Exhumation of geotextiles from a geosynthetic reinforced bridge abutment after 17 years of service

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ABSTRACT: The technology of geosynthetic reinforced bridge abutments (GSRBA) using a masonry block facing with geosynthetic reinforcement is currently one of the fastest growing segments of the geosynthetic industry. Due to their excellent aesthetics, low costs, ease of constructability, and regularly dependable performance, these structures are common throughout the world. However, some of these systems are being challenged for their durability. The focus of this paper is to present field data from such a GSRBA, located at the Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center in McLean, Virginia. The GSRBA is 17 years old, having been constructed in 1999. Despite the GSRBA being built solely for use as a test section, it is a full size abutment of 10 meters height. After disassembling the GSRBA and exhuming samples from six layers of the same type of geotextile, they were subsequently tested for physical, mechanical, hydraulic and endurance properties. The properties were then compared to those of the original material, which had been archived by the FHWA. Results will hopefully shed light on actual reduction factor for installation damage and degradation at this particular site.

Keywords: MSE wall, GSRBA wall, geotextile installation damage, geotextile durability

1 INTRODUCTION

Since service lives of 75-100 years are commonplace, it is imperative to use long-term durable reinforcement in the construction of GSRBA. The primary polymers used to make such reinforcement are polypropylene (PP), polyethylene (PE) and polyethylene terephthalate (PET). The potential long-term degradation mechanisms of these polymers are very different. PP and PE geosynthetics are sensitive to thermo-oxidative degradation while PET geosynthetics are sensitive to hydrolytic degradation. A laboratory investigation sponsored by the FHWA has investigated these two mechanisms. The results of the study were published in FHWA-NH1-00-044 by Elias (2001). They determined that the hydrolytic degradation of PET reinforcement increased 2.4 times when pH increased from 7 to 10. Therefore, in order to estimate the in-service longevity of PET geosynthetics one needs to know the actual pH level that the material is experiencing over time. It should be mentioned that their study did not address PP or PE products which had been evaluated previously, Koerner, et al. (2001).

2 THE FHWA TEST WALL

The full-scale test wall utilized in this paper was constructed by the FHWA to serve as a prototype GSRBA. The cross-section and profile views are shown in Figures 1 and 2 respectively. This abutment supports a 10m span at the Turner-Fairbank Highway Research Center in McLean, Virginia. It is constructed with Versa-Lock masonry block and Amoco 2002 polypropylene slit film woven geotextile. The wall has a maximum height of 10 m and length of 60 m. It has a geotextile layer, serving as the reinforcement, at each level of block (every 150 mm). It is then backfilled with AASHTO No. 57 stone. The wall was constructed in June of 1999.

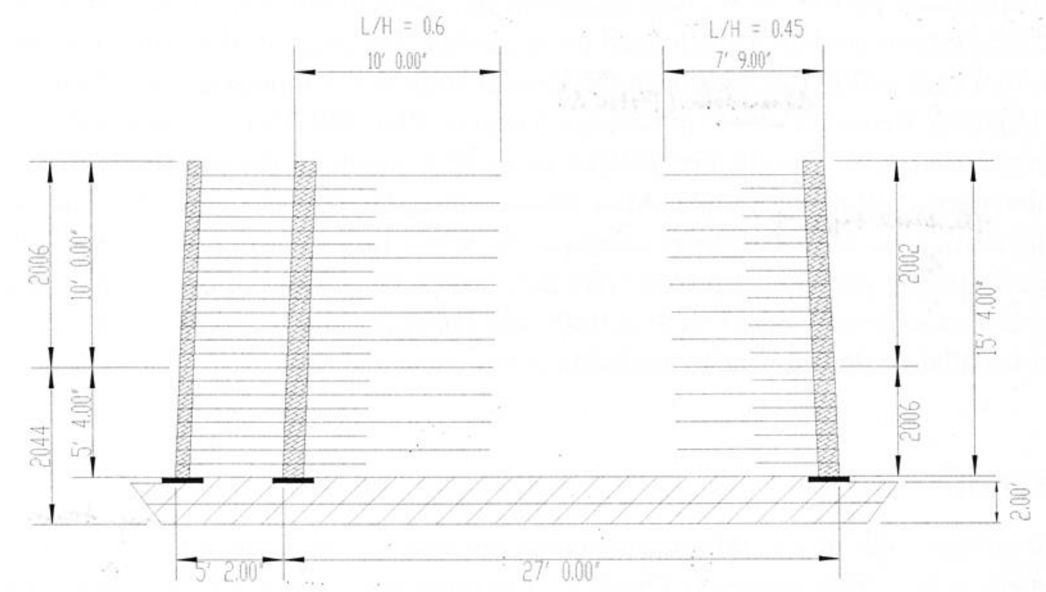

Figure 1. Cross-sectional view of abutment (US units)

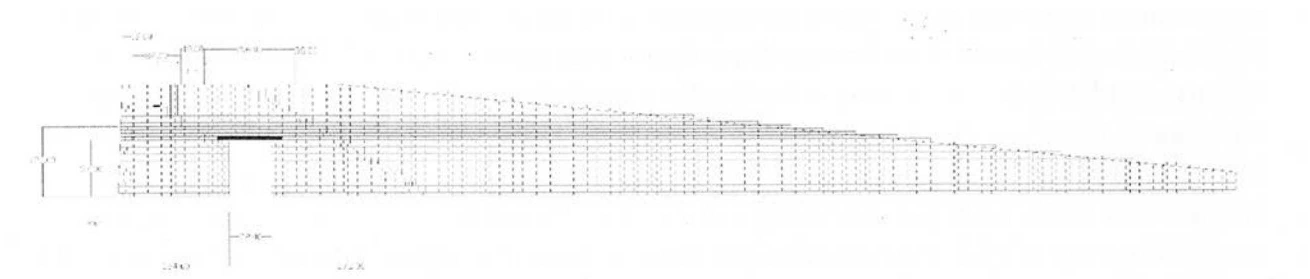

Figure 2. Profile view of bridge abutment (US units)

The geotextile used for reinforcement was a woven polypropylene slit film with a 3% open area. The ultimate tensile strength of the original material as determined per ASTM D4595 was 4.7 kN/m, with a corresponding elongation of 17%.

3 EXHUMATION OF THE GEOTEXTILE

The images below document the exhumation process of the geotextile from the stone backfill and masonry block units. The excavation site was located 21 m away from the edge of the abutment in order to avoid disturbing the soil surrounding the GSRBS's tunnel, located 4.5 m away from the same edge. Six layers of textile were exhumed from the surface, amounting to a total excavation depth of 1 m. See Figures 3 through 6 detailing the process. Due to the staggered arrangement of the masonry blocks, the size of the geotextile cut from each layer became progressively smaller as the excavation progressed. The width of the topmost layer (layer 1) was about 1 m, while the bottommost layer (layer 4) was only 0.5 m (Figure 7). After digging down the six layers and removing the textile sample, a roll of TenCate Mirafi HP770 was used as replacement material, and the hole was backfilled with the same AASHTO No. 57 gravel. Upon return from Virginia, the exhumed textiles were carefully cleaned, to remove any large particles of dirt that remained on the textile, and subsequently conditioned and prepared for testing (Figure 8).

Figure 3. Overview of the work site

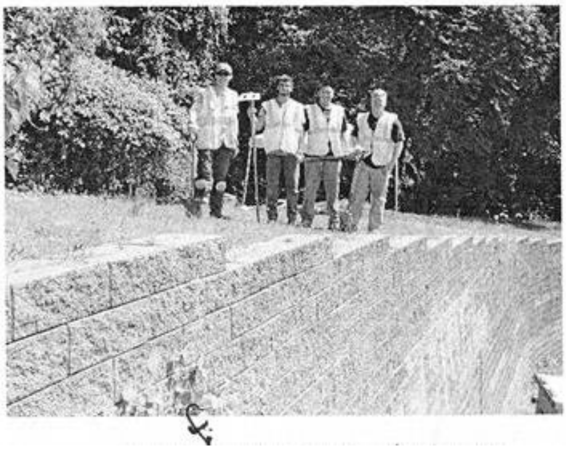

Figure 4. The excavation team

Figure 5. Cutting away the geotextile

Figure 6. Cross-section view of textile layers

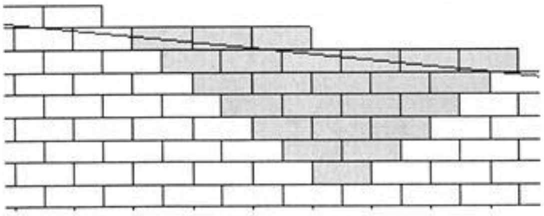

Figure 7. Block removal pattern

Figure 8. Exhumed and cleaned geotextiles

4 TEST RESULTS

In order to provide a holistic view of what effects seventeen years of service had on the geotextile, each exhumed layer was individually subjected to a series of physical, mechanical, hydraulic and endurance tests to examine possible degradation. The results are as follows.

The physical tests conducted were nominal thickness (ASTM D5199) and mass per unit area (ASTM D5261). However, due to the small particles of dirt that accumulated around the fibers of the geotextile, the physical tests did not produce very usable results. See Table 1 for each property, respectively.

Table 1. Physical property test value.

(1a) Nominal Thickness

	Thickness (mm)	%
As Received	0.60	100
Layer 1	0.55	91.4
Layer 2	0.57	94.5
Layer 3	0.64	106.9
Layer 4	0.56	93.6
Layer 5	0.62	103.0
Layer 6	0.63	104.7

(1b) Mass Per Unit Area

	Mass (g)	Mass/Area (g/m^2)	%
As Received	1.8769	181.8	100.0
Layer 1	1.8757	181.7	99.9
Layer 2	1.8879	182.9	100.6
Layer 3	2.0625	199.8	109.9
Layer 4	1.8178	176.1	96.9
Layer 5	1.9077	184.8	101.6
Layer 6	1.8943	183.5	100.9

Far more revealing were the mechanical tests, which include wide-width tensile (ASTM D4595), grab tensile (ASTM D4632), CBR puncture (ASTM D6241), and trapezoidal tear (ASTM D4533). On average, the exhumed material experienced a 30% decrease in strength from the original material; however the difference in strength loss between layers 1 through 6 were not very great. See Table 2 for each property, respectively. The mechanical test results are subsequently illustrated collectively in Figure 9.

Table 2. Mechanical property test results.

(2a) Wide-Width Tensile

	Max Strength (kN)	δ (kN/m)	%	Disp (mm)	ε (%)	%
As Received	4.678	26.1	100	17.9	17.64	100
Layer 1	2.997	25.6	64.1	11.7	11.51	65.2
Layer 2	3.73	27.3	80.6	13.8	13.62	77.2
Layer 3	3.696	26.6	79.0	13.9	13.70	77.7
Layer 4	3.550	26.8	75.9	13.3	13.05	74.0
Layer 5	3.204	26.6	68.5	12.0	11.84	67.1
Layer 6	3.008	23.6	64.3	12.7	12.53	71.0

(2b) Grab Tensile

	Max Strength (kN)	%	Disp (mm)	%
As Received	1.081	100	16.2	100
Layer 1	0.690	63.9	11.3	69.6
Layer 2	0.745	68.9	13.0	80.2
Layer 3	0.790	73.1	12.8	78.9
Layer 4	0.798	73.8	13.0	80.4
Layer 5	0.711	65.8	12.2	74.5
Layer 6	0.663	61.3	11.5	71.4

(2c) CBR Puncture

	Max Strength (kN)	%	Disp (mm)	%
As Received	3.691	100	45.76	100
Layer 1	2.921	79.1	38.67	84.5
Layer 2	2.824	76.5	35.90	78.4
Layer 3	2.709	73.4	36.40	79.5
Layer 4	2.005	54.3	30.76	67.2
Layer 5	3.038	82.3	41.21	90.0
Layer 6	2.881	78.1	39.98	87.4

(2d) Trapezoidal Tear

	Max Strength (kN)	%
As Received	0.4086	100
Layer 1	0.2357	57.7
Layer 2	0.2689	65.8
Layer 3	0.2085	51.0
Layer 4	0.2230	54.6
Layer 5	0.2570	62.9
Layer 6	0.2377	58.2

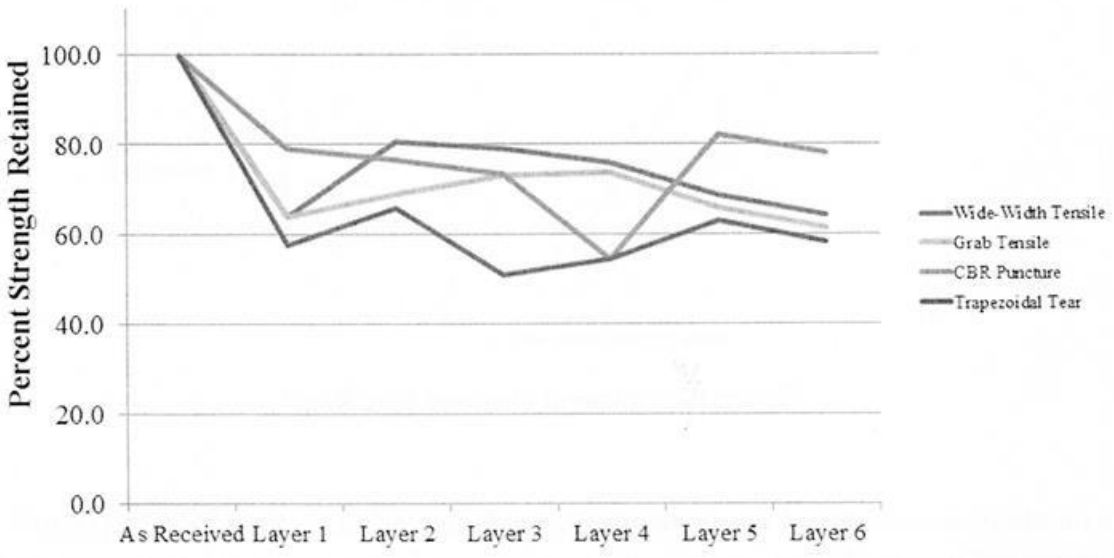

Figure 9. Average mechanical test results, showing the exhumed material’s percent strength retained on each layer.

The hydraulic tests conducted included permittivity (ASTM D4911) and apparent opening size (ASTM D4751, shown in Table 3 and Figure 10. Both test results show that the exhumed material has larger opening then it did when manufactured.

Table 3. Hydraulic property test results.

(3a) Permittivity

	Perm (1/sec)	%
As Received	0.07	100
Layer 1	0.10	143

(3b) Apparent Opening Size

Sieve #	140	100	70	50	40	30
mm	0.106	0.150	0.212	0.300	-/425	0.600
As Received (% Passing)	100	99.4	97.4	68.8	0.6	0
Layer 1 (% Passing)	100	99.0	75.9	4.6	2.0	0.1

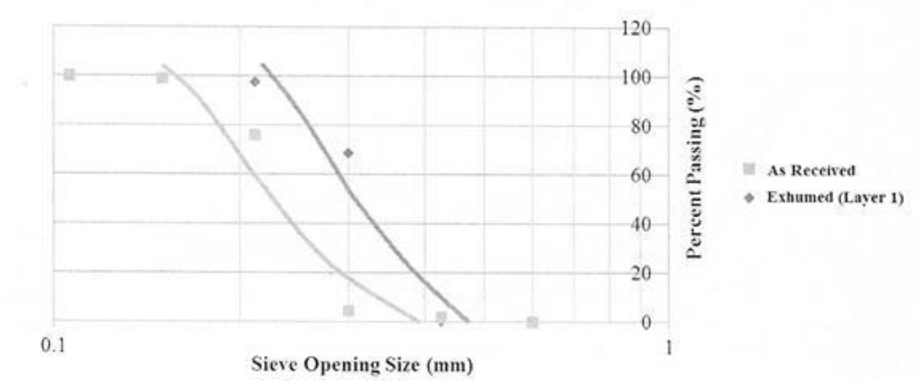

Figure 10. Apparent opening size results.

As a durability assessment of the geotextile, an oxidation induction time (ASTM D3895) endurance test was conducted, however the results proved mute. Since polypropylene slit film geotextiles such as this typically only contain high temperature antioxidants for production stability, not long term durability, the OIT time for this geotextile was expectedly small (less than 30 seconds); see Figure 11.

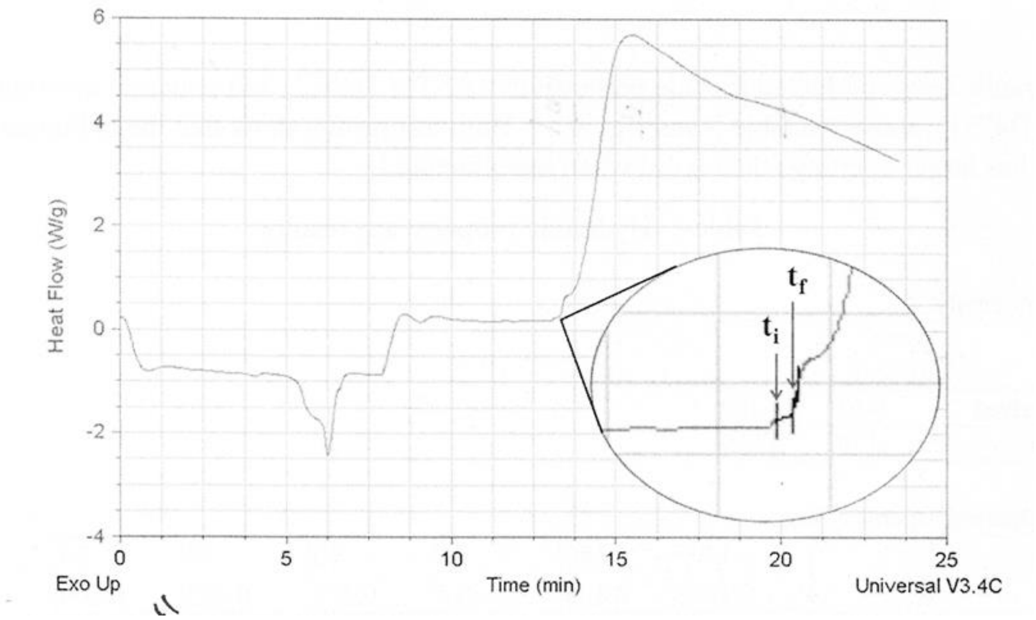

Figure 11. Oxidation Induction Time results for ‘as received’ material.

5 SOIL ANALYSIS

Along with testing the properties of the textile, the properties of the AASHTO No. 57 stone backfill surrounding the textile were also investigated in order to shed light on the cause of the loss of strength of the geotextile. The stone was mined from a local quarry. The FHWA supplied a sieve analysis of the aggregate from when the wall was built, and a Procter compaction test was performed with samples of the soil obtained from the excavation. These analyses were conducted to obtain a better understanding of the in-situ condition of the diabase soil, which was believed to be compacted at greater than 95% of optimum dry density. The results are shown in Figures 12 and 13 respectively.

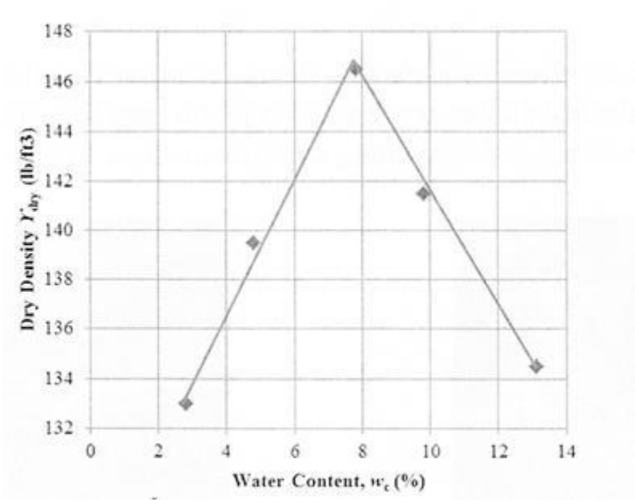

Figure 12. Procter compaction test results.

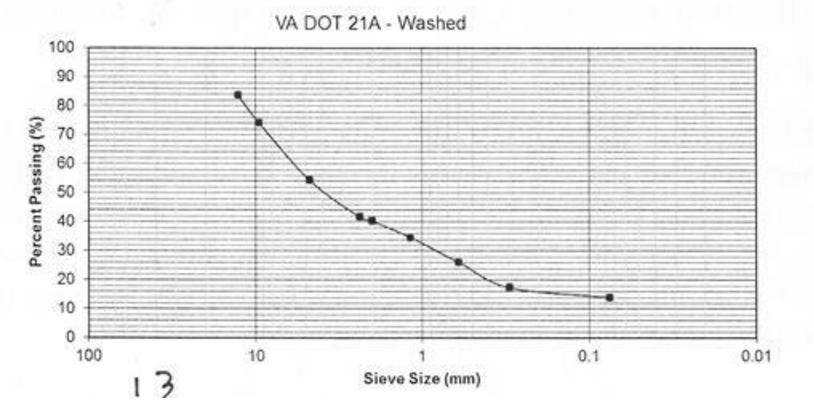

Figure 13. Sieve analysis of AASHTO No. 57 aggregate.

6 COMMENTARY

After analyzing the accumulated data, the 30% average decrease in overall strength, resulting in a reduction factor of 1.43, is accredited to damage that occurred during the installation and backfill of the geotextile.

Despite the GSRBA examined throughout this paper being a full scale test wall, it did not experience any significant traffic over the seventeen years. Therefore no major shifts in soil due to heavy travel, along with possible salt spray from roads and the environment, occurred during the timeframe. Also, the McLean, Virginia area environment is moderate insofar as precipitation (rain and snow), temperature extremes, cyclic freeze/thaw, or alternating wet/dry cycling.

As seen from the photographs taken under a microscope at 20X magnification (Figure 14 and 15), the exhumed material exhibits some signs of wear, such as surface scratches and foreign matter. This damage, typically caused during the installation of the geotextile, is felt to account for the mechanical strength decrease of the material. There also could have been minor cases of damages as a result of the exhumation process, despite our best efforts to be careful with the material.

The increased opening size between the textile's fibers can be attributed to the strain put on the individual fibers during the installation process. Also the soil particles, and other foreign matter, being forced through the already existing voids, made them larger as time progressed.

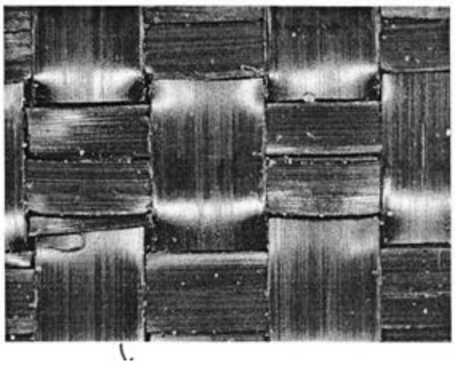

Figure 14. 'As Received' geotextile.

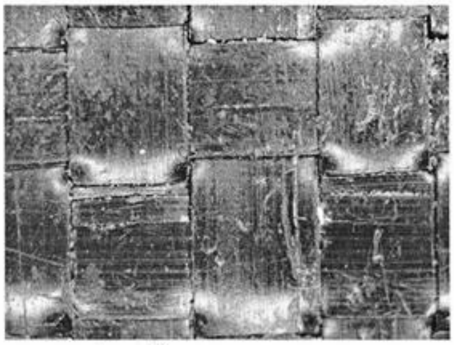

Figure 15. Exhumed geotextile

7 SUMMARY

The geotextile held up remarkably well as part of the geosynthetic reinforced bridge abutment. Despite damage that most likely occurred during the installation and backfill of the geotextile during the construction of the GSRBA, there seems to be no concern with the durability of the textile itself during its present service life. As often is the case with geosynthetics, this study shows that well formulated polymers can function for long service lifetimes in the context of most transportation and geotechnical environments.

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The help of three FHWA interns who aided in the physical labor involved in unearthing the geotextile from the test wall drastically expedited the exhumation process, for which we are very grateful.

- Nam Le, George Mason University
- Dylan Honardoust, Virginia Institute of Technology
- Christian Macht, Auburn University

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