Testing installation damage of geosynthetic reinforcement

Proper testing procedures lead to proper installation techniques—yielding stronger performance of materials in the field.

Installation damage is one of the three critical factors in determining T_a, the allowable strength in reinforcement design.

$$T_a = T_{ult} / (RF_{CR} \times RF_{ID} \times RF_D)$$

RF_{CR} = partial factor for tensile creep
RF_{ID} = partial factor for installation damage
RF_D = partial factor for chemical durability

The untested product default values for creep, RF_{CR}, installation damage, RF_{ID}, and chemical durability, RF_D, are established in the AASHTO Bridge Specifications and, as can be seen in **Table 1**, default values can be punitive to untested products.

The Federal Highway Administration Geotechnology Technical Note on Degradation Factors for Geosynthetics published May 1, 1997 cited installation damage as a key issue in determining geosynthetic performance characteristics in reinforcement design and provides ranges of installation damage reduction factors commonly used in design, as shown in **Table 2**.

Testing for installation damage

ASTM D 5818 provides general procedures for obtaining project-specific samples of geosynthetics from full-scale, on-site test sections, but it does not prescribe specific equipment loading, soil/aggregate material types, or installation procedures. ISO 10722 sets forth a small-scale "index" test procedure that includes a specific synthetic aggregate as well as prescribed aggregate layer thickness and cyclic loading criteria. Neither of these two standards has proven sufficient for the determination of appropriate reduction factors for geosynthetic reinforcement design. As noted, ASTM D 5818 results are project-specific and ISO 10722 results have no correlation to actual full-scale performance. Neither test assures that an "apples-to-apples" comparison of products can be made based on associated test results.

Thus, most full-scale installation damage testing to date has adopted an exposure, exhumation and testing method based on a protocol developed by Watts and Brady of the Transport Research Laboratory (TRL) in the United Kingdom and documented as TRL's "Procedure for Installation Damage Test for BBA Assessments" (CERC.SOIL.TM028, Jan. 1997). The protocol has been modified, as appropriate, to generally conform with ASTM D 5818. This approach to assessing installation damage has proven to be practical and repeatable, and produces results within expectations.

Installation damage has generally been shown to affect the ultimate strength of the geosynthetic, rather than its modulus. Therefore the effects of installation are commonly measured by ultimate strength reductions. The exhumed samples are then evaluated for retained ultimate tensile properties using ASTM D 6637, D 4595, EN ISO 10319 or other protocols as requested by the client.

Common full-scale installation damage procedures

Exposure procedure

Since compaction typically occurs parallel to the face of retaining walls and the

Table 1. Typical geosynthetic default and testing-derived values for ID reduction factors.

Factor Basis	**Reinforcement Partial Reduction Factors**			**Total of Reduction Factors**
	RF_{CR}	RF_{ID}	RF_D	RF
Default*	2.0-5.0	1.05-3.0	1.1-2.0	7
Typical from Testing Lab	1.5-4.0	1.05-2.0	1.1**/1.15-1.3***	2-3

*Per AASHTO Bridge Specs – only acceptable for preliminary design and non-critical structures.
**PP and PE must have UV Stability > 70%; ***PET must have MW>25,000 and CEG<30.

Table 2. FHWA installation damage findings.

Geosynthetic Type	**Max size 100 mm D50 ≅ 30 mm**	**Max size 20 mm D50 ≅ 0.7 mm**
HDPE uniaxial geogrid	1.20 – 1.45	1.10 – 1.20
PP biaxial geogrid	1.20 – 1.45	1.10 – 1.20
PVC-coated PET geogrid	1.30 – 1.85	1.10 – 1.30
Acrylic-coated PET geogrid	1.30 – 2.05	1.20 – 1.40
Woven geotextiles (PP and PET)	1.40 – 2.20	1.10 – 1.40
Nonwoven geotextiles (PP and PET)	1.40 – 2.50	1.10 – 1.40
Slit-film woven PP geotextiles	1.60 – 3.00	1.10 – 2.00

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contour lines of slopes, the machine direction is placed perpendicular to the running direction of the compaction equipment. To initiate the exposure procedure, four steel plates equipped with lifting chains are placed on a flat clean ground surface. A layer of soil/aggregate is then placed over the adjacent plates and compacted to a specified thickness (usually not less than 8 inches (0.20 m)). Next, each of four coupons of the geosynthetic sample is placed on the compacted soil over an area corresponding to an underlying steel plate. To complete the installation, the second layer of soil is compacted over the coupons. To guide and contain the compaction process, braced barriers define the long edges of the installation. The target cover compacted lift thickness and degree of compaction is 8 in. (0.2 m) and 90% modified Proctor, respectively, unless otherwise requested.

Compaction is accomplished using a 4550 kg ride-on steel-wheeled roller with vibratory capability. All compaction and exhumation procedures, as well as laboratory soil classification and field thickness measurements, are performed under the supervision of a licensed geotechnical engineer. Density measurements are made by a qualified geotechnical technician.

The following construction quality control measures are followed during exposure.

- Proctor and sieve analyses are performed on each soil/aggregate, when possible. (Proctors can not be performed on coarse aggregates.)
- Lift thickness measurements are made after soil/aggregate compaction.
- When possible, moisture and density measurements are made on each lift using a nuclear density gage to confirm that densities >90% of modified Proctor (per ASTM D 1557) are being achieved.
- In addition to the above, the number of compaction equipment loadings (i.e., passes) are recorded for each exposure and corresponding soil compaction effort.

To exhume the geosynthetic, railroad ties are removed and one end of each plate is raised with lifting chains. After raising the plate to about 45°, soil located near the bottom of the leaning plate is removed and, if necessary, the plate is struck with a sledgehammer to loosen the fill. The covering soil/aggregate is then carefully removed from the surface while "rolling" the geosynthetic away from the underlying soil/aggregate. This procedure assures a minimum of exhumation stress.

Photos 1 and **2** are representative of the procedures.

Gradation of backfill material

Each geosynthetic is exposed to soils/aggregates chosen by the client from a range of available stockpiles having different gradations. Typical soil gradation curves are shown in **Figure 1**.

Specimen preparation and wide width tensile testing

Upon removal from the exposure site, exposure coupons are allowed to dry. Coupons are then cleaned by removing surface soil via light hand sweeping. Soil trapped within the geosynthetic structure is not removed by washing or otherwise stressing the geosynthetic. No additional cleaning is performed and specimens are cut and tested in their soiled condition.

The evaluation of RF_{ID} is based on the results of wide width tensile tests per ASTM D 4595, *Standard Test Method for Tensile Properties of Geotextiles by the Wide-*

Photo 1. Geosynthetic samples are installed and exposed to field-scale placement and compaction stresses.

Photo 2. Tilting up of the underlying steel plates facilitates exhumation of samples without further damage.

Table 3. Exposure lane testing scheme.

Exposure Coupon 1					Exposure Coupon 2					Exposure Coupon 3					Exposure Coupon 4				
1	2	3	4	5	11	12	13	14	15	6	7	8	9	10	16	17	18	19	20

Figure 1. Soil grain size distributions.

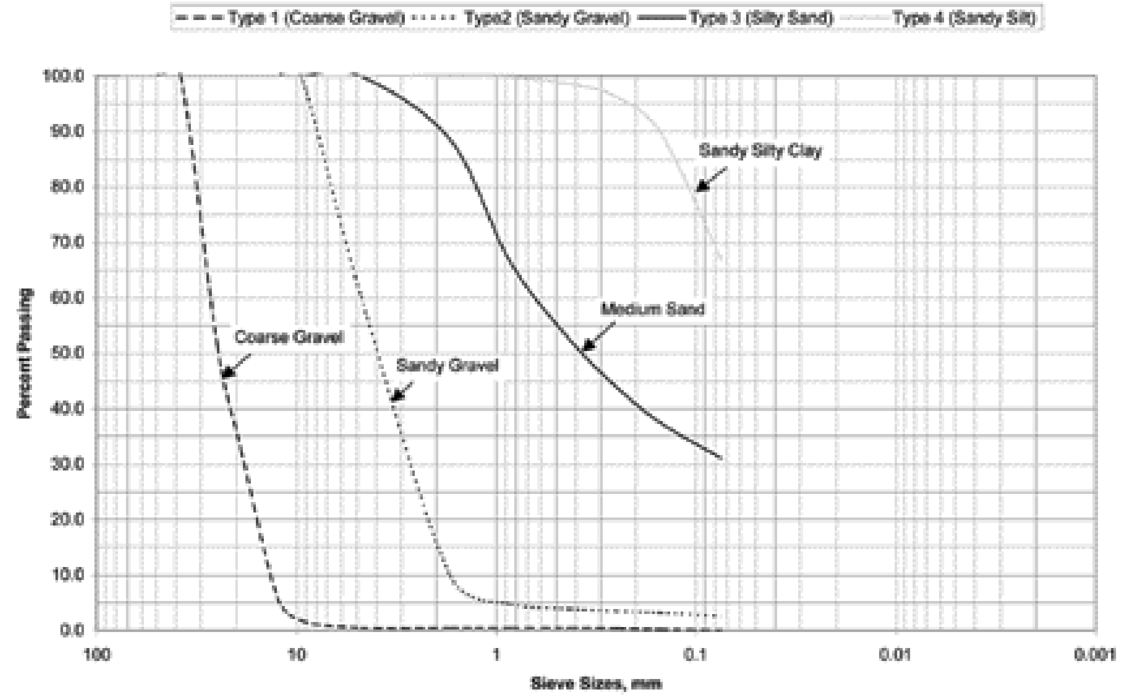

Table 4. Comparison of full-scale producedures

NHI guidelines	Common procedures	Effects of variation
Subject geosynthetic material to a backfilling and compaction cycle, consistent with field practice.	Geosynthetic material is subjected to a backfilling (though backfilling equipment does not run over backfill) and compaction cycle using full-scale equipment.	None. Installations using very coarse gravel done both with and without running backfilling equipment over the backfill produced the same results.
Baseline tensile testing shall be in accordance with ASTM D 4595, minimum of five specimens, COV < 5%.	Same.	No variation.
Place and compact 300 mm of soil (same as cover soil) on a flat, level, relatively incompressible subgrade.	200–300 mm of soil is placed on a steel plate that is placed on a flat, level, relatively incompressible subgrade.	Conservative. Steel plate is non-yielding and therefore is believed to create a more severe (conservative) condition.
Place geosynthetic with MD perpendicular to the face of wall (i.e., direction of compaction). Total sample size 5 m x 3 m (min.).	Same, except total sample size is approximately 5 m x 1.2 m.	None. Sample size yields 20 potential wide width specimens.
Place and compact 200–300 mm of soil (compacted thickness) using a front-end loader or D-4 to D-7 dozer.	200 mm of soil (compacted thickness) is placed on the geosynthetic using a front-end loader.	None to Conservative. No more than 200 mm of compacted thickness is used. (Also, see first requirement.)
Compact the backfill using a 4500–13,600-kg vibratory smooth-drum roller with a set number of passes. Assure at least 95% Modified AASHTO density.	Soil is compacted with a 4550 kg vibratory smooth-drum roller with a set number of passes to assure at least 90% Std Proctor density.	Uncertain.
Carefully remove backfill by hand and document any observable geosynthetic damage.	Steel plate is tilted to facilitate careful removal of backfill.	None.
A minimum of 9 specimens with consecutive numbers should be initially tested. Specimens having damage from the retrieval process should not be tested.	Initially, 9–10 consecutive specimens are tested. Specimens demonstrating inconsistent strength loss may be excluded.	None. Specimens demonstrating inconsistent strength loss are examined for extraneous damage and, if found to be non-representative, excluded.

Width Strip Method; ASTM D 6637, *Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-rib Method*, Method B; or ISO 10319, *Geosynthetics – Wide-width Tensile Test*. After exposure is complete, all baseline and exposed wide width tensile tests are performed during the same testing period.

Sampling and specimen selection

Each set of tensile tests of an exposed style of geosynthetic is compared with tensile tests of the same style of the geosynthetic in an unexposed, or "baseline," condition. It should be noted that tensile specimens are not representative of the roll width, but instead are specific to a defined region within the roll width. This approach is accomplished by cutting coupons (designated for baseline and exposure testing) in sequence along the length of the geosynthetic. This technique captures common yarns and/or ribs in the tested specimens to minimize variation.

Tensile tests of specimens taken from the damaged material after installation

The coupons and candidate specimens to be exposed to installation stresses are selected prior to exposure and installed in accordance with a defined sampling plan (via ASTM D 5818). Exposure coupons are laid within the exposure lane in consecutive order, each representing five specimens. Thus, the exposure lane is constructed with specimens 1 through 20 (**Table 3**).

Upon exhumation of the exposed coupons, specimens are cut and tested in numerical order. A minimum of ten exposed specimens from each testing condition is systematically selected for testing from the twenty candidate specimens. The test results are averaged and compared to the average of the baseline specimens.

NHI (HITEC) procedures

Another source of installation damage testing guidelines can be found in Publications FHWA NHI-00-043 and -044 of the National Highway Institute. These suggested procedures form the basis for the evaluation of installation damage data submitted for review by the Highway Technology Evaluation Center (HITEC). **Table 4** provides a summary comparison of the previously described common full-scale procedures and the NHI guidelines.

European index test

For the purposes of quality control (QC) or quality assurance (QA), it is often beneficial to have a small-scale, "index" test that relates to a product's field performance. Resistance to installation damage is one way in which a product must perform, and ISO 10722 is an index test that enables a manufacturer to verify that the product will perform consistently.

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