Discussion

Rainfall Effects on Pore Pressure Changes in a Coastal Slope of the Serra do Mar in Santa Catarina

Discussion by:
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The writers appreciate the contributions the authors of "Rainfall Effects on Pore Pressure Changes in a Coastal Slope of the Serra do Mar in Santa Catarina" made to improving the quality of field observations involving climate/soil interaction, and would like to offer some comments addressed to the authors.

The authors present a very interesting full-scale study carried out in a densely instrumented highway slope in the South of Brazil. The slope had a history of instability movements due to intense rainfall, with debris accumulation on the highway and traffic interruption. Geotechnical instrumentation including vibrating wire piezometers, electrical tensiometers, conventional slope inclinometers, and a rain gauge was installed in the slope.

The authors investigated how rainfall causes changes in the piezometric pore pressure and soil matric suction in the monitored slope from May 2012 to March 2013. Laboratory tests classified the top soil as a silty sand. The analysis of the results showed that, during the field monitoring period, there were no heavy rains (*i.e.*, between 16 and 50 mm/h). Three monitoring periods were identified by the frequency and intensity of rainfalls, and the authors concluded that "the soil pore pressure monitoring instruments showed significant variations in the high frequency period and low intensity rainfall, and little variation in low frequency period and high intensity rainfall".

The writers would like to include additional comments on the influence of rainfall changes on the soil suction distribution observed in soil slopes. The authors mention that tensiometer measurements showed an increase in the soil suction "during the period with less rain and a decrease as the rainfall occurs". It is important to note that the infiltration capacity varies not only with the soil type and frequency and intensity of precipitation, but also with the soil water content condition. If a soil is initially dry, the infiltration capacity is high (Fetter, 1994). In an experimental embankment in the Northeast of France, rainfall events caused significant effects on the soil suction distribution in the initial period of water surplus after a long period of water deficit (Bicalho *et al.*, 2015).

It should also be observed that slope instability is affected by a combination of various factors, including intensity and duration of rainfall, duration of previous rainfall, soil initial conditions, soil permeability (or hydraulic conductivity), vegetation, slope geometry and geographical location. Among these factors, some are more significant than others, and it is not straightforward to weight the effect of any individual factor.

Numerical studies on the effect of soil permeability on soil suction distribution (Pradel & Raad, 1993, and Tsaparas *et al.*, 2002) suggest that less permeable soil slopes may fail after sufficient duration of rainfall, while failure of slopes with comparatively high permeability may take place for shorter-duration and greater-intensity rainfalls. The water hydraulic conductivity function and the water storage function for an unsaturated soil are related to the soil water retention (or characteristic) curve (SWRC), a relationship between the amount of water in the soil and the suction in the pore water. Toll *et al.* (2012) mention that the water unsaturated hydraulic conductivity can drop by 4-5 orders of magnitude relative to the saturated permeability, Ksat, as the soil desaturates. Taibi *et al.* (2009) present experimental results on two fine-grained soils showing that the effective hydraulic conductivity has a small value ($\approx$ 0.05 Ksat) while the degree of saturation is relatively high ($\approx$ 80%). These results are consistent with the measured hydraulic conductivity values reported by Taibi (1994) and Bicalho (1999) for fine-grained soils. As a result, knowledge of the SWRC is fundamental for application of unsaturated soil mechanics into geotechnical problems.

These issues indicate that the rainfall events may not be the only factors to explain the observed variations in soil suction with time at specified depths in the soil slope. Additional measurements of spatial and temporal changes in soil suction and corresponding water content (*i.e.*, the field

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SWRC), as well as in-situ measurements of water hydraulic conductivity functions at predefined locations within the slope, should be continuously made in order to further understand the soil suction responses to natural climatic variations over long term periods.

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