Comprehensive Overview of Installation Damage Test on Geo-textiles

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Abstract

Nowadays soil reinforcement is necessary for geotechnical engineering and geo-textiles are being used as reinforcement since it is easy to install, long-lasting, and economic. Installation damage can be expected to modify the mechanical properties of geosynthetics. The study and investigation into the long-term performance, design life, and survivability of geo-textiles, especially due to installation damage are necessary. During installation, spreading, and compaction of backfill materials, geotextiles may encounter severe stresses which can be higher than they will experience in-service. This paper contributes to a better understanding of how installation damage affects the design life of geo-textiles and the importance of installation damage. Apart from these, steps taken to minimize the installation damage and test procedure to conduct the installation damage test are also discussed. Several authors have demonstrated that installation damage can be minimized to a larger extent by following standard installation procedures. The coarse backfill causes severe installation damage to the geotextiles so care should be taken accordingly to reduce the damage. The installation damage test, provide the reduction factor value of the geo-textile compared to the control specimen before the actual installation, which can be considered to evaluate the life of the design. Therefore, it is significant to perform the installation damage test of the geo-textiles.

Keywords

Geo-textiles, installation damage, reduction factor, tensile strength, design life

1. Introduction

Nowadays geo-textiles have become a part of road construction and soil stabilization techniques. The durability of the geo-textiles is one of the important parameters that need to be evaluated in design life. It depends on two characteristics namely degradation and resistance; degradation is caused mainly due to oxidation, ultra-violet radiation, hydrolysis, and chemical and biological agents(Hufenus et al. 2005). Resistance of geo-textiles towards installation damage, creep, stress relaxation, abrasion, and compressive creep. Among these, installation damage is a short-term effect that reduces the maximum tensile strength but does not affect the long-term properties such as creep and aging by hydrolysis, oxidation, and/or abrasion. The design period of the geo-textiles depends on the reduction factor. Hence, the durability of geo-textiles is assessed by the short-term accelerated tests under extreme conditions experienced in service(Cho et al. 2006). To establish the validity of these tests it is essential to compare their predictions with tests made on material from the site. Generally, the short-term properties after a certain period in the service specimen are compared with the same properties determined on the control specimen. This will give the installation damage factor of the geo-textiles. If the installation damage factor for a particular geotextile is less, certainly, the short-term strength requirement will also be less.

It is a well-known fact that installation damage is inevitable for the geo-textiles and should be avoided (Fox et al. 1998). The installation of the geo-textiles comprises viz. removing soil, surface preparation, handling and laying geotextile, carrying, placing, spreading, and compacting the backfill material over the geotextile(Sardehaei et al. 2019). Consequently, it is impossible to avoid the installation damage of the geo-textiles but it is possible to minimize the damage by following adequate construction techniques; such as cleaning and clearing the sharp and roots from the surface where geotextiles are placed, wrinkles must be removed from the geo-textiles before laying, the backfill should fall from a minimum height of 0.15 m over the geo-textiles(Corbella and Stretch 2012; Vieira et al. 2015). It must be noted that construction equipment should be placed only on the backfilled geo-textiles. In fact, during the installation process, geotextiles may encounter more stresses

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than during their service life, with the appearance of cuts, frays, and general abrasion. The installation of geo-textiles in the coarser material causes severe damage to the hydraulic and mechanical properties

1.1 Overview of installation damage of geo-textiles

Generally, the design of geotextile incorporated soil structures takes the following two factors into consideration namely: the maximum strain in the geo-textile throughout the design period, which is considered as serviceability, and the minimum strength of the geotextile that can take to rupture, which is known as the ultimate limit state. These factors depend on time and are degraded by the environmental conditions to which the geo-textile is exposed. The design period (Td) for the geotextile soil structures is typically 50 to 100 years(Bathurst et al. 2011). However, this period is too long for direct measurements and to be made in advance of construction. Therefore, reduction factors are evaluated by extrapolation of short-term data, where necessary tests are conducted at elevated temperatures and loads to accelerate the processes of degradation(Miyata et al. 2015). The degradation strength of geo-textiles is time bound and is classified accordingly into three modes viz., immediate reduction, gradual, and no reduction. The immediate reduction is due to installation damage, which decreases the tensile strength(Lim et al. 2013).

The installation damage is the primary reduction factor applied in the design life of the geo-textiles. Koerner and Koerner (1990)examined 75 different geosynthetics textiles and stated the retained tensile strength after installation and excavation. The results revealed that coarse, irregular, and frozen subgrades, poorly graded cover soil with large particles, small lift thicknesses, and heavy construction equipment created severe damage. Furthermore, Allen and Bathurst (1994) summarized the results of tensile load-strain tests performed on different geosynthetic reinforcement products in site-damaged and undamaged conditions. They observed a greater loss of modulus for nonwoven geotextiles compared with woven geo-textiles, owing to the thinner fibers used in the nonwoven geo-textiles. Greenwood and Brady(1992) showed that the damage factor due to installation damage and the frequency of damage increased when increasing the backfill grain size and number of passes. Most researchers emphasize that the level of damage depends directly on the weight, type, and a number of passes of the compaction equipment. The installation damage will destroy geotextile's hydraulic efficiency, that is the ability to allow free passage of water through rock armor whilst retaining and protecting the soil beneath from washing away from tidal currents and wave actions. Geosynthetic clay liners (GCL) are different types of geosynthetics and are prone to damage through installation. Depending on the product type and hydration conditions, such stresses may damage the carrier geosynthetics, damage the reinforcement, or cause bentonite migration and consequent reductions in local mass per unit area of the product. Primarily based on the field observations during construction, ASTM D 6102 is the most complete guideline for GCL installation currently available. However, there is a need for controlled field studies to substantiate and strengthen the recommendations of ASTM D 6102. Furthermore, neither ASTM D 6102 nor ASTM D 5818 provide details regarding field and laboratory procedures needed to conduct a controlled field test of GCL installation damage. Laboratory studies have investigated GCL bentonite migration under concentrated loads and areal load a controlled field study of GCL installation damage has not been reported. Watts and Brady (1990) developed a simple procedure with sufficient reproducibility for simulating installation damage on site. They showed that the tensile strength and the elongation at break were both substantially reduced by damage during installation, but Young's modulus was largely unaffected. Based on the literature results of installation damage for a wide range of geosynthetic reinforcements, the Federal Highway Administration (FHWA) has proposed the installation damage reduction factors according to Table 1. Apart from this, several researchers stated that creep strains are not affected by installation damage, unless the damage is severe, or unless the load level applied is very near the creep limit of the undamaged material (Allen and Bathurst 1994; Bathurst et al. 2011).

Table. 1 Installation damage factor as per FHWA recommendations

Geosynthetic type	Type 1 backfill size <102 mm D_{50}˜ 30 mm	Type 2 backfill size <20 mm D_{50}˜ 0.7 mm
Stretched biaxial PP grids	1.20–1.45	1.10–1.20
Stretched HDPE grids	1.20–1.45	1.10–1.20
PP slit tape woven	1.60–3.00	1.10–2.00
PVC coated PET grids	1.30–1.85	1.10–1.30
Acrylic coated PET grids	1.30–2.05	1.20–1.40
PP and PET woven	1.40–2.20	1.10–1.40
PP and PET nonwovens	1.40–2.50	1.10–1.40

2. Installation damage factor

The Geosynthetic Research Institute (GRI) Standard Test Method GG4 has given a method to determine the allowable strength and the long-term design strength of geo-textiles are calculated from Eq. 1 and 2 respectively, which is done by taking into consideration of the ultimate strength and the total Factor of Safety (FS) in the geo-textiles.

$$T_a = T_u\left[\frac{1}{RF_{id} + RF_{cr} + RF_{cd} + RF_{bd}}\right]$$

$$T_a = T_d\left[\frac{1}{RF_{id} + RF_{cr} + RF_{cd} + RF_{bd}}\right]$$

Whereas: Ta = allowable strength (N.m-1); Tu = ultimate strength (N.m-1), Td = long-term design strength (N.m-1),RFid = installation damage factor, RFcr = creep deformation factor, RFcd = chemical degradation factor, RFbd = biological degradation factor.

In other words, the installation damage factor is an allowance given for the geo-textile to damage at site conditions during the installation process. It is defined as the ratio of the mean tensile strength of the undamaged material to the mean tensile strength of the damaged material. Pinho-Lopes et al. (2016) stated that the reduction factor for installation damage obtained from tensile tests overestimated the effects of the installation conditions on the soil–geotextile interface.

2.1 Methods to avoid installation damage.

To avoid installation damage, the following precautions should be taken(Black et al. 1999; Carlos et al. 2015):

1. The geo-textiles must be installed by the installation guidelines provided by the manufacturer or as directed by the Engineer.
2. The geotextiles should be provisionally fixed in place with pins, sandbags, or staples as per the fill properties, fill placement procedures or weather conditions.
3. To reduce the damage to the low strength geotextile a cushion layer of sand should be placed over it.
4. It must be ensured that geo-textiles are not prone to sunlight for more than the maximum duration permitted in the approved installation procedures. If the manufacture does not provide any specific guidelines, then the geo-textiles must be covered within a day of installation.
5. Care should be taken if the backfill of the soil is coarser and the backfill should fall from a height less than 1.5 m.

3. Installation damage test setup

The installation test is carried out as per the ASTM D5818, ISO 13437, and UK code of practice for geo-textiles. Primarily, the initial condition of geo-textile is identified such as identification and description of the structure, geo-textile environment, characteristics, and testing standard references. As per the standard specifications the installation damage test is carried out in three stages viz., 1. Installation of geo-textiles specimen, 2. extracting the specimen from the soil, and 3. testing on the extracted specimen in the laboratory(Jeon et al. 2010). The BTRA is planning to create the site for the installation of the specimens as per the specifications and then the testing of specimens extracted to evaluate the damage factor of the geo-textiles.

3.1 Installation and retrievals of the specimen.

To avoid the faulty test results ASTM D5818 and ISO 13437 have provided certain guidelines to follow: the number of samples is determined by the dimensions of the structure, the physical and chemical variations in the environment in which the geo-textiles is installed, and the repercussions that a failure of the geo-textiles function would cause. On the other hand, the number of retrievals depends on the design life. The installation damage specimen is taken after the test and the control specimen is taken from the material before installation and it should be as close as possible to the material used in the installation damage specimen. Note: the dimensions of the installation damage specimen and control specimen are identical and should have an equal number of scheduled retrievals.

3.2 Installation damage test procedure

To initiate the testing, the subgrade was prepared and compacted using the vibratory compactor. Five steel plates are taken and the dimension of each plate is as follows 2m in length and 1.5m wide. The steel plates are equipped with steel chains and placed over the subgrade(Nikbakht et al. 2006). A layer of 200 mm thick soil/aggregates was then placed over the steel plates and then well compacted using the 10ton vibratory compactor. Five samples of geogrids, each of dimension 2m x 1.5m are placed over the compacted soil exactly where the steel plates were placed(Diederich 2000). The geogrids are placed in a way such that the machine direction of the geogrids is perpendicular to the direction of the compaction which represents the actual practice carried out in a reinforced soil structure. To complete the installation, a layer of 200 mm thick soil/aggregates was placed over the geogrids and compacted with the vibratory compactor. The compaction is done using a tandem steel-wheeled roller with vibration capability. Ten full roller passes are allowed to simulate the effective compaction as per the site conditions.

3.3 Exhuming the samples

After the completion of the testing, the samples shall be exhumed within 48 hours after the installation. To collect the exhumed samples, the soil/aggregate layer over the geogrids was carefully removed by lifting the steel plate to 45 ˚with the help of lifting chains attached to the steel plates. Particular care is taken that there is no further damage to the geogrids while extraction. Exhumed samples shall be handled and stored in such a manner to eliminate, or minimize, further damage or degradation by exposure to ultraviolet light.

3.4 Gradation of the backfill material

As pet ASTM D5818 specifications geo-textiles are exposed to the soil/aggregates of three different gradations. Soil types used in the tests are sandy gravel (BBA-1), gravelly sand (BBA-2), and silty sand (BBA-3) and are presented in Table.2 (Hufenus et al. 2005; Atmatzidis et al. 2009; Bathurst et al. 2011).

Table 2. Soil aggregate gradation for installation damage test

Installation DamageSoils / Aggregate gradation			
Sieve Size (mm)	Percentage Finer (%)		
	BBA-1 (Sandy Gravel)	BBA-2 (Gravelly Sand)	BBA-3 (Silty Sand)
75	100	100	100
65	99.60	100	100
37.5	85.78	100	100
26.5	-	100	100
19	69.48	100	100

Installation DamageSoils / Aggregate gradation			
Sieve Size (mm)	Percentage Finer (%)		
	BBA-1 (Sandy Gravel)	BBA-2 (Gravelly Sand)	BBA-3 (Silty Sand)
9.50	52.32	99.6	100
4.75	38.74	93.7	96.1
1.70	-	65.5	74.5
0.6	13.23	21.3	40.6
0.425	-	14	32.4
0.3	11.05	6.5	21
0.15	2	0.9	4.1
0.075	0	0.4	1.1
USCS Classifi cation	GP	SP	SM
	Poorly graded gravels with little or no fines	Poorly graded sands with little or no fines	Silty Sand

3.5 Tensile strength test

The collection of exhumed samples and tensile strength tests should be conducted within 48 hours after the installation. The tensile strength test can be conducted as per the ASTM D6637-1 2016 Method A. Tensile strength test results for the both control specimen and exhumed specimens gives the reduction factor i.e., the installation damage factor.

4. Conclusion

It is concluded from the literature review that an installation damage test is necessary for the geotextiles since it will evaluate the damage factor of the geo-textiles.

In India, IRC SP 102 provided the importance of the installation damage tests for the geo-textiles. The installation damage test is one of the most sophisticated tests to be conducted on the geo-textiles and it is observed that test facilities are limited due to the complications in performing the test. Nowadays many geotextile industries, contractors, and agencies are willing to perform the installation damage test to evaluate the damage factor criteria of the geo-textiles because this will estimate the long-term performance of the geo-textiles. At the BTRA the test facilities will be developed to conduct the installation damage test as per the standard specifications. It is seen from many researchers that the installation damage is invertible however, it can be minimized to a greater extent by following standard operating procedure and careful supervision.

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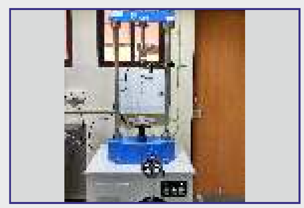




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