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Damage induced by recycled Construction and Demolition Wastes on the short-term tensile behaviour of two geosynthetics

Castorina Silva Vieira *, Paulo M. Pereira

University of Porto – Faculty of Engineering, Department of Civil Engineering, R. Dr. Roberto Frias, 4200-465 Porto, Portugal

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ABSTRACT

Geosynthetics have been used as a reinforcement material in roadways and railways construction. Notwithstanding, one of the main questions of using is their durability. The damage caused by the mechanical actions during installation and the chemical and biological degradation are important issues to consider in the physical, mechanical and hydraulic behaviour of geosynthetics. The change in their properties induced by these degradation processes can compromise the performance of these materials. In order to study the chemical and environmental degradation induced by a recycled Construction and Demolition Waste (C&DW) on the short-term tensile behaviour of two geosynthetics (a uniaxial HDPE geogrid and a nonwoven PP geotextile reinforced with PET yarns) used commonly as reinforcement material, a damage trial embankment (2 m × 3 m in plan) was constructed. This paper presents and discusses the effects produced by the recycled C&DW on geosynthetic samples exhumed after 6 months of the embankment construction. The constituents and the leaching behaviour of the recycled C&DW are presented. Wide width tensile tests were performed on exhumed and intact (as-received) geosynthetics and their tensile behaviour is compared. Scanning electron microscope (SEM) images of intact and exhumed specimens are also presented. As expected the degradation induced by the recycled C&DW after 6 months of exposure is not very expressive. On the HDPE geogrid the recycled C&DW induced a small decrease on the tensile strength and the reduction of the tensile stiffness modulus. The geocomposite experienced some reduction on the tensile strength (16% on average) but the effects on tensile stiffness and shape of the load–strain curves were not significant.

Introduction

Granular materials are commonly used in civil engineering applications, such as embankments, retaining walls, road bases and railway ballast. In addition, over the last years the environmental sustainability has been demanding a progressive increase in the waste recycling in general and in the waste valorisation in construction industry, in particular. Some studies and applications of recycled Construction and Demolition Materials (C&DM) have been performed in recent years, mainly related to the production of aggregates for use in concrete and in base and sub-base layers of transportation infrastructures (Jiménez et al., 2012; Arulrajah et al., 2013a; Rahman et al., 2013, 2015).

Construction and Demolition materials have been found to be viable alternative materials in applications such as

* Corresponding author. Tel.: +351 225081586; fax: +351 225081446.
E-mail address: cvieira@fe.up.pt (C.S. Vieira).

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Notation

J	geosynthetic axial stiffness (kN/m)
$J_{2\%}$	secant stiffness modulus at strain of 2% (kN/m)
J_{Tmax}	secant stiffness modulus at ε_{Tmax} (kN/m)
RF_{ID}	installation damage reduction factor (dimensionless)
RF_{CR}	creep reduction factor (dimensionless)
RF_D	durability reduction factor (dimensionless)
RF_W	reduction factor for weathering (dimensionless)
RF_{CH}	reduction factor for chemical/environmental effects (dimensionless)
R_T	retained tensile strength (dimensionless)
R_ε	retained peak strain (dimensionless)
$R_{J2\%}$	retained secant modulus at 2% of strain (dimensionless)
T	load per unit width (kN/m)
T_{al}	available long-term tensile strength (kN/m)
T_{max}	geosynthetic tensile strength or maximum tensile force (kN/m)
T_{nom}	nominal tensile strength of geosynthetic (value declared by the producer) (kN/m)
T_{ult}	ultimate tensile strength (kN/m)
ε	geosynthetic strain (dimensionless)
ε_{Tmax}	geosynthetic strain for T_{max} (dimensionless)

pavement sub-bases and other road construction applications (Arulrajah et al., 2013a). However, the properties of these alternative materials are not well understood compared to natural quarried materials, and, hence, their usage continues to face many barriers (Arulrajah et al., 2013b).

Geosynthetics, particularly geogrids and high strength geotextiles, are used as a reinforcement material in various geotechnical engineering applications such as roads and railway embankments. Consequently, the assessment of their behaviour during and after exposition to recycled C&DM is an important research issue to overcome the barriers on the usage of recycled aggregates.

The durability is one of the main questions on the use of geosynthetics in ground applications. The damage caused by mechanical actions during the installation and the chemical and the biological degradation are important issues to be considered in the behaviour of these materials. The changes in their physical, mechanical and hydraulic properties, induced by these degradation processes, can control the performance of the structures where these materials are used.

The available long-term tensile strength of a geosynthetic (AASHTO, 2012; FHWA, 2010), T_{al}, or the design strength for the ultimate limit state (BS 8006, 2010), can be estimated as:

$$T_{al} = \frac{T_{ult}}{RF_{ID} \times RF_{CR} \times RF_D} \quad (1)$$

where T_{ult} is the ultimate tensile strength (per unit width) determined according to the standards (ASTM D6637-11; ASTM D 4595; EN ISO 10319), RF_{ID} is the installation damage reduction factor (that accounts for the damaging effects of placement and compaction of soil or aggregate over the geosynthetic during installation), RF_{CR} is the creep reduction factor (that accounts for the effect of creep resulting from long-term sustained tensile load applied to the geosynthetic) and RF_D is the durability reduction factor (that accounts for the strength loss caused by chemical and biological degradation of the polymers used in the geosynthetic). Instead of the durability reduction factor, RF_D, the British Standard (BS 8006, 2010) considers two reduction factors: a reduction factor for weathering, RF_W, and a reduction factor for chemical/environmental effects, RF_{CH}.

Over the last years several field studies regarding the installation damage of geosynthetics have been performed (Hufenus et al., 2005; Lim and McCartney, 2013; Pinho-Lopes and Lopes, 2014; Troost and Ploeg, 1990; Watts and Brady, 1990, 1994). They have shown that the type of geosynthetic, the weight, type and number of passes of the compaction material, the gradation and angularity of the fill influence the level of damage. The results presented by Watts and Brady (1990) revealed that the tensile strength and the elongation at break were both substantially reduced by the damage during installation but the Young's modulus was largely unaffected. Troost and Ploeg (1990) also found that the shape of the load–strain curve remains almost identical after installation damage, provided that not too many yarns were broken. More recently, the results reported by Hufenus et al. (2005) have also shown that the slope of the load–strain curve was not largely affected by the installation damage even when the maximum tensile strength and elongation at break decreased.

Based on data from controlled installation damage trials reported in the literature, Allen and Bathurst (1994) concluded that the initial modulus of the load–strain curves may or may not be shifted and the modulus of some materials does not change and in some cases appears to be slightly greater after exhumation.

Chemical and biological degradation has been studied mainly on geosynthetics used in landfill barrier systems. A review on the degradation and field long-term of HDPE geomembranes was presented by Rowe and Sangam (2002). Based on examination of both laboratory and field data, Rowe and Sangam (2002) have concluded that the projected service lives of HDPE geomembranes may range from many centuries to less than a decade, depending on the material and exposure conditions.

The oxidation degradation of geosynthetic in field conditions is affected by the temperature, oxygen partial pressure and chemical constituents of the surround media (pH, transition metal ions, etc.) (Hsuan et al., 2008). Temperature plays the most critical role of all physical and chemical processes. The oxidation mechanism is governed by the transport processes of oxygen which are all strongly temperature dependent. The available oxygen concentration in the environment surrounding the