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Effects of the loading rate and cyclic loading on the strength and deformation properties of a geosynthetic

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HIGHLIGHTS

- The tensile behaviour of a geosynthetic (PP nonwoven geotextile reinforced with high strength PET yarns) was investigated.
- The axial stiffness of the geosynthetic increased with loading frequency and number of loading cycles.
- Previous cyclic loading did not induce a significant reduction of the geosynthetic tensile strength.

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ABSTRACT

The paper describes monotonic and cyclic load-extension tensile tests performed on a geocomposite used as soil reinforcement material. The effects of the loading rate and cyclic loading on the geocomposite behaviour are important to improve numerical codes. This study showed that the damping ratio tends to decrease, while the stiffness tends to increase, with the loading cycles. The unload and reload stiffness are not very sensitive to the loading frequency, for the range of values analysed. The damping ratio tends to decrease with frequency of loading. Previous cyclic loading did not induce significant reduction of the geosynthetic tensile strength.

1. Introduction

Geosynthetics are polymeric materials that are specially fabricated to be used in geotechnical, geoenvironmental, hydraulic and transportation engineering applications. Geosynthetics can be classified into categories based on method of manufacture as geotextiles, geogrids, geomembranes, geonets, geocomposites, geosynthetic clay liners, geocells, geopipes and geofoams. The present paper refers to a geocomposite that combines the functions of reinforcement and drainage, being suitable to reinforced soil structures constructed with cohesive fills and road or railway applications.

When a geosynthetic is used to reinforce a geotechnical structure, its main function is to resist tensile stress not supported by the soil and, simultaneously, to reduce deformations. The use of geosynthetics as reinforcement elements of granular backfills has been widely used. However the use of fine grained soils, often referred as marginal fills, is not recommended by international guidelines and standards [1] since they are susceptible to reduction in strength due to pore water pressure generation.

The use of locally available soils has cost benefits and sustainable gains. Some studies [2,3] have shown that in many cases excess pore water pressure is not generated and when the fill is compacted close to the optimum moisture content, the reinforced structure contains significant suctions (negative pore water pressures). The research shows that, in order to utilise wet cohesive fills, there is a need for a geosynthetic that provides both drainage and reinforcement functions [4]. The geocomposite selected for the present study meets this requirement.

Geosynthetic reinforced soil structures are being used in a wide range of applications such as retaining structures and infrastructures. These structures are subjected to various loading conditions including repeated or cyclic loads. The geosynthetic properties used for the design of reinforced soil structures under dynamic or seismic loading are typically based on the results of monotonic load-extension tests or creep tests. According to several authors [5–8] the strength and stiffness of polymeric materials are

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Nomenclature

D	damping ratio (dimensionless)
f	loading frequency (Hz)
J	geosynthetic axial stiffness (kN/m)
J_0	initial tangent stiffness (kN/m)
J_1	stiffness of the primary loading (kN/m)
$J_{5\%}$	secant stiffness at strain of 5% (kN/m)
J_{reload}	reload stiffness (kN/m)
J_{Tmax}	secant stiffness at ε_{Tmax} (kN/m)
J_{unload}	unload stiffness (kN/m)
T	load per unit width (kN/m)
T_{max}	geosynthetic tensile strength or maximum tensile force (kN/m)
$T_{max,cyc}$	geosynthetic tensile strength after cyclic loading (kN/m)
T_{nom}	nominal tensile strength of geosynthetic (value declared by the producer) (kN/m)

Greek letters

ε	geosynthetic strain (dimensionless)
$\dot{\varepsilon}$	strain rate (%/min)
ε_{cum}	cumulative strain (dimensionless)
$\varepsilon_{max,cyc}$	maximum strain recorded during cyclic loading (dimensionless)
ε_p	plastic strain (dimensionless)
ε_{Tmax}	geosynthetic strain for T_{max} (dimensionless)

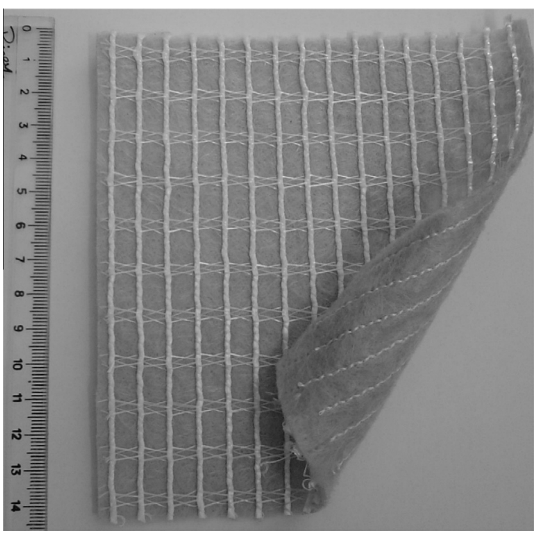

Fig. 1. Visual aspect of the geocomposite (ruler in centimeters).

sensitive to strain rate, so it should be expected that the behaviour of these materials under repeated loads could be more complex.

The standard tests used typically for load-extension geosynthetics characterization (EN ISO 10319 [9], ASTM D 4595-11 [10]) do not describe the non-linear behaviour of these materials under cyclic loading conditions. Although the common approach in the analysis of geosynthetic reinforced structures under dynamic loads is to ignore the effects of the loading rate on reinforcement properties and to use pseudo-static limit equilibrium methods [11–13], it is important to characterize the cyclic behaviour of geosynthetics and to implement suitable hysteretic models in numerical codes.

Few studies have been conducted to investigate the tensile properties of geosynthetics under cyclic loadings [6,7,14,15]. These studies are mainly related to the behaviour of geogrids. This work aims to improve the knowledge related to the effects of the loading rate and cyclic loading on the strength and deformation properties of a geocomposite suitable for reinforcement of fine grained soils or marginal fills.

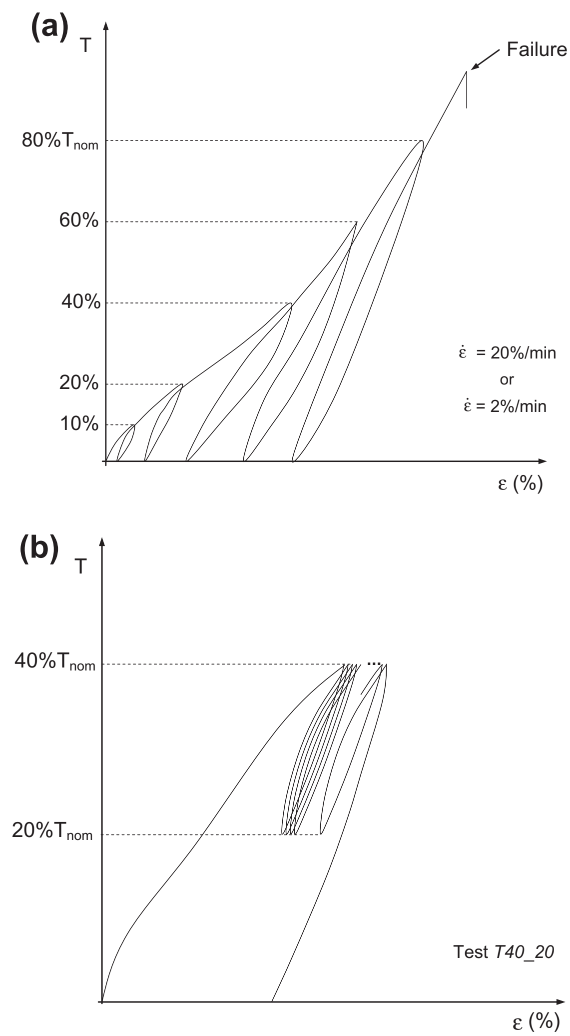

Fig. 2. Schematic examples of cyclic tensile tests: (a) constant strain rate tests and (b) constant load rate test with partial cyclic unloading.

2. Experimental testing program

The material used in this experimental program is a geocomposite reinforcement consisting of polypropylene continuous filament nonwoven geotextile reinforced with high strength polyester (PET) yarns, with nominal tensile strength of 50 kN/m (value declared by the producer of the material). The spacing of PET yarns is approximately 8.3 mm, which corresponds to 120 yarns per meter of geotextile width (Fig. 1). The geocomposite has a thickness of 2.1 mm and mass per unit area equal to 310 g/m^2.

The tensile strength of the nonwoven geotextile is negligible compared with the strength of PET yarns. This geocomposite combines the functions of reinforcement (PET yarns) and drainage (polypropylene nonwoven geotextile).