastic bags for testing and evaluation. Analysis of the magnified polypropylene filaments showed little to no degradation over time. For photomicrograph analysis of the geotextile polymer, it was necessary to remove as much dirt and other interference as possible. Repeated attempts to clean the dirt from the samples by washing failed. A DuPont technical assistant suggested and demonstrated that ultrasonic cleaning was effective, and using that procedure many photos of the exhumed geotextile fiber structure were taken and compared with unused, recently produced geotextile. There was no indication of polymeric deterioration observed even when magnified 3,000 times. Only mechanical damage to the outer layer of the geotextile surface fibers was apparent. In addition that damage appeared more obvious on the fill side of the geotextile as a result of the fill texture being harsher than the subgrade. The damage is also more severe than normal because of the underdesign fill thickness (15 cm versus 38 cm needed for proper design) and overloaded conditions permitting more stress to reach the geotextile.

Overall it appears that photomicrograph analysis may be more sensitive to polymer deterioration than other methods under consideration. That combined with stabilizer analysis may give more conclusive evidence of projected life expectancy.

Polymer Evaluation

One of the goals of this study was to determine whether the same amounts of antioxidants and ultraviolet stabilizers are present today as were added to the material in production 20 years ago. In pursuing this goal, it became clear that current techniques (gel-permeation chromotography and oxidation induction) cannot provide any relevant information for comparison. We are, however, able to review the heat flow (melting) curve, review the thermo oxidative breakdown of polypropylene, and compare the 1972 stabilizer package with today's stabilizer package.

Differential scanning calirometry (DSC) was performed on the 20-year-old samples. The melting point for polypropylene is not a sharp peak, and the peak melting point varies from pellet to pellet. The melting point observed (about 160°C) and the resulting heat flow curve for the 20-year old sample is typical for polypropylene.

Polypropylene is a long chain polymer in which structural damage can be initiated by heat or light with time by the development of free radicals. The presence of oxygen is a fundamental requirement for breakdown to occur (John Daniel, unpublished data).

Oxygen content in soils is quite low and continues to diminish exponentially the deeper one goes below the surface. This helps explain the relatively undisturbed condition of the filaments examined in the photomicrographs.

The potential breakdown is a surface phenomena caused by the presence of all the necessary ingredients (heat, light, oxygen) at the surface of a filament. Once the free radical development begins, the next reaction will occur with the nearest neighbor molecule (John Daniel, unpublished data). This explains the circumferential crack development of a well-oriented polypropylene fiber where heat or light degradation, or both, has occurred.

Manufacturers add stabilizers to polymers to retard and quench the free radical reaction. These stabilizers either hinder the development or react with free radicals to make them nonreactive.

The stabilizer package of 1972 is radically different and much less effective than today's stabilizer packages. The 1972 Typar 3401 stabilizer package consisted of the following:

- UV 531—Absorbs ultraviolet light and releases it as energy. Major drawback was that it could easily be washed away.
- Dilaurylthiodiproprionate (DLTDP) and Topanol CA—Thermal stabilizers interact with free radicals, quenching the thermal degradation process.

Today Typar uses the latest in hindered amine light stabilizer packages (HALS). HALS act as free radical scavengers no matter what type of free radical is developed; they quench the degradation process and in the process regenerate themselves. Typar's specific HALS package is proprietary.

Even though the 1972 Typar sample had a stabilizer package inferior to what is available today, the photomicrographs clearly show that polymer degradation is minimal to nonexistent. From the standpoint of long-term durability, this is primarily the result of the lack of oxygen in the soil, with secondary support from the stabilizer package.

CONCLUSIONS

Site inspection and Shelby tube samples indicate that the thermally spunbonded nonwoven geotextile is still performing the function originally intended when it was installed 20 years ago, even though grossly underdesigned.

By the indicators available and used, including DSC, the scanning electron microscope, and physical testing, the polymer had no measurable deterioration, and the only damage to the geotextile was mechanical—primarily to the upper filament surface layer—even though the geotextile was only 15 cm below the surface. Further examination of the geotextile is continuing. For future studies ultrasonic cleaning of field samples is effective in removing soil embedded in the geotextile matrix to permit more accurate analysis and more revealing photomicrographs. Cross-sections of fibers make it possible to see any sign of polymeric breakdown. Even though the installation was intended to be temporary and was grossly underdesigned, overall it has continued to function effectively.

For over 20 years, a geotextile has ably performed the job of permeable separation in Smyrna, Delaware. The positive results of the 1972 test section are strongly supported by the current analysis. Current visual inspection of the site clearly shows that the use of a geotextile dramatically increases the performance of an unpaved road over an extended period of time. Moreover analysis of the polypropylene geotextile shows little to no degradation over its 20-year life. It is concluded that the relative lack of oxygen in the soil surrounding the geotextile over the past 20 years is the main contributor to the insignificant degradation. Similar physical index test results from 1972 and 1993 coupled with more revealing photomicrograph analysis of the polymer confirm this insignificant degradation. Advances in stabilizer packages such as the HALS package currently used in Typar products will only increase a geotextile's effective design life.

Polypropylene geotextiles such as Typar offer strong evidence that a geotextile can be used effectively over a long period of time.

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REFERENCE

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