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Experimental studies of the geosynthetic anchorage – Effect of geometric parameters and efficiency of anchorages

S.H. Lajevardi [a,1], L. Briançon [b,2], D. Dias [c,*]

[a] University of Qom, Bvd. Amin, Qom, Iran
[b] Cnam Paris, 2, rue Conté, 75003, Paris, France
[c] Grenoble Alpes University, LTHE, Grenoble, France

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A B S T R A C T

The soil reinforcement by geosynthetic is widely used in civil engineering structures: embankments on compressible soil, slope on stable foundations, embankments on cavities and retaining structures. The stability of these structures specially depends on the efficiency of the anchors holding the geosynthetic sheets. Simple run-out and wrap around anchorages are two most commonly used approaches. In order to improve the available knowledge of the anchorage system behaviour, experimental studies were carried out. This paper focuses on a three-dimensional physical modelling of the geosynthetics behaviour for two types of anchors (simple run-out and wrap around). The pull-out tests were performed with an anchorage bench under laboratory controlled conditions with three types of geosynthetic (two geotextiles and one geogrid) and in the presence of two types of soil (gravel and sand).

The results show that there is an optimum length for the upper part of the geosynthetic for the wrap around anchorage.

1. Introduction

Presently, geosynthetics are utilised as reinforcing elements in a wide variety of structures: reinforced slopes and walls, embankments on soft soils, reinforcement in the base layers of railroads and road constructions, bridging over sinkholes or reinforced abutments. These structures may also present different behaviours according to the reinforcement type, the soil type and the anchorage system type. Extensibility, disposition and shape of reinforcements lead to behaviour more or less complex in terms of deformation and strength. Geotechnical characteristics of the soil have an influence on the stress distribution between the reinforcements and the adhesion at the soil/reinforcement interface. Configurations of anchorages also have an influence on the anchorage capacity.

The stability and durability of geosynthetics in reinforced earth structure depends partly on the efficiency of the anchors holding the geosynthetic lining. The role of the anchor is to withstand the tension generated in geosynthetic sheets by the structure. In most cases, these reinforced structures need anchoring zones where the friction forces between the soil and the geosynthetic sheet balance the horizontal tensile force induced in the geosynthetic. Depending on the available space and on the applied loads, the anchorage systems can be configured using different shapes: simple run-out, anchorage on trenches with different geometries and anchorage with wrap around. The geosynthetic sheets are often installed in trenches, with a L-shape, V-shape or U-shape (Fig. 1), to optimise the dimensions of the anchor zone (minimal horizontal area occupied) and to ensure effective anchorage. The interest of the wrap around anchorage is to reduce the anchorage zone (Fig. 2). These anchorages are often oversized because of the absence of detailed knowledge about the developed mechanisms. Designing the required sizes of these anchorages remains then problematic.

In order to size the system, it is necessary to estimate the tension that can be mobilised in the anchor (anchorage capacity) according to its geometry and the properties of the constituent materials.

In order to improve the knowledge about the behaviour of different kinds of anchorage, experimental and numerical studies were developed jointly (Briançon, 2001; Briançon et al., 2008; Chareyre, 2003; Chareyre et al., 2002; Chareyre and Villard, 2004; Girard et al., 2006; Lajevardi et al., 2012a,b; Lajevardi, 2013).

* Corresponding author. Tel.: +33(0) 4 76 82 79 31.
E-mail addresses: h.Lajevardi@qom.ac.ir (S.H. Lajevardi), laurent.briancon@cnam.fr (L. Briançon), daniel.dias@ujf-grenoble.fr, d.dias69@gmail.com (D. Dias).
[1] Tel.: +98(0) 91 28 52 19 75.
[2] Tel.: +33(0) 1 40 27 21 10.

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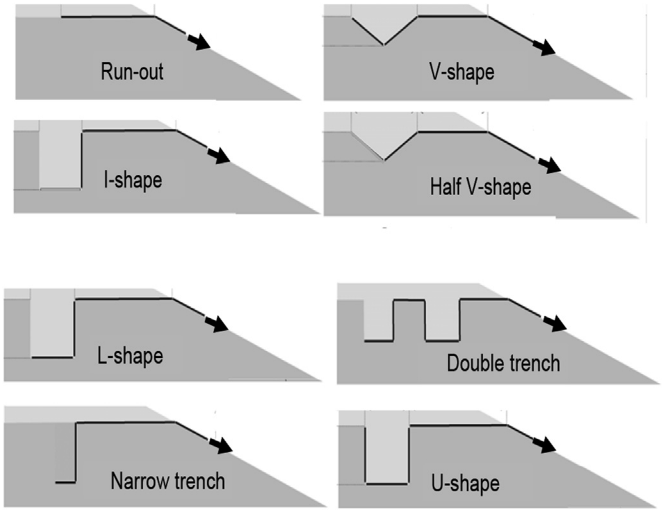

Fig. 1. Different types of anchors trenches.

In the case of experimental studies and after a review of the literature concerning equipment and experiments, the pull-out test is the most suitable test to determine the soil/geosynthetic interface under low and high confinement stress. They also permit to model the anchorage systems for determining their anchorage capacity and to analyse the different mechanisms relating such systems. The pulling out of geosynthetics, conducted under controlled and instrumented conditions will help to establish the difference in behaviour between different anchorage systems.

Several authors have been interested in this type of test to determine the interaction parameters of different types of reinforcements (Abdelouhab et al., 2010; Alfaro et al., 1995; Chang et al., 1977; Fannin and Raju, 1993; Farrag et al., 1993; Koerner, 1994; Lopes and Ladeira, 1996; Moraci et al., 2004; Moraci and Recalcati, 2006; Ochiai et al., 1992; Palmeira and Milligan, 1989; Raju, 1995; Sugimoto et al., 2001).

These authors carried out several tests on different types of extensible reinforcements and different devices.

A review of the literature (Abdelouhab et al., 2010, Bakeer et al., 1998, Goodhue et al., 2001, Lajevardi et al., 2013, Lopes and Ladeira, 1996, Moraci and Recalcati, 2006, Ochiai et al., 1996, Pinho-Lopes et al., 2006, Sieira et al., 2009, Sugimoto et al., 2001, Sugimoto and Alagiyawanne, 2003, Wilson-Fahmy et al., 1994) concerning the laboratory pull-out tests shows that:

- Most of the boxes are of rather rectangular shape, their size (length × width) varies between 0.4 × 0.25 and 2 × 1.10 m. Large scale tests should be preferred, particularly due to the fact that increasing the test scale will reduce the boundaries effect.
- In most of the cases, the sample sizes are smaller than the box sizes.
- Many types of soil were used: sand, gravel, clay and lightweight soils.
- Several types of geosynthetics were used with tensile strengths between 6.2 and 200 kN/m: geotextile, geogrid, geocomposite and synthetic strip.
- Pull-out rate varies between 1 and 22 mm/min but most of the tests were performed with a standard rate of 1 mm/min.
- The confinement stress ranges from 5 to 200 kPa and can simulate an embankment or a slope with a height between 0.25 and 10 m.

Available experimental models show that:

- Most of the physical tests were carried out for the anchorage trenches,
- There is no complete experimental study on the geosynthetic behaviour with a wrap around anchorage.

In order to study the capacity and the behaviour of geosynthetics for two different anchoring systems (simple run-out and wrap around) and to analyse the physical mechanisms, a set of instrumented pull-out tests in the presence of two types of soil and of three types of geosynthetic is carried out. Different anchorages geometries are tested under low confinement stresses. This paper describes the effect of geometric parameters of the trench and the efficiency of anchorages.

2. Pull-out tests

The anchoring behaviour of a geosynthetic sheet under tension is studied experimentally. The reinforcement was equipped with force and displacement sensors and was set in a box filled with soil. Two physical quantities were monitored: Head geosynthetic tensile force and displacements at different locations in the reinforcement.

2.1. Description of the physical model

2.1.1. Experimental box

The pull-out tests were carried out with an experimental device consistent with the standards recommendations ASTM D6706-01 (2007) and EN 00189016 (1998). This physical model (Fig. 3) consists of a 1.10 m wide, 1.10 m depth and 2.00 m long box. The traction system is fixed onto the geosynthetic (geotextile or geogrid) with a metallic clamp located in a guidance box inside the metallic box (supposed to be indeformable). The tensile force (applied on the 0.5 m width geosynthetic sheet) and the displacements of the metallic clamp and the anchorage area are monitored during the pulling out test.

2.1.2. Studied soil materials

The soils studied in these tests are a fine sand (Hostun RF: Flavigny et al., 1990; Gay, 2000) and a coarse soil (gravel 0/31.5 according to the USCS classification procedure). This classification

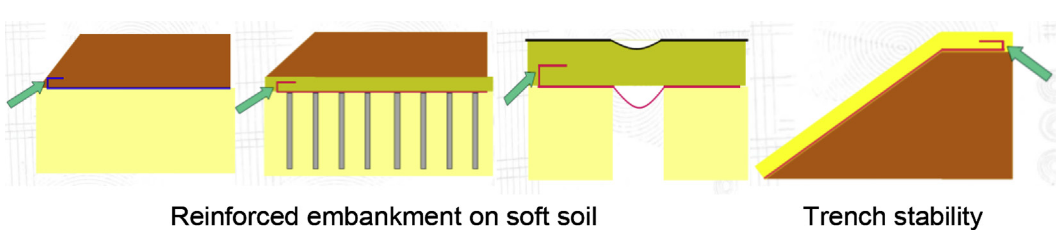

Fig. 2. Different applications of wrap around anchorage.