GEOSYNTHETIC INSTALLATION DAMAGE TESTING – A STATUS REPORT

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ABSTRACT

New and frequent evaluation of the reduction factors associated with the installation damage of geosynthetic reinforcements has resulted in the development of a new test procedure as well as product feature awareness. This paper will review the history of the test procedure used to quantify installation damage, new developments regarding its use, and observations regarding test results generated.

BACKGROUND

The determination of allowable strength of a geosynthetic reinforcement product \( (T_a) \) relies on an assessment of a number of reduction factors specific to the product and its application. These reduction factors are outlined below.

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T_a = \frac{T_{ult}}{(R_{FCR} \times R_{FID} \times R_{CBD})}
\]

- \( T_{ult} \) = ultimate tensile strength as measured via wide width tensile testing
- \( R_{FCR} \) = reduction factor for tensile creep
- \( R_{FID} \) = reduction factor for installation damage
- \( R_{CBD} \) = reduction factor for chemical and biological degradation

These reduction factors are typically established from product-specific laboratory testing and/or predicted based on field experience, with the former being preferred for accuracy. While related testing procedures represent some of the more involved and expensive tests performed in support of geosynthetics design, the testing community has made significant progress in establishing protocols that are repeatable, timely with regard to turnaround of results, and affordable.

Included in these improved evaluations is the assessment of the installation damage reduction factor \( (R_{FID}) \). This reduction factor is born of an acknowledgement that when a reinforcement geosynthetic is installed it undergoes damage that immediately reduces its long-term strength. The test procedure itself has been one of the last to be standardized with ASTM D 5818 providing only a guide with respect to exposure of specimens, and primarily intended for project-specific on-site evaluations. This guide has been further refined by different regulatory and assessment communities including the Federal Highway Administration’s publication NHI-00-043 and -044 of the National Highway Institute (used in the Highway Technology Evaluation Center (HITEC)), Washington Department of Transportation Test Method 925, the British Board of Agrément (BBA), and others. These refinements turned the “project-specific guide” into “typical” procedures that could be applied each time installation damage was to be evaluated. However, the substantial cost of these full-scale procedures and lack of agreement on what is actually a “typical” exposure has limited its widespread and continued use.
The assessment of RFID was eventually significantly improved by establishing a test procedure 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).

In this approach, the entire process of geosynthetic exposure and exhumation has been made much more controllable and repeatable by employing a standard, yet full-scale, out-door laboratory approach. The tested geosynthetics are placed within a simulated retaining wall or reinforced slope backfill using a prescribed construction technique and full-scale equipment and then exhumed and tested for tensile strength loss. Other situations can be simulated accordingly. As shown in Figure 1, a substratum of four steel plates, equipped with lifting chains, is incorporated into the exposure regime. The layers of compacted soil/aggregate are constructed on top of the plates with the geosynthetic installed accordingly. The geosynthetic is then exhumed by first raising one end of the steel plates with lifting chains to about a 45° angle. Soil located at the lower end of the tilted plate is removed and, if necessary, the plate is struck with a sledgehammer to loosen the fill. As the upper lift falls away, the geosynthetic is removed by “rolling” it away from the underlying lift. This procedure significantly minimizes exhumation damage unrelated to installation damage.

The exhumed samples are then allowed to dry, and then “cleaned” of surface soil via light hand sweeping. Significantly, the soil trapped within the product structure is not removed by washing or otherwise stressing the material. The materials are cut and tested in their “soiled” condition. Other un-exposed samples are also cut and tested from the same roll of material to establish “baseline” tensile strength. The evaluation of RFID is typically based on the results of wide width tensile testing in accordance with various responsive test procedures. These include:

Figure 1 - Sequential steps in installation damage assessment per this test procedure.

(a) underlying steel plates that can tilt

(b) placement of aggregate

(c) geosynthetic placement

(d) placement of overlying layer

(e) vibratory roller compaction

(f) exhumation of samples
After exposure and exhumation, all baseline (unexposed) and exposed specimens are tested at the same time.

The modified Watts and Brady procedure has been extensively used to characterize products and has provided the majority of data available from large scale testing. Indeed, one of its greatest benefits is its economy of scale and related opportunities to investigate variables and their effect on the measured results. Included in these variables are the following:

- lift thickness (of the underlying and overburden soil/aggregate layers),
- equipment loads (large vs. smaller compaction equipment),
- durability (hardness) of aggregate/soils, and
- angularity of soils/aggregates (see Figure 2).

Data have demonstrated the Watts and Brady modified test to be capable of a robust exposure regimen. Where uncertainties regarding the relative conservatism of the procedure have been suggested compared to actual field exposures, the procedure has been modified and made specific to assure aggressiveness. The procedure now adopts large heavy equipment and durable (maximum LA wear test requirement of 35%) angular to subangular soils/aggregates. The increased durability of the soil/aggregate also contributes to exposure consistency during large testing programs involving numerous repetitive tests.

(a) less aggressive rounded aggregate                 (b) angular, more durable aggregate

Figure 2. Illustration of “roundness” of aggregate.
TRADITIONAL THOUGHTS REGARDING RF\textsubscript{ID}

The measurement of RF\textsubscript{ID} has traditionally been sensitive to two parameters; the gradation of the soil aggregate (commonly characterized by the D\textsubscript{50}) and the relative strength or mass per unit area of the product tested. Figure 3 presents commonly expected installation damage trends based on these parameters.

As the D\textsubscript{50} of the soil/aggregate increases, so does the expected RF\textsubscript{ID}. As the mass and strength of the geosynthetic increases, the expected RF\textsubscript{ID} decreases. While results consistent with Figure 3 have certainly been observed, they represent only examples of generated data, with many exceptions existing. Indeed, a significant base of experience has demonstrated many product specific features contributing substantially to measured strength loss and resulting RF\textsubscript{ID}-values. The following sections detail some of these product features and the related phenomenon associated with RD\textsubscript{ID}.

![Figure 3. Anticipated RF\textsubscript{ID} results.](image-url)
Polyethylene Geogrids and Polypropylene Woven Geotextiles

Laboratories have sometimes observed a small increase in ultimate tensile strength as a function of exposure. After some warranted suspicion, this increase in strength has been verified with additional exposures and retesting. This phenomenon seems to be dependent upon the geogrid rib or geotextile tape dimensions and their relation to the gradation of the exposure soil/aggregate, and is not observed in all applications. The phenomenon is real and may be caused by the densification of the polyolefin under the soil compaction stresses, and a related increase in molecular friction during extension. This then translates, in some conditions, to small increases in material strength. Together with the increased tensile strength, this compression of the material may have other effects on the material that need investigating, such as time dependency of the effect, long-term performance ramifications, etc.

![Graph showing tensile strength vs. strain for installation damage exposed to Type 2 Sandy Gravel, D₅₀ = 4mm](image)

Figure 4: Example wide width tensile (ASTM D 4595) test results for baseline and exposed woven polypropylene geotextile showing a slight increase in strength.

Coated Polyester Yarn Geogrids

Coated yarn type geogrids consist of a knitted or woven polyester yarn matrix enveloped by a polymeric coating serving to provide geometric stability and resistance to mechanical damage. A number of product features have significant impact on measured strength retention for these products. Most important among these may be the quantity and thickness of the coating. The thoroughness of coverage and thickness of the final coating can govern the resulting RFᵢᴰ for a tested product. Thin or breached coatings can provide very limited protection from damage where the soils/aggregates are allowed to penetrate through to the core yarns and rip or tear the
material. Alternatively, complete and thick coverage can sometimes provide for almost no measured damage.

The assessment of the amount of coating is challenging using only visual inspection and therefore uncomfortably subjective, see Figure 5. Indeed, there currently exists no standardized test procedure for this critical feature of the product and generally no specification by the user community for minimal required coating thickness or level of distribution. With new sensitivity regarding this important issue, a national testing program has recently required participating manufacturers to report the mass per unit area associated with the uncoated and coated products they supply.

The testing of such a feature is challenging as the coating does not typically exist around the yarns only, but instead provides some of its protection by being absorbed into the yarn structure, permeating yarn bundles and ribs. Thus a simple close inspection of the cross sectional area of a coated rib does not lend itself well to a quantitative evaluation. Still, a need for an evaluation technique exists so that this feature can eventually be related to the corresponding RF\textsubscript{ID}, and meaningful criteria may be established to assure a minimum protection.

![Figure 5. Thin coating with breaches apparent.](image)

Another feature of woven and coated geogrids affecting the measured RF\textsubscript{ID} is the geometric configuration of the product. Sometimes, the difference in a relatively light-weight, weaker product and stronger heavier product is the structure of the additional yarn bundles added to individual geogrid ribs. See Figure 6 for such a comparison. These additional yarn bundles add weight and strength to the product. However, when these are added horizontally at the cost of aperture size, the exposed surface area to mass ratio of the product changes, resulting in more damage absorbed. This may sometimes result in higher reduction factors associated with stronger products than with lighter weight products. Alternatively, ribs made stronger by increasing the size of the yarn bundles rather than the number of yarn bundles have shown immunity to this additional damage and have often shown increased resistance to installation
damage, as expected. This is believed to be due to the increase in strength without the increased surface area to mass ratio.

Figure 6. Skinny versus large flat geogrid ribs.

These product features are important and not always selected or manufactured with sensitivity to the related RFID. More aggressive and more frequent testing has created new awareness and opportunity to respond to these observed phenomena with deliberate product designs and verification measurements.

TOWARDS ONE APPROACH

Standardized guides have the gift and curse of flexibility. They facilitate the freedom to meet project specific needs, yet without firm procedural requirements, sometimes penalize those who try and employ data to support other projects or related applications. It has not been uncommon for test results to be rejected due to very small differences in required gradations, soil/aggregate lift thicknesses, weight of construction compaction equipment, etc.

Recently, the modified Watts and Brady approach has been used extensively by manufacturers, regulatory communities, and users alike to characterize products with respect to a variety of soil/aggregate gradations as well as site-specific project oriented soils/aggregates. The approach, as modified through the years, is being adopted in a revised and updated ASTM D 5818, and recently has been harmonized with the BBA procedure as applied in Europe and the American Association of State and Highway Officials’ (AASHTO’s) National Transportation Product Evaluation Program (NTPEP) program for reinforcement geosynthetics. This creation of a singular standardized approach is significant in that it affords the opportunity for manufacturers to spend resources on characterizations that can then be used in more than one regulatory and user environment. Small differences in required test parameters will no longer result in rejected test results, and nearly redundant re-testing.
CONCLUSION

The development of a standardized approach for the assessment of the installation damage reduction factor (RFID) has realized a number of significant benefits.

- An awareness that product performance and comparative evaluations do not always follow anticipated trends.
- A new appreciation for the many product features that contribute to observed material behavior.
- A standardized procedure maximizing the opportunities for characterization and benefit of testing.

As increased use of this procedure is realized, significant research opportunities exist to investigate site and project-specific impacts on product configurations, strengths and other relevant variables.