Hydro-mechanical response of bare and root-permeated soil slopes to rainfall: from a multi-scale laboratory research to modelling

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ABSTRACT

To predict the hydro-mechanical behaviour of a vegetated soil slope, it is necessary to understand and quantify all the effects that plants are inducing on the porous media. Soil-roots interactions involve multi-scale and multi-physical processes that are affecting both the macroscopic behaviour of the matrix and the structural-functional features of the root system. For this reason, several mechanical and hydraulic tests at the laboratory-specimen and micro-scales have been carried out on a root-permeated slightly compacted clayey soil. Large-cell direct shear tests have been performed under saturated and partially saturated conditions to quantify the effect of roots on the tensional-deformation behaviour on shearing. Results showed that roots provided a noticeable increase of soil shear strength, even if larger volumetric compressive deformations were recorded as horizontal displacements progressed. Results have been analysed within the context of the shear strength criterion for unsaturated soils with matric suction affecting cohesion . Roots did not affect in a significant way the friction angle, thus results have been only interpreted as an increase of apparent cohesion. Roots geometrical and mechanical traits were assessed to be used within a soil-root reinforcement well-established model, which provided results in good agreement with observations. The hydraulic properties of the clayey soil were evaluated as well, for the same range of porosity as the mechanical tests. Results coming from the analyses of oedometer and permeameter tests evidenced that roots caused an increase of the water saturated permeability, in the order of three times that obtained for bare soil [1]. Retention properties were also affected by roots: in particular, the air-entry value and the suction associated with each water content of a bare soil decreased. All the observations have shown that roots are dramatically modifying the soil structure. To better assess these changes, micro-tomography and mercury intrusion porosimetry testswere carried out at different soil hydraulic states on both bare and rooted soil samples. Reconstructed and joined information concerning pore size distributions evidenced that roots are generally increasing pores with diameters larger than 100 μm, due to fissuring, while reducing smaller porosities due to physical and chemical clogging [1]. This information allowed better understanding macroscopic observations such as water saturated permeability and retention changes, as well as to justify the larger volumetric deformations recorded during root-permeated soil shearing. Results have been used for calibrating the model parameters for soil water retention curves and relative water permeability [2] The parameters obtained from the hydro-mechanical constitutive laws were used to simulate the behaviour of the soil within a slope subjected to rainfall by adopting a limit equilibrium approach. Slope safety factor was evaluated at different hydraulic states, starting from a partially saturated one and until failure occurred within the bare soil under transient hydraulic flow conditions. By comparing results of bare and root-permeated soil slope it was possible to detect the faster response of interstitial pressure increase within the latter case and the drop in the value of the safety factor SF. Throughout the simulation the SF was higher in the case of a soil with plants and it remained higher than the unity even when the hydraulic flux reached the stationary conditions. As a conclusion, roots were proved to be mechanically beneficial for a slope (increasing shear strength), but more attention has to be paid to their hydraulic effects within a stability study of this kind of reinforcement.

REFERENCES

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