Procedia Engineering

Volume 143, 2016, Pages 379–386

Advances in Transportation Geotechnics 3 . The 3rd International Conference on Transportation Geotechnics (ICTG 2016)

Cyclic and Post-cyclic Shear Behaviour of a Granite Residual Soil – Geogrid Interface

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Abstract

The dynamic frictional properties of the soil-geosynthetic interface play an important role in the design and stability analysis of geosynthetic-reinforced soil structures under repeated loadings, such as those induced by compaction, traffic and earthquakes. This paper describes a laboratory study carried out using a large-scale direct shear test device, aiming to investigate the cyclic and post-cyclic behaviour of an interface between a granite residual soil and a biaxial woven geogrid. In the cyclic direct shear tests, the interface was subjected to 40 cycles of sinusoidal displacement, with semi-amplitude and frequency ranging from 1-10 mm and 0.05-0.5 Hz, respectively. To evaluate the effect of the cyclic loading on the interface shear strength, monotonic direct shear tests were performed immediately following the cyclic tests. The results indicated that the loading frequency has little impact on the interface shear stiffness during the loading cycles. In contrast, the influence of the displacement semi-amplitude on the interface stiffness was found to be significant. The cyclic loading did not lead to the degradation of the post-cyclic interface shear strength. The post-cyclic peak shear strength tended to increase with the semi-amplitude of the shear displacement, which may be associated with an increase in soil density.

Keywords: Soil-geosynthetic interface, direct shear test, cyclic/post-cyclic shear behaviour, interface shear stiffness, semi-amplitude, frequency, granite residual soil

1 Introduction

The understanding of the soil-geosynthetic interface behaviour under cyclic loading conditions is essential for the design and stability analysis of geosynthetic-reinforced soil structures subjected to repeated loadings, such as those resulting from compaction, traffic and earthquakes. Over recent decades, many researchers have investigated static shear properties of soil-geosynthetic interfaces through direct shear tests (Bergado et al. 1993; Abu-Farsakh et al. 2007; Liu et al. 2009; Ferreira et al. 2012, 2013, 2015). In contrast, experimental data concerning the behaviour of such interfaces under cyclic loading conditions is very scarce (O'Rourke et al. 1990; Ling et al. 2008; Vieira et al. 2013).

Selection and peer-review under responsibility of the Scientific Programme Committee of ICTG 2016

doi:10.1016/j.proeng.2016.06.048

In the seismic design of geosynthetic-reinforced soil structures, it is common to use the interface shear strength evaluated under monotonic conditions to analyse the sliding stability along the interface between the geosynthetic and the reinforced fill or the foundation. The Federal Highway Administration (FHWA) suggests the use of the interface friction coefficient, determined from soil-geosynthetic direct shear tests in accordance with ASTM D 5321, in sliding stability analyses of geosynthetic-reinforced soil retaining walls under static or seismic conditions. However, there are few previous experimental studies showing that under dynamic loading no reduction occurs in the soil-geosynthetic interface shear strength.

In this study, the cyclic and post-cyclic shear behaviour of an interface between a granite residual soil and a biaxial woven geogrid was investigated through large-scale direct shear tests. The influence of soil density, displacement amplitude and loading frequency on the interface shear stiffness was evaluated and discussed. The effect of the cyclic loading on the interface shear strength was assessed by comparing the results from monotonic direct shear tests carried out immediately after the cyclic tests with those obtained from monotonic tests on fresh specimens.

2 Experimental Research

2.1 Direct Shear Test Device

The large-scale direct shear test device used in the present study (Figure 1) was developed during previous research at the University of Porto (Vieira et al. 2013). The device allows the analysis of the direct shear behaviour of soils, soil-geosynthetic and geosynthetic-geosynthetic interfaces under monotonic and cyclic loading conditions.

The apparatus is composed of a shear box, divided into upper and lower boxes, a support structure, five hydraulic actuators and respective fluid power unit, an electric cabinet and several internal and external transducers. The inner length, width and thickness of the upper and lower boxes are 600 mm × 300 mm × 150 mm and 800 mm × 340 mm × 100 mm, respectively. The upper box is fixed in the horizontal direction and vertically moveable through hydraulic actuators installed on its edges. The lower box is rigidly fixed to a mobile platform running on low-friction linear guides and its horizontal displacement is controlled by a hydraulic actuator. The normal stress is applied by a rigid plate with pressure-controlled double acting linear actuators and recorded by a pressure transducer. The shear force applied in the lower box is measured by a load cell and its horizontal movement is recorded by an internal displacement transducer. More details about the direct shear test device and a description of the test procedures may be found in Ferreira et al. (2015).

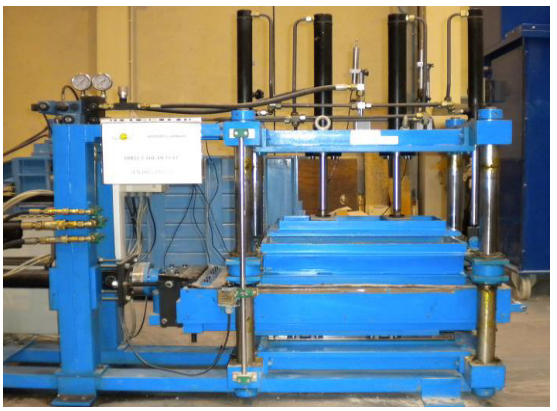

Figure 1: Direct shear test device