Geotextiles in Unpaved Roads: A 35-Year Case History

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Abstract

This paper presents current information on a geotextile separator used experimentally in an unpaved road 35 years ago. At that time, geotextiles were largely untested, and the site was set up to determine the comparative performances of several potential Geotextiles, in an accelerated field test. After the initial few years of successful performance and durability; the ultimate potential lifetime became the major factors in assessing the value of geotextiles in unpaved roads. A primary issue in the long-term test turned out to be the lack of adequate cover, in some cases, less than the minimum recommended 6 inches of stone for protection of the geotextile in this application. The polymer stabilization package used when the fabrics were produced, but not designed for this application was inadequate and has since been properly designed.

Background

The purpose of geotextile separation is to prevent two simultaneous mechanisms that tend to occur in a roadway cross section over time; see Figure 1. The first is that the stone base tends to penetrate into the subgrade soil, thereby compromising its load bearing capacity. The second is that fine-grained subgrade soil tends to intrude into the voids of the stone base, thereby compromising the stone base's drainage capacity. In both cases, when the base intermixes with fine-grained particles from the subgrade soil, the stone base (or the lower portion of it) is no longer effective for load bearing or drainage. The situation is heightened in areas of freeze/thaw and wet/dry cycling. Environmental changes such as frost, infiltration, drainage and increased loading all adversely challenge the paved or unpaved road base.

No geotextile (soil subgrade pumping) | No geotextile (stone aggregate penetration) | Geotextile Separator (prevents both mechanisms)

Figure 1 - Long-term benefits of highway geotextile separators.

It should be noted that many unpaved roads eventually become paved (usually with asphalt) and, if the stone base is protected from the beginning against subgrade soil contamination, the paved road design can be done with confidence.

In 1972, nonwoven fabrics were being used in Europe in road support applications on soft soils and at construction sites. The results appeared to be positive. Recognizing this, DuPont, an established nonwoven fabric producer, developed a program to produce a geotextile for use in similar applications. As part of that program, several materials were evaluated under roads in several locations and several existing fabrics were installed in unpaved road test sections for performance revaluations.

The purpose was to determine which fabric products would best perform the required functions of reinforcement, stabilization and/or separation. Several materials were installed and evaluated in different geographic locations. One location still functioning is in Smyrna, Delaware. In June, 2007, this particular site was visited and samples were exhumed. Reviewed in this report are installation and current conditions, field performance, and current status for these test sections; which is one of the oldest known existing accessible geotextile separation applications. Through evaluation of physical, mechanical and chemical properties, the geotextiles' separation performance, survivability and durability properties were evaluated and compared.

Details of the Smyrna, Delaware, Site and the 1972 Design Approach

The source of most of the historical information in this section is the original test evaluation report by Crane and Hutchins (1974) and discussions with its co-author, Dick Hutchins (2007).

The Smyrna, Delaware, test section created by DuPont used a farm road over a sandy clay soil with a load-bearing capacity of CBR $\simeq$ 1.0 (California Bearing Ratio) when wet, and a CBR $\simeq$ 6.0 when dry.

Unlike the other test sections constructed by DuPont at the same time, the Smyrna Road site was completely controlled by the designers. During the initial testing, the Smyrna road was not subject to repair. The test focused on providing useful information for predicting the performance of potential geotextiles used beneath stone base courses. A number of different commercially available fabrics were available and used at the site. The Smyrna test used a 1000-foot (310 m) section of road that was purposely under-designed. Using 40-kN wheel loads above the low-load-bearing soil normally calls for a 15-inch (38 cm) gravel base; however, only 6 inches (15 cm) of gravel base (40 percent of design) was actually used, according to Hutchins in 2007. The idea was to encourage or accelerate failure so that the test geotextiles could be evaluated quickly. The tests were run in two stages: 1. a dry run, in which the loaded vehicle transversed while the road is dry and then samples were excavated and removed and; 2. a wet test, in which loaded vehicles were run after a heavy rain and then samples were excavated and removed.

The site is in the area of a fill. There is slope of about 0.5% from north to south. As can be seen from the plan view of Figure 4, the road acts as a dike across the farmer's field. Standing water in areas of this field indicates low points and poor drainage.

The site's climatic conditions can be generally characterized by noting that it is in FHWA Region 1 and FHWA climatic zone I-A. This means that the site is located in an area with high potential for moisture; it is, in fact, less than a mile from the Delaware Bay.

Normal road construction techniques were used for installation of the geotextiles. Heavy construction equipment was used to make grade. The construction sequence is detailed in an internal DuPont report by Crane and Hutchins. Laborers spread the geotextiles by unrolling the materials on the subgrade in advance of a dozer spreading base material. In addition, a control section was installed where no fabric was placed under the 6-inch (15-cm) gravel base.

A general description of the road would be a "private road through a farmer's field." The number of passes on this road is low; however, during planting and harvesting season, the loads are heavy and frequent. From historical records, the CBR of the site before construction was 2 and the field CBR was approximately 8 (dry). The subgrade soil was a silty sand (SM) with 12% passing the #200 sieve, and the modified base was a well-graded gravel (GW) with thickness of 4 to 8 inches. Specifics about the geotextiles and site soils are given in Tables 2 and 3.

The dry run (142 passes of loaded vehicles) produced no noticeable differences between the sections where fabric was used and the control section. After a heavy rain, the wet test was carried out.

In the control section (without fabric), complete failure occurred after 20 passes. In the Typar 3401 section, soft spots only occurred after 120 passes. From these initial tests, Typar 3401 was determined to be the best initial candidate for these types of geotextile separation and drainage applications. After the wet test, all candidates were excavated and evaluated. The fabric maintained sheet integrity and it was concluded that this product provided the best results of all products used at the Smyrna road project. The relative strength loss after 35 years with insufficient base cover was 50 percent for trapezoid tear and 35 percent for puncture. It was concluded that, for heavy-duty construction stresses such as this, fabrics should be at least equivalent to the Typar 3401, osy (136 g/m^2) and covered with at least 6 inches of base material, or significant loss of properties will occur.

Table 2 – Geotextile Properties at Smyrna Test Road

Property	Unit	ASTM Method	GT-A	GT-B	GT-C	GT-D Typar	GT-E	GT-F
Style			Typar	W-PP	Reemay	K-12	Typar	Tyvek
Manufacturer			DuPont/ Fiberweb	Amoco	DuPont /Fiberweb	DuPont /Fiberweb	DuPont /Fiberweb	DuPont
Weight	oz/yd^2	D 5261	3.5	3	3	4	4	2.2
Thickness	in	D 5199						
M.D. Grab Strength	lbs	D 4632	110	210	180	140	130	155
M.D. Grab Elongation	%	D 4632	57	15	25	55	60	14
M.D. Tear Strength	lbs	D 4533	45	38		80	77	8
Puncture Strength	lbs	D 4833	34	40		35	40	23
Burst Strength	psi	D 3786	153	273		185	197	118
M.D. WWT Strength	lbs/in.	D 4595	36	138		32	32	
M.D. WWT Elongation	%	D 4595	35	18		36	24	
M.D. WWT Modulus	psi	D 4595	48,000	59,000		34,000	42,000	
Permittivity	1/sec	D 4491	0.8	0.2	1.0	0.7	0.7	>0.001
A.O.S.	#	D 4751	70	50	70	80	80	>200

Table 3 – Soil Testing Results at Smyrna Test Road

Property	Unit	Method	Base	Subgrade
Description	---	na	Well graded gravel	Silty sand
USCS Classification	---	D 854	GN	SM
d10	mm	D 422	0.25	0.01
Cu	---	D 422	20	40
Cc	---	D 422	0.5	1.6
Passing #200	%	D 422	4	24
LL	---	D 4318	16	21
PI	---	D 4318	nr	4
Estimated Dry CBR	---	D 4429	9	8
Average Cone penetration	psi	CN 973	>300	210
optimum moisture content	%	D 698	14	17
maximum dry density	pcf	D 698	119	113
average insitu density	pcf	D 1556	115	110
Average insitu Wc	%	D2216	10	15

Exhumation After 35 Years of Service

In June 2007, 35 years after installation, George Koerner of GSI and the author returned to the Smyrna Road site to determine the status of the road and the condition of the geotextiles. After the various test plots were located, photographs were taken to characterize the general area conditions as well as the specific plots.

Sample exhumation followed. Pick and shovel were required to break up the hard crust of the unpaved road surface, which was well compacted because the exhumation was done in the most critical area, the tire tracks. After probing for the location of the geotextile elevation, which was 4 to 8 inches (10 to 20 cm) from the ground surface, careful removal of the fill by hand proceeded over an area of approximately 1 m^2. The fabric was then brushed clean. More photos were taken and the samples were removed and stored in plastic bags. Figures 2 and 3 illustrate how the geotextile samples and soil were collected, in addition to monitoring of field soil conditions.

Figure 2 - Taking field measurements

Figure 3 - Samples brushed clean

Technical Evaluation

General Observations

Photographs confirm that even though the geotextile was installed 35 years ago and the project was under-designed, some geotextiles endured to effectively perform the primary function as a permeable separator. At the site, it was obvious where the geotextile was used because there was no significant rutting at those locations. It was equally obvious where no geotextile was used; lateral spreading of the embankment was noted and rutting was evident.

Table 4 - Measurements and Observation at Smyrna Test Road – June 2007

Number	Description	Geotextile Condition	Cover Depth (inches)	Rut Depth (inches)
* 1 (GT-A)	3.5 osy Typar	good	6	0.7
2	3 osy K-12 Typar	Not exhumed	NA	1.0
3 (GT-B)	3 osy Woven PP	poor	8	1.5
4 (GT-C)	3 osy Reemay	Very poor	7	0.5
* 5 (GT-D)	4 osy K-12 Typar	Very good	9	0.8
6	3.5 osy K-12 Typar	Not exhumed	NA	2.3
7 (GT-E)	4 osy Typar	poor	3	1.3
8	Control (no GT)	NA	NA	2.5
9 (GT-F)	2.2 osy Tyvek	poor	4	2.3

As observed from Table 4, there are 2 test sections 1 (GT-A) and 5 (GT-D) which had minimum cover (6 inches or more) and were still performing well. The others were not exhumed or in “bad condition.” Test Section 7 (GT-E) had inadequate cover (only 3 inches) and showed significant physical damage.

 

(a) GT-A (b) GT-B

 

(c) GT-C (d) GT-D

 

(e) GT-E (f) GT-F

Figure 4 - Exhumed geotextiles at Smyrna, Delaware, site

Evaluation

As shown in Table 4, eight different geotextiles were used at the site. Table 2 shows the results of index and performance testing of 6 of the fabrics used at this site, prior to installation. There were only two soils (subgrade and base) used for this project, and their characteristics are given in Table 3.

The geotextile samples were brought to the lab to compare their current physical characteristics with those of 1972. Unfortunately only GT-A (3.5 osy) and GT-D (4.0 osy) could be tested because the other geotextiles were significantly damaged. Grab tensile results show on average a 37 percent strength retention and a 52 percent elongation retention compared with historical production data for Typar. Current trapezoid tear strength retention was approximately 50 percent, and puncture strength 93 percent on average. Note that current testing was very limited. A summary of results for the two geotextiles can be seen in Table 5.

Analysis of the magnified polypropylene filaments showed some degradation. For photomicrograph analysis of the geotextile polymer, it was necessary to remove as much soil and other interference as possible. Repeated attempts to clean the soil from the geotextiles were marginal at best, which is why mass per unit area and thickness results are not reported. As can be seen from the photos, polymeric deterioration was readily observed in all samples examined. This deterioration was not only observed in the outer layer of the fibers' surface but some was also apparent in the core of the fibers.

It should be pointed out that the stabilizer package used in 1972 was quite different and much less effective than today's stabilizer. Today, Typar uses the latest in hindered amine light stabilizer packages (HALS). HALS packages act as free radical scavengers no matter what type of free radical develops.

Table 5 – Comparison of Geotextiles' Mechanical Properties as received and after 35 years of service at Smyrna Test Road

Property	Unit	ASTM Method	Before GT-A	After GT-A	% Change	Before GT-D	After GT-D	% Change
Style			Typar	Typar	Typar	K-12	K-12	K-12
Manufacturer			DuPont /Fiberweb	DuPont /Fiberweb	DuPont /Fiberweb	DuPont /Fiberweb	DuPont /Fiberweb	DuPont /Fiberweb
Weight	oz/yd^2	D 5261	3.5	NA	NA	4	NA	NA
Thickness	in	D 5199		NA	NA	NA	NA	NA
M.D. Grab Strength	lbs	D 4632	110	42	38	140	51	36
M.D. Grab Elongation	%	D 4632	57	25	44	55	33	60
M.D. Tear Strength	lbs	D 4533	45	23	51	80	40	50
Puncture Strength	lbs	D 4833	34	41	>100	35	30	86
M.D. WWT Strength	lbs/in.	D 4595	36	NA	NA	32	NA	NA
M.D. WWT Elongation	%	D 4595	35	NA	NA	36	NA	NA
M.D. WWT Modulus	psi	D 4595	48,000	NA	NA	34,000	NA	NA
Permittivity	1/sec	D 4491	0.8	NA	NA	0.7	NA	NA
A.O.S.	#	D 4751	70	NA	NA	80	NA	NA

Never the less, one of the goals of this study was to determine whether the same amounts of antioxidants and ultraviolet stabilizers are present today as when the material was produced. In pursuing this goal, it became clear that a review of the heat flow (melting) curve and a review of the thermo oxidative time and temperature as compared to the 1972 stabilizer package would be of interest.

Differential scanning calorimetry (DSC) was performed on the aged polypropylene samples and compared to that of un-aged samples. The oxidative induction temperature of GT-A went from 228 to 212 degrees Celsius in 35 years. However, the oxidative induction times of GT-A and GT-B are near 1 minute. This indicates that there is a small amount of the original package currently left in these materials.

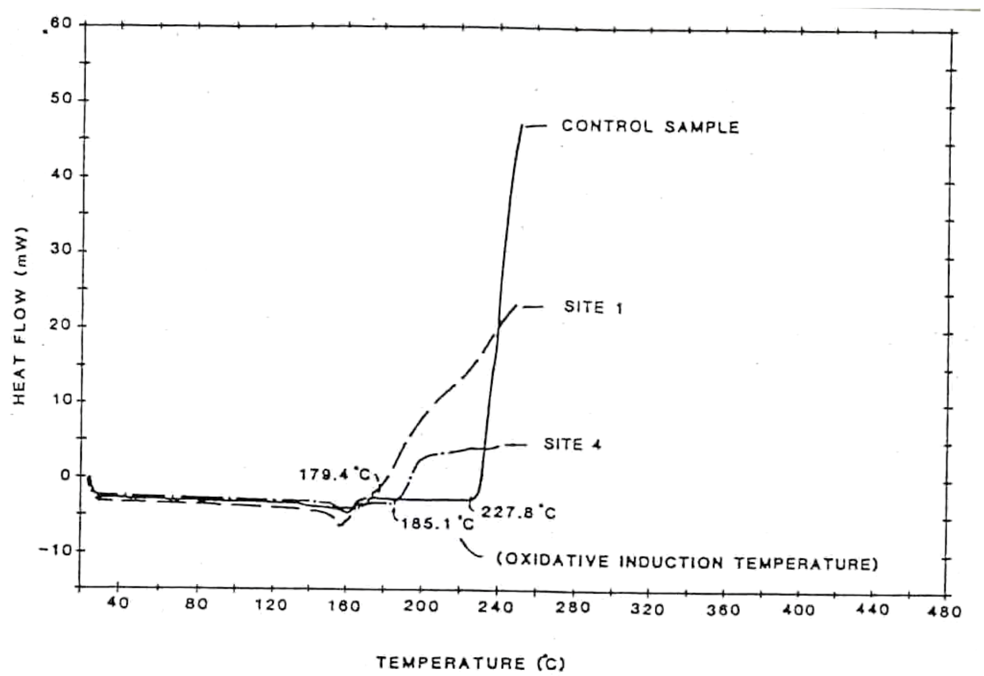

Figure 5 - Original 01 temp curve for Typar

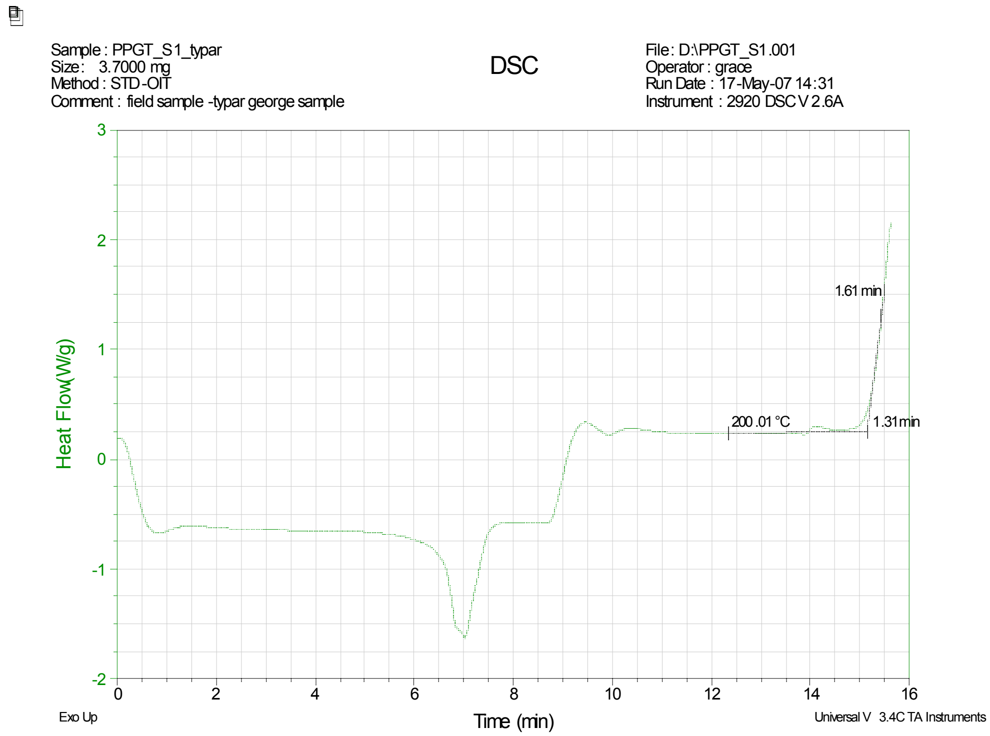

Figure 6 - Oxidative Induction Time of Field sample #1 (GT-A) a heat-set nonwoven geotextile

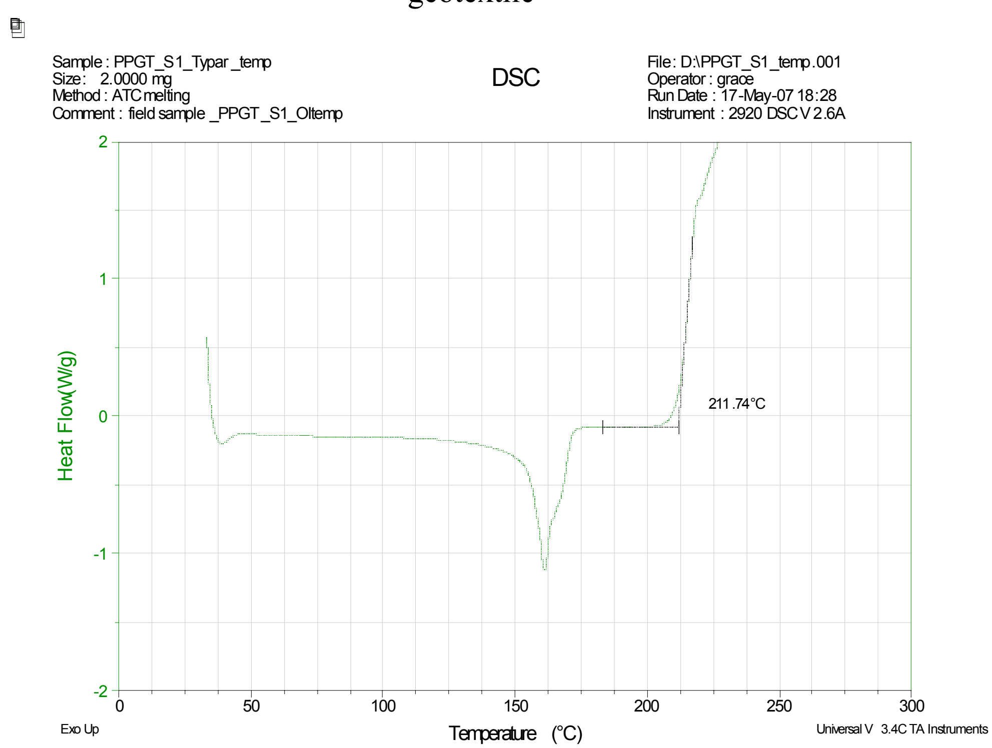

Figure 7 - Oxidative Induction Temperature of Field sample #1 (GT-A) a heat-set nonwoven geotextile

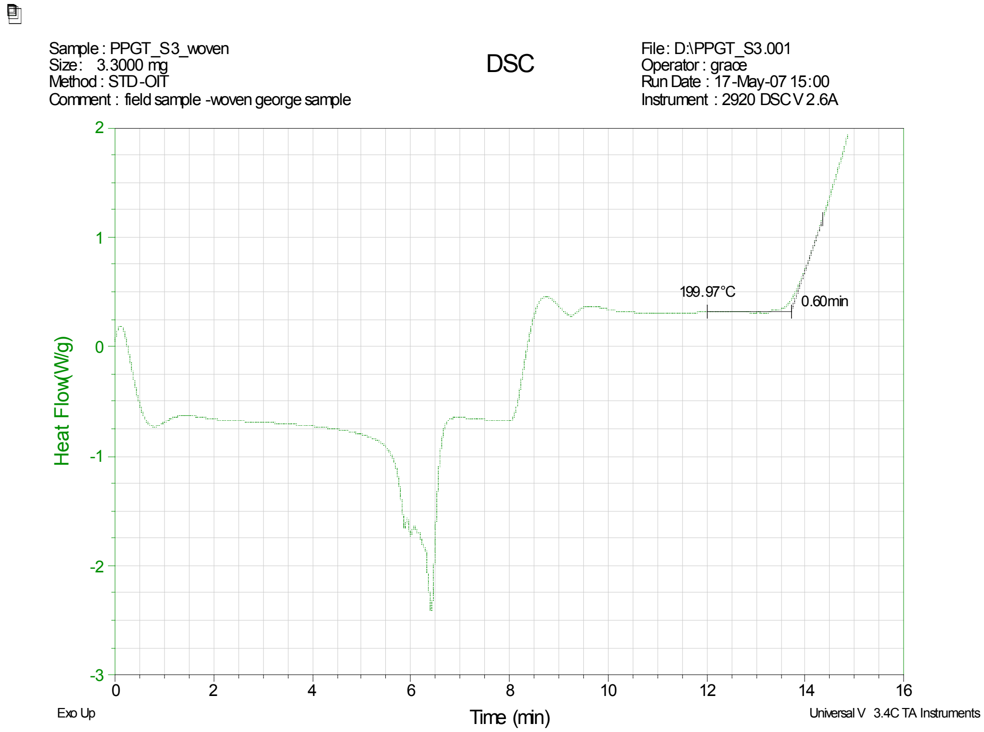

Figure 8 - Oxidative Induction Time of Field sample #3 (GT-B) a woven geotextile

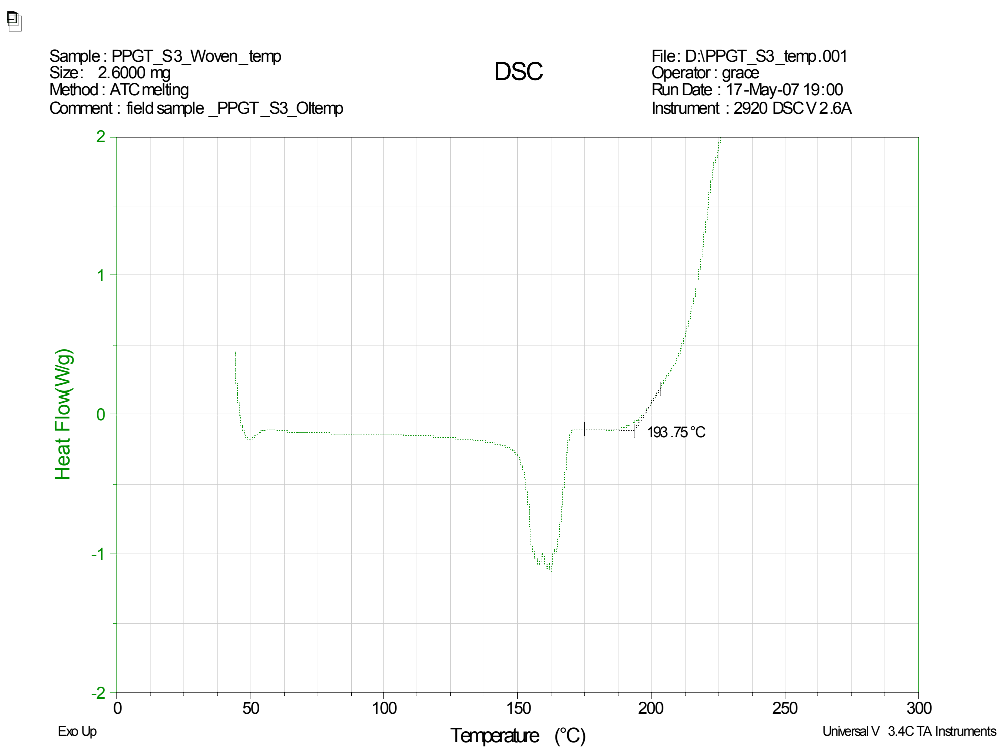

Figure 9 - Oxidative Induction Temperature of Field sample #3 (GT-B) a woven geotextile

Summary and Conclusions

The report is unusual in that it documents the use of a geotextile type of fabric and its performance over a 35 year period.

The initial purpose of the test, 35 years ago, was to determine if and which fabric would perform effectively as a geotextile in a separation application under an unpaved road. (A test of durability was not part of the initial purpose). It showed that Typar 3401 could perform that function very effectively, even though it was not specifically designed for that use and was installed with inadequate "safety factors" – too little base cover for the extreme loads it was subjected to "saturated", wet, conditions.

The loads used in the initial testing would normally require a minimum of 2.5X the base used and the tests were conducted after heavy rain. A severe test to say the least.

The fabric, Typar 3401 has performed the separation function for 35 years and is still working. Analyses of the fabric for survivability and durability indicate the stabilizers used then are not nearly as effective as those used today. The fabrics suffered significant mechanical damage as a result of overloading but were still performing. Indications of inadequate protection of the polymers by stabilizers are not surprising, but the stabilizers used today last much longer and are more effective.

However, site inspection and samples indicate that, if at least 6 inches of gravel remains over the geotextile, thermally spunbonded nonwoven geotextiles are still performing the function as originally intended 35 years ago, even though the site was grossly under-designed. Unquestionably, good performance is predicated on adequate soil burial. All geotextiles suffer survivability problems with a gravel thickness less than 6 inches.

By the indicators available and used, including DSC, physical testing, mechanical testing and scanning electron microscope, the PET geotextiles have undergone measurable deterioration. This is beyond the mechanical damage to the geotextile as a result of thin overburden coverage. DSC and photomicrograph analysis revealed that the stabilizer packages used in Typar products at that time have been depleted in the last 35 years. With today's stabilizer packages, a geotextile's effective design life has been increased significantly.

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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