A Study of T_{all} for Reinforcement with Respect to Polyester Geotextiles

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ABSTRACT: A series of laboratory tests were undertaken to evaluate the effect of installation damage on the wide-width tensile strength of three Exxon Chemical woven polyester geotextiles. A variety of subgrade and backfill materials was used to simulate different field survivability levels. Tests were performed using a 1.2 meter by 1.2 meter installation damage box at Georgia Institute of Technology. An examination of unconfined creep testing of the highest strength woven polyester geotextile (10,000 hours after initial tensile loading) is also included. The results of this study enable one to obtain design oriented factors of safety for these specific, high strength polyester woven geotextiles, and provides general information on geosynthetic installation damage assessment.

1 INTRODUCTION

The wide-width tensile strength (ASTM D-4595) is frequently used to characterize the ultimate strength of a geotextile for reinforcing applications. To calculate an allowable strength for use in design, engineers typically use partial factors of safety to reduce the ultimate wide width strength of the geotextile.

$$T_{all} = T_{ult} \cdot \frac{1}{F_{ins} \cdot F_{cr} \cdot F_{dgr}}$$

Where T_{all} is the design strength, T_{ult} is the ultimate strength of the undamaged geotextile, F_{ins} is the partial factor of safety to account for installation damage, F_{cr} is the partial factor of safety to account for creep potential, and F_{dgr} is the partial factor of safety to account for chemical and biological degradation. In the absence of information for a particular fabric, default factors of safety are used to reduce the ultimate strength. Significant savings are often possible if this default can be reduced by using the results of tests on specific factors to establish actual factors of safety.

Due to the construction environment, geotextiles are susceptible to damage during installation. As a result of this damage, the mechanical properties of the material (most importantly for reinforcement, the wide-width tensile strength) may be markedly different after placement than before construction.

Installation damage assessments for reinforcement applications are necessary for the determination of long term design allowable tensile strengths. Default factors of safety, used in the absence of actual installation data are conservative, in many cases extremely conservative. However, field installation data is expensive and time consuming to obtain.

A laboratory test program was developed to simulate field installation conditions. These conditions include actual soil subgrade, backfill soils, and compaction energy approximating field compaction criteria. Large specimens are installed, buried, then exhumed and tested to determine strength retained.

Results show the installation damage factor of safety is greater as the harshness of the backfill increases, and as the unit weight of the geotextile decreases. Factors of safety are recommended based on type of backfill and physical properties of the geotextiles being evaluated for installation damage. Finally, a factor of safety for creep for the highest strength polyester geotextile is provided.

2 GEOTEXTILES

The geotextiles provided for this series of tests were GTF 550T (350 g/m^2), GTF 1000T (595 g/m^2) and GTF 1500T

(780 g/m²). These geotextiles are woven, multifilament polyesters (PET). The extent of the damage experienced during installation was based on the minimum average roll value (MARV) wide width tensile strengths of virgin specimens of the same geotextiles. Damage to each of the geotextiles was measured in both the warp and fill directions.

Table 1 Minimum wide-width tensile strengths for virgin geotextile specimens via ASTM D4595

PET Geotextile	Orientation	Strength (kN/m, lb/in)
350 g/m²	Warp	88/500
	Fill	88/500
595 g/m²	Warp	175/1000
	Fill	140/800
780 g/m²	Warp	263/1500
	Fill	140/800

3 SUBGRADE AND BACKFILL PROPERTIES

Four combinations of subgrade and backfill were used for all three geotextiles. These materials were chosen to represent materials that might be used in construction. The four combinations of subgrades and backfills are shown in Table 2.

Table 2 Combinations of subgrade and backfill materials used for installation damage tests

Series No.	Subgrade	Backfill
1	Gravel	Gravel
2	Sand	Sand
3	Clay	Gravel
4	Clay	Clay

The gravel used was crushed stone and is classified as a GP according to the Unified Soil Classification System (USCS). It is a uniform gravel with a median grain size ranging from 4.5 to 6.5 mm and relatively few fines. This type of crushed stone is commonly used in drainage blankets in pipe and highway construction. A manufactured sand was used as both a backfill and subgrade for Test Combination No. 2. The sand is classified as an SP. The clay used as a subgrade in the gravel/clay and the clay/clay tests was Georgia "red clay." The soil is actually a silty sand (SM). The material was chosen because a sufficient quantity was available. The backfill in the clay/clay tests was is a low-plasticity clay (CL) with liquid and plastic limits of 36 and 17, respectively.

Standard Proctor compaction tests (ASTM D 698-78) were performed on all four soils to use in calculating the percent compaction of the subgrade and backfill in the installation damage tests. The maximum dry densities and optimum water contents are given in Table 3.

Table 3 Maximum dry densities and optimum water contents

Soil Type	Maximum Dry Density (KN/m³,pcf)	Optimum Content (%)
Gravel (GP)	16/102.5	6
Sand (SP)	18/114.5	8
Red clay (SM)	15/97.5	23
Low plasticity clay (CL)	18/115.0	15

4 TEST EQUIPMENT

Installation damage tests were performed in a 1.22m x 1.22m square box approximately 2.1m deep. The box is constructed of steel plates with two removable doors on the front of the box to facilitate the removal of subgrade and backfill. A 5cm x 5cm steel angle is attached horizontally to the inside rear wall of the box at the midpoint of its height. This angle is used to anchor the geotextile to keep it in place during placement and compaction of the backfill.

The size of the geotextile specimen used in these laboratory tests is much less than that used in full scale, field applications. Nonetheless, the size of the test box allowed multiple geotextile specimens to be obtained for wide-width testing while still permitting carefully controlled test conditions.

A gas powered compactor was used to compact the subgrade and backfill. It proved to be an excellent tool for achieving uniform compaction across the test box.

The in-place density and water content of the subgrade and backfill were measured using a nuclear moisture/density gauge. Because the nuclear gauge was used inside the steel test box, trench box corrections and procedures were used and the nuclear gauge was calibrated inside the box. All measurements of in-place density were obtained using the backscatter mode of testing. At random times during testing, the backscatter results were compared to the results of direct transmission tests at 5cm and 10cm to ensure accuracy.

5 TEST PROCEDURE

To minimize the amount of material to be placed into the test box and removed following each test, part of the subgrade was "permanently" placed. Red clay was selected because it was available in large quantities. The red clay was compacted to a depth of approximately 75cm in the bottom of the test box. The permanent subgrade was compacted to 95 percent of the maximum dry density from the standard Proctor compaction test at the optimum water content. Either the gravel, sand or additional red clay were used to complete the remaining 25cm of the subgrade depending on the backfill/subgrade combination being used. Earlier studies have found that the strength of the subgrade had a minor influence on the amount of installation damage (Narejo, 1990). Thus, all subgrade materials were compacted to 95 percent of the standard Proctor maximum dry density.

With the subgrade at the desired elevation, the 1.83m x 1.83m section of geotextile was anchored to the back wall of the test box with the 5cm x 5cm angle. The geotextile was smoothed out to ensure no folds or wrinkles existed. The fabric was allowed to drape out the front of the test box. The excess material on the sides of the test box was taped up to the walls of the box to prevent the material from doubling over during placement of the backfill.

The desired backfill was then placed on top of the geotextile in a 25cm-thick lift. It was determined that lift thickness had only a minor influence on construction damage as long as the compaction energy per unit volume of backfill remained the same (Narejo, 1990). Based on these results, a lift thickness of 25cm was specified in all tests. Following placement, the backfill was compacted using the gas-powered compactor to 95 percent of the maximum dry density from the standard Proctor test.

Once the backfill compaction was complete, the geotextile was carefully exhumed and sent to an independent laboratory for wide-width tensile tests.

6 RESULTS

Installation damage was evaluated using the percentage of wide-width strength retained by the test specimens relative to the MARV strength of virgin specimens. An independent laboratory performed either three or six wide-width tensile tests in both the warp and the fill directions for each geotextile specimen. From these tests a mean tensile strength was obtained for both directions.

The percentage of strength retained for each fabric and backfill/subgrade combination is given in Table 4. The results are consistent with the expectations for these geotextiles and backfill/subgrade conditions. In general, all three geotextiles experienced greater installation damage as the severity of the backfill/subgrade conditions increased from clay/clay to gravel/gravel. Similarly, the amount of installation damage decreased as the weight of the geotextile increased. This series of tests demonstrates that the amount of installation damage is most likely geotextile specific. Care should be taken in generalizing the results of these tests to other geotextiles. Suggested factors of safety for each geotextile with various backfills is given in Table 5. Table 5 also shows Task Force 27 values for comparison.

Table 4 Percentage of strength retained for installation damaged specimens

		Percentage of Strength Retained			
PET Geotextile	Direction	Clay/ Clay	Sand/ Sand	Gravel/ Clay	Gravel/ Gravel
350 g/m^2	Warp	90.2	74.7	73.8	60.8
	Fill	86.6	80.0	72.0	61.0
595 g/m^2	Warp	82.2	71.2	75.6	66.2
	Fill	92.1	82.3	80.0	76.8
780 g/m^2	Warp	93.1	-*	77.1	68.6
	Fill	91.8	80.1	88.3	81.0

*material mislabeled and discarded

Table 5 Suggested installation damage factor of safety, FS_{id}

	FS_{id}			
PET Geotextile	Clay/ Clay	Sand/ Sand	Gravel/ Clay	Gravel/ Gravel
350 g/m^2	1.25	1.4	1.4	1.7
595 g/m2	1.25	1.4	1.4	1.6
780 g/m2	1.1	1.4	1.3	1.5

Task Force 27 preliminary FS_{id} default values

No product specific construction damage tests	Construction damage data exists, but unknown backfill
3.0	1.25 minimum

Note: Lower values must be substantiated by site specific testing.

6.1 Damage mechanism

In many of the tests, no visible signs of damage (i.e., holes or other flaws) were evident after careful exhumation of the geotextiles. Because of this lack of easily discerned damage, a sample from the gravel/gravel test (the most heavily damaged sample) was studied under an electron microscope; no localized damage was noted. Although individual yarn testing and chemical analysis were beyond the scope of the project, they deserve consideration to understand the exact mechanism by which these geotextiles are being damaged during installation.

7 UNCONFINED CREEP TESTING

Polyester materials have proven to be less creep sensitive than other polymers used in reinforcement (denHoedt, 1986). In the absence of actual testing, Task Force 27 has established a polyester creep factor of safety of 2.5 for preliminary design only (Task Force 27, 1990). Using the Geosynthetic Research Institute's test method GT5, the 780 g/m^2 PET was loaded to 53.3% and 64% of ultimate load in the warp direction (see Table 1). These tests were conducted for 10,000 hours after initial tensile loading (GT5, 1991). Both 780 g/m^2 PET geotextiles were preloaded with 222.4 Newtons of tension where the deflection was set to zero. Roller clamp grips and a pneumatic loading device were used for this creep testing. The 10,000 hour strain on the 780 g/m^2 PET loaded to 53.3% of ultimate was 8.2%. The 10,000 hour strain on the 780 g/m^2 PET loaded to 64% of ultimate was 11.08%. Both materials achieved 80 to 90% of the total strain in the first minute of loading. Fig. 1 charts elapsed time versus percent strain.

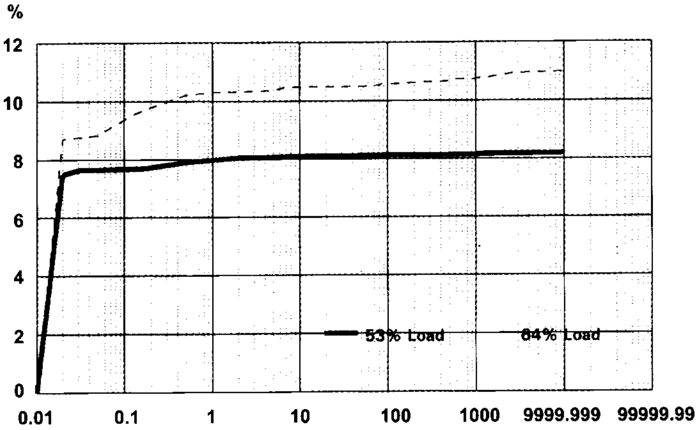

Figure 1: Unconfined Creep

780 Grams/Square Meter PET Geotextile (MD Direction)

With the limited amount of 10,000 hour testing performed to date, a factor of safety for the highest strength geotextile, the 780 g/m^2 PET, can be established at 1.9. While the geotextile loaded to 64% of ultimate was relatively unchanged out to 10,000 hours, the total strain is greater than 10%. This amount of elongation (11.08%) may unduly compromise the structure over its design life (FHWA, 1992).

8 CONCLUSIONS

Scant information on installation damage of high strength geotextiles used in reinforcement has been presented to date. This laboratory evaluation of three high strength geotextiles confirms that established factors of safety for installation damage as outlined by Task Force 27 are indeed conservative for these select polyester woven geotextiles. Also, as the severity of the backfill/subgrade increases, the amount of installation damage increases; conversely, as the weight of the geotextile increases, the amount of installation damage decreases. Moreover, a look at the unconfined creep behavior out to 10,000 hours for the 780 g/m^2 PET material confirms that the Task Force 27 default creep values for polyester are also conservative. For these high strength geotextiles, lower factors of safety for installation damage and creep can be established based on these laboratory results. In the absence of testing as performed in this paper, Task Force 27 default factors of safety for T_{all} are validated.

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