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Fundamental investigations on shear reinforcement of soil by vegetation

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Growing interest in the use of vegetation for stabilising slopes is rooted in its cost-effectiveness, environmental benefits and aesthetics. Although engineers are keen to adopt this approach, they are wary because predicting the influence of vegetation on slope stability is fraught with uncertainty. Previously published work has concentrated on measuring the mechanical reinforcement of vegetation by direct shear testing either in situ or on planted soil tubes in the laboratory. Simple design methods to quantify root reinforcement are based on measured root area ratio (assuming that all the roots in the soil are mobilised) and the breakage strength of the roots (assuming the mechanism of failure is the breakage of the roots across the shear plane). Due to the natural complexity of root systems in soil, however, it is very difficult to untangle the fundamental mechanisms responsible for root reinforcement of soil using these approaches and therefore develop better models. Our research gained greater fundamental insight by investigating key mechanisms individually that control soil reinforcement by roots. The complexity of natural roots was controlled by using root analogues where mechanical behaviour and geometry could be controlled, with the same tests extended to real root systems. Root geometry was controlled by forming analogue roots with different branching patterns and mechanical behaviour was controlled by using different materials. Testing involved examining root-soil composite behaviour through direct shear tests and then the behaviour of individual roots with pull-out tests. Four different types of root-soil interaction test were thus performed: (i) direct shear tests on grown roots in soil; (ii) pull-out tests on grown roots in soil, (iii) direct shear tests on root analogues in soil; and (iv) pull-out tests on root analogues in soil. Tests were

conducted in pots in the laboratory, including the use of 2D axisymmetric tests where movements in the root and soil could be observed through a Perspex face and small scale displacements measured with image analysis (PIV). Data from the tests and image analysis allowed us to determine the key root reinforcement mechanisms. Of particular importance is the combined effect of root orientation, biological distribution, morphological and material properties on the shear behaviour of root-soil composite. These, combined with the interface properties between root and soil, appear to control the level of mechanical reinforcement. This increased understanding suggested design methods which take into account of the appropriate root and soil properties. Finally, the work has emphasised the need for multi-disciplinary studies to fully understand both the engineering and biological issues in the vegetation reinforcement of soil.

Through further investigation using more complex real and analogue model systems that could be quantitatively characterized, we hope to improve the fundamental understanding of soil reinforcement by vegetation using geotechnical approaches extended from soil nailing and piling. Extending the test programme to scaled-down model slopes would provide more information on larger scale and longer term effect of vegetation on slope stability. Future geotechnical centrifuge model slope tests using real and analogue root systems will allow quantification of these effects and provide input parameters for validated slope analysis methods.