Procedia Engineering

Volume 143, 2016, Pages 419–426

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

Investigation of the Mechanical Behaviour of the Interface between Soil and Reinforcement, via Experimental and Numerical Modelling

Elena Kapogianni[1*], Michael Sakellariou[1†], Jan Laue[2‡] and Sarah Springman[3‡#]

[1]*National Technical University of Athens, Athens, Greece.*

[2]*Luleå University of Technology, Luleå, Sweden.*

[3] *ETH Zürich, Zürich, Switzerland.*

elkapogianni@gmail.com, mgsakel@mail.ntua.gr, jan.laue@itu.se, sarah.springman@igt.baug.ethz.ch

Abstract

The purpose of this study is to investigate the interface properties between soil and reinforcement, via experimental and numerical modelling of reinforced slopes. In particular, several scale models were built and tested under enhanced gravity in the geotechnical drum centrifuge at ETH Zurich and corresponding prototype numerical models were analyzed via a finite element stress analysis code. Optical fibre sensors were attached on the reinforcement layers of the experimental scaled models in order to measure linear strain during the increase of the g-level, and the results were compared to linear strain that was derived by the numerical analysis of the correspondent prototype reinforced slopes. The interface between soil and reinforcement was expressed in terms of normal and shear stiffness on the soil-reinforcement boundary and different values were tested in order to achieve validation of the experimental and numerical results.

Keywords: Physical Modelling, Numerical Modelling, Centrifuge Model Tests, Reinforced Slopes, Optical Fibre Sensors, Interface Properties

[*] Postdoctoral Researcher
[†] Professor Emeritus
[‡] Chaired Professor
[#] Rector

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

doi:10.1016/j.proeng.2016.06.053

1 Introduction

Reinforced soil slopes are traditionally investigated by applying experimental, numerical and analytical methods with the main goal being to define their behaviour and failure mechanisms due to static and seismic loading. A more comprehensive analysis can be made for reinforced slopes with various geometrical and mechanical characteristics by combining the above methods so that useful conclusions can be derived about the methods applied.

Experimental investigation requires detailed physical modelling of the planned construction and large or small scale models can be built and tested. The main forces that are applied and define the behaviour of soil structures, and reinforced slopes in particular, are those of self-weight. The simple gravity field is often inadequate when small scale models are examined. Numerical modelling in geotechnics requires detailed simulation of the mechanical and geometrical characteristics of the models. Finite element stress analysis is traditionally applied, and special attention should be given to the simulation of the interface between soil and reinforcement for the case of reinforced slopes. Analytical investigation of reinforced slopes is also applied for the design of reinforced slopes that are subjected to static and seismic loading and in order to examine their vulnerability. The analytical methods are based on the limit equilibrium method (Terzaghi, 1943) and on the limit analysis method (Drucker & Prager, 1952), and are applied for the design and evaluation of reinforced slopes (Kapogianni & Sakellariou, 2008).

2 Centrifuge Modelling of Reinforced Slopes

In order to recreate stress and strain due to gravity in a small scale model "1/n", it is necessary to apply "n" times the gravity field. Enhanced gravity can be applied with the help of geotechnical centrifuge technology. Whereas the idea of using a centrifuge originated from Philips (1869), the application as a geotechnical centrifuge came from the 1930s (Pokrovsky & Fedorov, 1936; Bucky, 1931), and many drum and beam centrifuges have been built around the world since then, establishing centrifuge technology as a powerful tool for the experimental investigation of geotechnical constructions (Laue, 2014; Springman, 2014; Craig, 2014 & 2001; Mayne et al., 2009; Schofield, 1980).

For the simulation of the prototype model behaviour in the geotechnical centrifuge, several scaling laws should be taken into account. Such laws have been presented in the past by Schofield (1980) and can be used in order to create models with geometrical and mechanical characteristics similar to those of prototype structures. Also, materials used for the model construction should satisfy the corresponding scaling laws and boundary effects should be minimized (Laue, 2002). Especially for reinforced slopes involving reinforcement layers, difficulties are encountered concerning the choice of materials, mainly because the reinforcements used in prototype constructions are inappropriate for small scale models, since they don't replicate the full-scale stress-strain behaviour and the geometrical conditions at small-scale. Such scaling laws have been presented by Garnier et al. (2007), Viswanadham and Mahajan (2007), Viswanadham et al. (2006), Zornberg et al. (1997), and are applied for the purposes of the current study. The physical modelling of reinforced slopes in the centrifuge has also been studied by Balachandran and Springman (1997) and Springman et al. (1997).

Several scaled wrap-around reinforced sand slope models were built and tested for the current study, under enhanced gravity up to 50g, in the ETH Zurich drum geotechnical centrifuge (Springman et al., 2001), with a facing slope inclination of 2V:1H (63.43°) and a total height of 20 cm (Figure 1a). The soil material used for the models was Perth sand from the west coast of Australia. Perth sand is white, fine grained sand with rounded grains. The angle of deposition is between 31^0 to 33^0 and the diameter of the grains lays between 0.125-0.5 mm. This soil is classified as uniform sand (Nater, 2006). The height of the reinforced soil mass was 18 cm and the wall was built on a 2 cm sand