Geophysical Research Abstracts
Vol. 12, EGU2010-12591, 2010
EGU General Assembly 2010

Soil-root mechanical interactions within bundles of roots

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Root-soil mechanical interactions play an important role in strength and force redistribution in rooted soil. Recent advances in root reinforcement modeling implement detailed representation of root geometry and mechanical properties as well as root-soil mechanical interactions. Nevertheless, root-soil mechanical interactions are often considered at the single root scale ignoring interactions between neighboring roots and root bundles known to play important role in similar applications such as engineered composite material reinforcement. The objective was to quantify mechanical interactions among neighboring roots or roots network using pullout laboratory experiments and modeling. We focus on the on effects of such interactions on global pull out force of a bundle of roots via better understanding of transmission of radial stresses to soil matrix due to the friction at the interface soil-root. Additionally, we wish to predict how cumulative friction changes along a single root axis with and without branching points during the slipping out. Analytical models of fiber reinforced materials show the magnitude of bonded friction depends on three key parameters: bond modulus, maximal bond strength and difference between the Young moduli of fiber and Young moduli of matrix. Debonded friction is calculated assuming failure follows Coulomb failure that includes apparent cohesion, effective normal stress and residual root soil friction angle. We used a pullout device to measure displacement and force of individual roots and for the bundle of roots. Additionally, we monitored and detected activation of root-soil friction by six acoustic emission sensors placed on waveguide in contact with the soil matrix. Results from experiments with parallel and crossing roots demonstrated the importance of considering factors such as distance of root axis, branching points, crossing of roots and roots diameter for the behavior of bundle of roots and inclined roots during pullout. Acoustic emission measurements provided interesting insights into progressive activation of root-soil friction. These results enhance understanding of root reinforcement mechanism and enable more realistic implementation of root reinforcement modeling for stability calculation of vegetated slopes.