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Influence of mechanical damage induced in laboratory on the soil-geosynthetic interaction in inclined-plane shear

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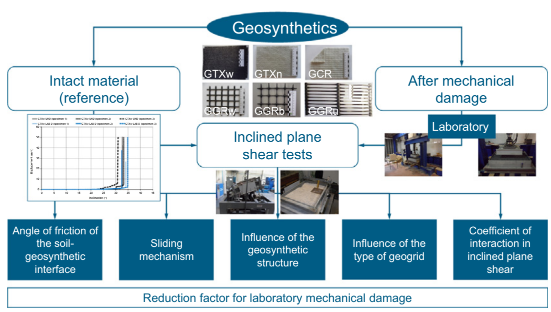
HIGHLIGHTS

- Friction angle of soil-geosynthetic interface increased after mechanical damage.
- Sliding mechanisms not repeatable; progressive slinging more common after damage.
- Planar geosynthetics with interface strength lower than geogrid of similar strength.
- Mechanical damage caused an increase in the skin friction available.
- Reduction factor for tensile strength conservative to represent interface strength.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper contributes to better understanding how mechanical damage associated with installation affects soil-geosynthetic interaction, particularly for inclined plane shear movement. The mechanical damage was induced in laboratory, adapting a standardised procedure to allow for large samples. Six geosynthetics were studied: two geotextiles, one geocomposite and three geogrids. The soil-geosynthetic interface was characterised using inclined plane shear tests. The laboratory mechanical damage affected the soil-geosynthetic interface strength and the sliding mechanisms observed. The results showed that the mechanical damage caused an increase in the skin friction available, due to the damage mechanisms observed. The structure of the geosynthetic affected the inclined plane shear response after mechanical damage. The friction mobilised in the solid area of the geogrids increased after mechanical damage, which depended on the geogrid and on the consequences of mechanical damage. The reduction factors for mechanical damage associated to installation showed that the interface strength did not change significantly. The reduction factor obtained from tensile tests was, in most cases, conservative to represent the changes observed on the soil-geosynthetic interface strength. The structure of the geosynthetics had a higher impact on their tensile response after mechanical damage than on the soil-geosynthetic interface in inclined plane shear. For the interface strength in inclined shear plane movement, the mechanical damage induced in laboratory of the woven geotextile was conservative compared to field installation damage, while for the woven geogrid the mechanical damage induced in laboratory was within the range of damage induced in the field. Despite some heterogeneity of responses, the standardised laboratory tests to induce mechanical damage in laboratory seem to be able to represent the effect of the mechanical damage associated with installation on the inclined plane shear response of soil-geosynthetic interfaces.

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Nomenclature

c'	drained cohesion (Pa)
d	displacement (m)
d_{2kPa}	nominal thickness (m)
d_{long}	thickness of longitudinal ribs (m)
d_{trans}	thickness of transverse ribs (m)
D_{10}	largest particle size in the smallest 10% of the soil particles (m)
D_{50}	largest particle size in the smallest 50% of the soil particles (m)
D_{max}	maximum soil particle size (m)
d_s	displacement of the upper box in the inclined-plane shear test for which the sudden movement of the box occurs (m)
f	soil-geosynthetic coefficient of interaction (–)
$F_r(\beta)$	force required to restrain the empty upper box for an inclination of β (N)
g	acceleration of gravity (m^2/s)
I_D	soil relative density (%)
m_b	mass of the upper box (kg)
m_s	mass of soil in the upper box (kg)
$RF_{LABD,ips}$	reduction factor for mechanical damage obtained from the inclined plane shear tests (–)
$RF_{LABD,tensile}$	reduction factor for mechanical damage obtained from the tensile tests (–)
T_{guide}	tangential component of the reaction of the guidance system (N)
$T_{max\ DAM}$	mean value of the tensile strength of the damaged sample (N/m)
$T_{max\ UND}$	mean value of the tensile strength of the undamaged sample (N/m)
W_s	vertical force acting on the interface (N)
α_o	open fraction of the geogrid (dimensionless)
α_s	solid fraction of the geogrid in the contact with the soil in the upper box (dimensionless)
β	inclination of the upper box in the inclined-plane shear tests, relatively to the horizontal (°)
β_0	inclination angle of the upper box in the inclined-plane shear tests, relatively to the horizontal, at the static limit equilibrium (°)
β_{50}	inclination angle of the upper box in the inclined-plane shear tests, relatively to the horizontal, to a displacement of 50 mm (°)
β_s	inclination angle of the upper box in the inclined-plane shear tests, relatively to the horizontal, for non-stabilized sliding (°)
ϕ'	drained friction angle (°)
ϕ_0	static or initial angle of friction of the soil-geosynthetic interface (°)
ϕ_{50}^{stat}	angle of friction of the soil-geosynthetic interface from EN ISO 1257-2 (BSI, 2005) (°)
ϕ_{50}^{stat} DAM	mean value of the angle of friction for the soil-geosynthetic interface for damaged samples (°)
ϕ_{50}^{stat} UND	mean value of the angle of friction for the soil-geosynthetic interface for undamaged samples (°)
ϕ_{lim}	limit angle of friction of the soil-geosynthetic interface for uniformly accelerated movement (°)
ϕ_{sg}	angle of friction mobilised in the solid area of the geogrid (°)
ϕ_{ss}	angle of friction of the soil (°)
μ	mass per unit area (kg/m^2)
γ	soil unit weight (N/m^3)
γ_c	constant acceleration of the upper box (m^2/s)
CV	coefficient of variation
GCR	geocomposite
GGR	geogrid
GTX	geotextile
HDPE	high density polyethylene
LAB D	damaged in laboratory
UND	undamaged
PET	polyester
PP	polypropylene

1. Introduction

Mechanical damage associated with installation is one of the key durability agents affecting the performance of geosynthetics. Particularly for applications in soil reinforcement, it is common to assess changes in tensile strength of the geosynthetics. However, the soil-geosynthetic interaction is essential for an effective development of the reinforcement mechanisms. Thus, it is important to understand if and how mechanical damage associated with installation influences the soil-geosynthetic interface strength. As inducing installation damage under real conditions is lengthy and expensive, laboratory simulations of that damage may be of use.

In this paper the influence of mechanical damage (associated with installation and induced in laboratory under standardised conditions) on the soil-geosynthetic interface strength in inclined plane shear movement was studied for one soil and six geosynthetics. The soil-geosynthetic interface strength and the sliding mechanisms developing were analysed. For two of the geosynthetics the influence of mechanical damage induced in laboratory on the inclined plane shear response was compared to installation damage induced in field under real conditions.

2. Background

An effective transference of tensile stresses from soil to reinforcements is key for achieving reinforced soil structures with adequate performance. Thus, the soil-geosynthetic interface mechanisms and properties play a fundamental role in the design of reinforced soil structures. The inclined plane shear test is often used to characterise the soil-geosynthetic interaction under low normal pressures corresponding to soil heights above the geosynthetic up to 1.0 m, namely for slopes, such as linings in cover systems of waste disposal areas or erosion control systems [1].

The inclined plane shear test is a standardised procedure [2], which allows determining the angle of friction for the soil-geosynthetic interface by measuring the angle at which a box filled with soil slides when the base supporting the geosynthetic is inclined at a constant rate. This test procedure and its conventional interpretation have been criticised, as they do not capture differences in response commonly observed for both soil-geosynthetic and geosynthetic-geosynthetic interfaces and are non-conservative [3,4]. Additionally, the standardised inclined plane shear test procedure has been criticised because of the way the tests results are interpreted [3,4] but also because of the inclination rate used in the test. According to Briançon [5], the inclination rate of (3.0 ± 0.5)°/min prescribed in the inclined plane shear test standardised procedure [2] influences the responses observed in the tests and recommended a smaller inclination rate (0.5 ± 0.2)°/min. Nevertheless, according to Reyes Ramirez and Gourc [3], the inclination rate has no significant influence of inclined plane shear test results.