Construction Damage Assessment of a Nonwoven Geotextile

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Current state-of-the-practice geosynthetic design has evolved to the "design-by-function" concept. When geosynthetic materials are incorporated as reinforcing elements in highway widening projects the designer will often use a default value for the partial factor of safety associated with construction durability (i.e., installation damage). Since Task Force 27 has recommended a default value of 3.0, it is beneficial for the manufacturer to determine the influence of construction-induced stresses on their materials. A test pad was constructed and a geosynthetic test program conducted to determine the actual partial factor of safety associated with installation damage. This information will aid future designers, specifiers, and manufacturers in developing such a test program and will enhance the data base for future investigators.

When geosynthetics are used as reinforcing elements within earth structures the designer must consider the influence of construction damage, aging, temperature, creep, and confining stresses on the allowable design strength, T_a. In the absence of sufficient test data, T_a can be calculated by using the following simplified expression (*1,2*):

$$T_a = \frac{T_{\text{ult}}\ (\text{CRF})}{\text{FD} \times \text{FC} \times \text{FS}} \leq T_s$$

where

T_{ult} = ultimate (or yield tensile strength) from wide-width strip tensile tests (ASTM D-4595);
T_s = long-term tension capacity of geosynthetic at a selected design strain (usually 5 percent or less);
FD = durability factor of safety (dependent on susceptibility of geosynthetic to attack by microorganisms and chemicals, thermal oxidation, and environmental stress cracking and can range from 1.1 to 2.0. In the absence of product-specific durability information, use 2.0);
FC = construction damage factor of safety (Task Force 27 recommends a minimum value of 1.25 when specific backfill source is unknown but construction installation damage test data are available. In the absence of product-specific construction damage information, use 3.0);
FS = overall factor of safety to account for uncertainties in geometry of structure, fill properties, reinforcement properties, and externally applied loads (for permanent, vertically faced structures, FS should be a minimum of 1.5); and
CRF = creep reduction factor (CRF = T_l/T_{ult}, where T_l is creep limit strength obtained from creep test results). If CRF value for specific reinforcement is not available, Task Force 27 recommends 0.2 for polypropylene, 0.4 for polyester, 0.35 for polyamide, and 0.2 for polyethylene.

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On the basis of this information it is in the best interest of the manufacturer to work with the designer to establish the appropriate partial factor of safety values.

Of all the values indicated, emphasis is placed on the determination of a partial factor of safety associated with construction damage, FC. The construction damage assessment program should take into consideration the supporting subgrade conditions, gradation and angularity of backfill, geotextile properties, method of backfill placement, lift thickness, and compaction. These conditions will have an effect on the post-construction mechanical properties of the geosynthetic and will be dependent on site conditions and construction requirements established within project specifications.

PROJECT DESCRIPTION

The Salmon–Lost Trail Pass Highway project is an experimental project initiated by the FHWA Western Federal Lands Highway Division to evaluate the use of nonwoven geotextiles for the construction of steep slopes. The project is located in Idaho's Salmon National Forest and involves the widening of Idaho Forest Highway 30. A portion of the highway widening involves the construction of a 45-degree permanent geotextile-reinforced slope 172 m (565 ft) long, 2 to 15 m (5 to 50 ft) high.

TEST PROGRAM

A construction damage assessment program should include an upfront site evaluation, construction of a test pad, geotextile testing, and development of a partial factor of safety after evaluation of test data. This process is broken down into the following eight steps:

1. Evaluate subgrade conditions,
2. Evaluate backfill soil,
3. Conduct geotextile placement,
4. Conduct backfill placement,
5. Perform compaction,
6. Determine lift thickness,
7. Conduct geotextile testing, and
8. Develop partial factor of safety.

Each of these steps is dependent on the intended end use of the geosynthetic. In the following paragraphs these steps are examined for the case of a nonwoven geotextile used as reinforcement in the construction of a steep slope on the Salmon–Lost Trail Pass Highway project.

Subgrade Conditions

Cut material that would be removed prior to embankment construction was deemed as an appropriate embankment construction material. As a result the most economical means of performing the construction damage assessment program involved construction of a test pit. By excavating a pit 0.5 m (1.5 ft) deep along the shoulder on Highway 30, the undisturbed soil simulated actual construction conditions. Soil removed from this test pit was stockpiled for use in the test program.

Backfill Soil

The cutbank soil evaluation included visual observation, compaction, Atterberg limit testing, mechanical sieving, and pH testing. On the basis of visual observation it is expected that gravel and cobbles will be present throughout the proposed fill material. To limit construction damage potential, all material larger than 102 mm (4 in.) will be removed during construction of the geotextile embankment. Compaction tests indicated that a maximum density range of 18 to 21 kN/m^3 (115 to 130.6 lbf/ft^3) can be achieved at a moisture content range of 13.5 to 9.5 percent, respectively. From Atterberg limit testing, the cutbank soil was found to exhibit a liquid limit of 28 and a plasticity index that ranged from 7 to 10. Based on results of Atterberg tests and mechanical analysis, the cutbank soil is described as a silty sand with gravel (SM) in accordance with the unified soil classification system. Results of a pH test indicate that cutbank soil exhibits a pH range of 5.8 to 7.1. Because of the short-term exposure to soil during this test program, the influence of soil chemistry on the mechanical properties was deemed negligible.

All soil evaluation tests were conducted by the materials section of FHWA's Western Federal Lands Highway Division. Testing protocol and results associated with this work are found elsewhere (*3*).

Geotextile Placement

A 15.25-m (50-ft) by 3.96-m (13-ft) sample of an enhanced-modulus nonwoven geotextile was submitted by the manufacturer to FHWA. This geotextile was designated as geotextile Type IX within the project specifications and is a 407-g/m^2 (12-oz/yd^2) polypropylene continuous-filament needle-punched nonwoven geotextile manufactured for reinforcement applications. The properties required for this project are given in Table 1. At the site, 7.62 m (25 ft) by 3.96 m (13 ft) of the sample was placed on the undisturbed soil within the test pit. The remaining material was set aside to be used as the control in the testing program.

Backfill Placement, Compaction, and Lift Thickness

The geotextile sample was divided into three zones each measuring approximately 2.44 m (8 ft). Within each zone stockpiled soil was placed with a rubber-tire front-end loader to a loose depth of 152 mm (6 in.), 305 mm (12 in.), and 457 mm (18 in.). All stones and cobbles larger than 102 mm (4 in.) were removed from the backfill in accordance with project requirements. A fully loaded 10-yd, 10-wheel dump truck was then used to simulate compaction. A total of 25 passes were made across the entire section, resulting in lift thicknesses of 102 mm (4 in.), 203 mm (8 in.), and 305 mm (12 in.), respectively.

The compacted soil was loosened with a pick and removed within the trafficked areas with shovels. A geotextile sample was then removed from each section and labeled accordingly.

Geotextile Testing

The purpose of geotextile testing was to determine the influence of construction activities on the ultimate strength, T_{ult}, of the geotextile in the direction of load application, namely the machine direction. To aid in the interpretation of this information, additional testing was deemed appropriate.

In accordance with survivability requirements established by FHWA (*4*) and AASHTO (*5*), the Mullen burst, puncture resistance, trapezoidal tear, and water permeability values were evaluated as part of this investigation. Results of testing are presented in Table 2. Each test series was conducted in accordance with the ASTM method designated in Table 2. A compilation of geosynthetic testing procedures is presented in *ASTM Standards on Geosynthetics* (*6*).

Partial Factor of Safety

As indicated in Table 2, for the soil and placement conditions considered in this study, there is no reduction in machine-direction

TABLE 1 Construction Geotextile Property Requirements

Property	Test Procedure	Value[a]	Units
T_{ult} [b]	ASTM D 4595	20,000 (115)	N/m (lbf/in)
Mullen Burst	ASTM D 3786	2756 (400)	kPa (psi)
Puncture Resistance	ASTM D 4833	601 (135)	N (lbf)
Water Permeability	ASTM D 4491	0.30	cm/sec

[a] Minimum Average Roll Values: the sample average test results for any roll tested within a lot designated as first quality, tested in accordance with ASTM D 4759-88, must meet or exceed the values listed.

[b] Machine direction strength

TABLE 2 Geotextile Construction Damage Test Results

Property	ASTM Test Procedure	Control[a]	102 mm (4 in) lift	203 mm (8 in) lift	305 mm (12 in) lift	Units
T_{ult} [b]	D 4595	22565	22022	22232	23984	N/m
		128.8	125.7	126.9	136.9	lbf/in
Mullen Burst	D 3786	4747	3864	3278	3934	kPa
		689	560.8	475.8	570.9	psi
Puncture Resistance	D 4833	838	761	861	769	N
		188.3	171	193.4	172.9	lbf
Water Permeability	D 4491	0.329	.443	.438	.468	cm/sec
Trapezoidal Tear [c]	D 4533	453	635	567	594	N
		101.9	142.7	127.5	133.5	lbf
Trapezoidal Tear [d]	D 4533	555	695	638	582	N
		124.8	156.2	143.3	130.7	lbf

[a] Sample average test results for the field sample which was tested in accordance with ASTM D 4759-88.

[b] Machine direction strength

[c] Machine direction strength

[d] Cross direction strength

wide-width strip tensile strength for the 305-mm (12-in.) lift thickness. For the more severe conditions involving smaller lift thicknesses of 102 mm (4 in.) and 203 mm (8 in.), test data indicate reductions of 2.4 and 1.5 percent, respectively. Comparison of T_{ult} for the 102-mm (4-in.) and 203-mm (8-in.) lift thickness values against that of the 305-mm (12-in.) lift thickness indicates 8.2 and 7.3 percent losses, respectively. On the basis of this information, the construction damage partial factor of safety, FC, was set at 1.1, the lower limit established by Christopher et al. (*1*). Results of additional tests indicated a slight increase in permeability and trapezoidal tear stength. In contrast, puncture and Mullen-burst testing led to reductions in strength for the 305-mm (12-in.) lift thickness of 8 and 17 percent, respectively, when compared with the control sample. Because all values are well above those required by AASHTO for a high-survivability geotextile, it appears that the current AASHTO criteria are useful as a starting point.

CONCLUSIONS

A construction damage assessment program should replicate conditions that may exist during construction. The key steps in this process are the evaluation of subgrade and backfill soil, geotextile placement, backfill placement, compaction, determination of lift thickness, geotextile testing, and determination of the partial factor of safety. Because it is not possible to precisely model the field conditions it is important for designers to include a minimum construction installation damage factor, FC. As recommended by Christopher et al., this factor should not be less than 1.1.

A construction damage assessment program was examined for a high-strength nonwoven geotextile to be used in the construction of a reinforced soil structure. For nonwoven geotextiles used in these applications, evaluation should include the ultimate strength evaluation (i.e., wide-width strip tensile strength) in the direction of stress transfer, along with key index properties. For this particular needle-punched nonwoven geotextile, influential index properties were found to include the Mullen burst, puncture resistance, and permeability.

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