AN EXPERIMENTAL INVESTIGATION OF PLANT-INDUCED SUCTION AND ITS IMPLICATIONS FOR SLOPE STABILITY

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Landslides pose a threat to the environment and humanity due to possible damages to residential areas, infrastructure, or to ecological goods and services in the aftermath. Therefore, stability of slopes with risks of failure is a major concern for the organisational bodies and people responsible for the protection of human lives, properties and infrastructure against natural hazards[1]. Loss of suction due to increasing saturation ratio, which can result from rainfall, snowmelt or rising groundwater, is one of the main causes of shallow landslides.

An extreme rainfall event in late August 2005 caused considerable damage, and even loss of lives, by landslides, floods and debris flows in large parts of Switzerland. 50 shallow landslides in Praettigau, Switzerland were documented after this event in a database[2], which was used in combination with experiments on the soil procured from one of the documented landslides to investigate how changes in the plant-induced suction affect the shear strength of soil, and the stability of slopes.

An extensive laboratory study was conducted on specimens prepared with different species, represented by grasses, legumes, herbs and trees abundantly found in subalpine grasslands and pastures, and commonly used for eco-engineering measures. The effects of plant growth duration and mycorrhizal fungi on the hydrological and mechanical characteristics of root-permeated soils under partially saturated conditions were investigated by measuring plant-induced suction and performing large-scale direct shear tests.

The shear strength of the root-permeated soils tested in this study was controlled primarily by the plant-induced suction. Furthermore, gravimetric water content of the soil was inversely related to matric suction and shear strength. Root biomass, as well as root:shoot ratio, was negatively correlated with the water content, and positively correlated with matric suction and shear strength. Comparison of different treatments showed that longer plant growth duration, higher number of species, and the inoculation with mycorrhizal fungi increased the mean root biomass, and in turn, means matric suction and shear strength of root-permeated soil.

A total of 300000 Monte Carlo simulations, with 100000 randomly generated data at depth of 0.93, 1.22 and 1.48 m, were made to check which combinations of slope angle and suction stress could be critical to trigger a landslide in the Praettigau region based on infinite slope analysis in partially saturated conditions. Shear strength parameters were taken from the direct shear experiments under saturated conditions, landslide geometry was taken from the landslide database and the suction stresses were calculated based on soil-water retention curve (SWRC) parameters and matric suction measurements[3].

Mean and standard deviation values of FoS were 1.33 ± 0.34, 1.14 ± 0.28 and 1.03 ± 0.24 and the failure percentages out of 100000 simulations were 15.2 %, 34.7 % and 51.4 % with

increasing depth. Figure 1 shows the slope angle – suction stress simulations that yielded an FoS less than 1, and the separation between stable and unstable zones. The solid lines show the fitted second-order polynomials, of which the coefficients are functions of depth.

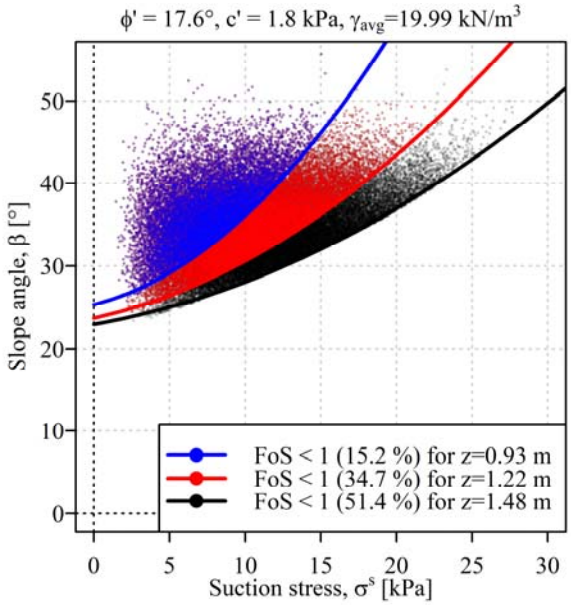

Figure 1: Slope angle and suction stress values of simulations that yielded a factor of safety (FoS) less than 1 for varying depths based on infinite slope analysis under partially saturated conditions. The percentages in the legend show the frequencies of failure out of 100000 simulations.

The outcome of this analysis, i.e. separation of the stable and unstable zones of slope angle – suction stress graph with varying depth, can be used as a quick determination of slope stability tool. It requires the monitoring of volumetric water content or matric suction at different depths, knowledge of the SWRC, determination of the slope angle from geographical information system (GIS) applications or field measurements. The applicability of this method is limited to the Praettigau region, however it can be applied to different locations, if the shear strength parameters of the soil are known, and the fitted distributions of the randomly generated data can be validated.

Keywords: Shallow landslides, direct shear test, plant-induced suction, infinite slope.

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