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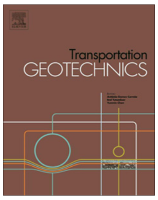

Synergisms between laboratory mechanical and abrasion damage on mechanical and hydraulic properties of geosynthetics

M. Pinho-Lopes [a,*], M.L. Lopes [b,1]

[a] *Faculty of Engineering and the Environment, University of Southampton, Highfield, Southampton SO17 1BJ, United Kingdom*
[b] *Department of Civil Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal*

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ABSTRACT

This paper analyses the existence of synergisms between some endurance durability agents of geosynthetics – mechanical damage (usually associated with installation) and abrasion damage (often associated with cyclic actions, for example due to contact with ballast). Three geosynthetics (geotextile, geogrid and geocomposite) were submitted to mechanical damage and abrasion damage using index laboratory tests. The geosynthetics were exposed first individually to each agent (single exposure) and then sequentially to the two agents (multiple exposures). To ensure the results were statistical representative, each set of tests was performed three times. The consequences of the damage induced were visible (naked eye). Abrasion damage was found the most critical damage mechanism for the tensile properties, particularly for the geogrid and geocomposite tested. The connections between their components created potential fragility points in the abrasion test. Due to its structure, combined with high mass per unit area and thickness, the geotextile tested survived well the damage induced. A positive synergy between the mechanical and the abrasion damage induced was found for the tensile properties of the geosynthetics most affected by damage, more important for their tensile strength than for their secant stiffness. The mechanical damage was the most critical mechanism for the permittivity of the geotextile and the geocomposite, likely due to clogging of their pores. For the permittivity and the characteristic opening size of these geosynthetics, negative synergy between mechanical and abrasion damage was found; the traditional approach was found likely to result in unsafe estimates of these properties.

Introduction

Geosynthetics are often used in transportation engineering applications, replacing traditional construction materials or enhancing them and increasing the sustainability of engineering works. The functions of geosynthetics are drainage, filtration, protection, reinforcement, separation, surface erosion control, barrier and stress relief (EN ISO 10318-1). Although it is common to identify a primary function, in many cases geosynthetics perform two

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Abbreviations: CI, confidence intervals; GCR, geocomposite; GGR, geogrid; GTX, geotextile; PET, polyester; PP, Polypropylene.

[*] Corresponding author. Tel.: +44 (0)2380 598363.

E-mail addresses: M.Pinho-Lopes@soton.ac.uk (M. Pinho-Lopes), lcosta@fe.up.pt (M.L. Lopes).

[1] Tel.: +351 5081564; fax: +351 5081446.

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Notation

Basic SI units are given in parentheses

d_{90}	particle size for which 90% of the mass fraction is smaller than the mass of measured particles (m)
$J_{\text{sec 2\%}}$	secant tensile stiffness modulus at 2% of strain (N/m)
$J_{\text{sec 2\% res}}$	residual secant tensile stiffness modulus at 2% of strain (dimensionless)
n	size of the sample
O_{90}	characteristic opening size (m)
$O_{90\ \text{nom}}$	nominal characteristic opening size (m)
$O_{90\ \text{res}}$	residual characteristic opening size (dimensionless)
RF	reduction factor (dimensionless)
$RF_{\text{Jsec2\%}}$	reduction factor for the secant tensile stiffness modulus at 2% of strain (dimensionless)
RF_{O90}	reduction factor for the characteristic opening size (dimensionless)
RF_{ψ}	reduction factor for the permittivity (dimensionless)
RF_{Tmax}	reduction factor for the tensile strength (dimensionless)
R_Y	residual value of property Y (%)
$t_{1-(\frac{\alpha}{2})}$	t-Student distribution
t_{nom}	nominal thickness (m)
T_{nom}	nominal peak tensile strength (N/m)
T_{max}	maximum tensile strength (N/m)
T_{res}	residual tensile strength (dimensionless)
VI_{H50}	water flow velocity for a head loss of 50 mm (m/s)
Y_{dam}	mean value of property Y for the damaged sample
Y_{und}	mean value of property Y for the undamaged sample
$\bar{x}$	population mean
α	level of significance
ε_{nom}	nominal strain at break (dimensionless)
ε_{f}	strain at break (dimensionless)
ε_{res}	residual strain at break (dimensionless)
σ	standard deviation
ψ	permittivity (s^{-1})
ψ_{nom}	nominal permittivity (s^{-1})
ψ_{res}	residual permittivity (dimensionless)
μ_{nom}	nominal mass per unit area (kg/m^2)

or more functions simultaneously. Geosynthetics are designed for all those functions, considering their hierarchy. Durability of geosynthetics is one of the key issues affecting their performance and includes (Koerner, 2005): degradation (oxidation, ultra-violet radiation, hydrolysis and chemical and biological agents) and endurance (installation damage, creep, stress relaxation, abrasion and compressive creep). Several studies have focused on the beneficial effect of using geosynthetics in transportation engineering (for example, Hussaini et al., 2015; Chen et al., 2014, 2012; Indraratna et al., 2014, 2013). Examples of such favourable effects include: providing additional lateral confinement of aggregates, reducing settlements, increasing stiffness, reducing rutting, providing drainage and filtering fine particles. However, during service the geosynthetics properties may differ significantly from their initial values. Therefore, understanding how functional properties of geosynthetics are affected by the endurance durability agents and mechanisms is essential to achieve realistic and economic designs.

This paper focus on two endurance durability factors: mechanical damage and abrasion damage. Mechanical damage resulting from installation procedures (which encompass handling and placing the geosynthetics and compaction actions associated with the placement of fill material) can considerably affect the performance of geosynthetics. Such damage is relevant to most applications of geosynthetics and its effects on relevant functional properties of geosynthetics (mechanical and hydraulic) need to be quantified. For some applications, where there is cyclic relative motion (friction) between the geosynthetic and contact soil during service, abrasion is relevant. The synergy between mechanical and abrasion damage on properties of geosynthetics are yet to be studied extensively. Some authors (e.g., Greenwood et al., 2012) point out the high scatter associated with relevant properties of geosynthetics after damage (usually after one mechanism only) and the need to increase the number of specimens tested.

The mechanical damage associated with installation depends on the geosynthetic (its structure and nature of the constituent polymer; Hufenus et al., 2005), fill material (grain size, angularity, thickness of layers), procedures and construction equipment and climatic conditions (Watn and Chew, 2002). Adequate selection of the material and control of the installation conditions can minimise the mechanical damage induced during installation. Nevertheless, often such damage cannot be avoided.

The consequences of installation damage on the mechanical properties of geosynthetics have been studied using field damage tests (Pinho-Lopes and Lopes, 2013; Lim and McCartney, 2013; Bathurst et al., 2011; Hufenus et al., 2005; Bräu, 1998; Allen and Bathurst, 1994); mechanical damage due to installation has been simulated using laboratory tests (ENV ISO 10722-1 or EN ISO 10722); correlations between those two types of tests have also been attempted (Pinho-Lopes and Lopes, 2013 and Huang and Wang, 2007). According to Huang and Wang (2007), using an aggregate similar to that of the project and changing the cyclic load intensity, the standard laboratory test ENV ISO 10722-1 could properly simulate field installation damage. Pinho-Lopes and Lopes (2013) concluded that, for the set of materials and conditions considered, the laboratory damage tests was more severe than the field trials.