Rooting for research

Field trials of vegetated slope behaviour should help designers quantify the effects of vegetation on slope stability, says John Greenwood.

The various effects and influences that vegetation may have on the stability of a slope were illustrated in *Use of vegetation in civil engineering* (CIRIA 1990). The theoretical incorporation of these effects within routine stability equations is relatively straightforward (**Figure 1**).

The difficulty for engineers is in assessing the actual contribution that different types of vegetation may make and defining suitable planting and maintenance regimes to maximise its contribution over the design life of a project. The work requires multidisciplinary skills, with landscape architects and horticultural soil and plant specialists all playing major roles in advising the geotechnical and project engineers during the development of a bio-engineered design.

The design engineer must always recognise the possibility of complete failure of the vegetation

Figure 2. Cutting on the M69 where vegetation may have stabilised sections next to the failure.

and consequent increased risk of slope instability. For this reason, vegetation would not normally be allowed to be the prime factor governing slope stability where the consequences of failure threaten life or property.

There are, however, many natural and formed cutting and embankment slopes adjacent to highway, railway and canal networks where the consequences of failure are not immediately life threatening. Here, appropriate vegetation regimes may be able to provide an additional factor of safety.

To quantify the possible benefits of vegetation, a bio-engineering field trial, sponsored by CIRIA, was set up in 1993 between junctions 7 and 8 of the M20 motorway at Longham Wood cutting, near Maidstone, Kent. Observations and monitoring of the slope continued until 1999 when it was necessary to sacrifice the site for the construction of the Channel Tunnel Rail Link.

This field trial provided an opportunity to investigate the effects of three vegetation types (willows and alder; broom; and forbes and grasses) on both drained and undrained plots on a 1 in 3, slip prone, Gault Clay slope. Results of the trial are given in the forthcoming CIRIA publication PR81 *Bioengineering – Longham Wood Cuttting field trial.*

Results indicated that over the five to six year trial period, soil moisture changes due to the vegetation tended to be masked by the large seasonal moisture changes in the Gault Clay. Similarly, the seasonal water table fluctuations were not noticeably influenced by the presence of the vegetation. The main benefit from the vegetation was in the enhanced shear strength developed by the root reinforced soil.

Research has been carried out at Nottingham Trent University to measure the tensile strength of tree roots in the laboratory, and to measure insitu field strengths by root pull out and plane shear tests on root reinforced soil.

The mechanisms of soil root reinforcement and the general benefits of vegetated slopes in resisting landslides are to be researched in detail at Nottingham Trent as a partner in the major European project, ECOSLOPES, (http://lrbb3.pierroton.inra.fr/ and click on the "ecoslopes" button) funded under the 5th Framework Programme.

A database of parameters relating to typical vegetated slopes will be established to build a national and European reference of case studies to indicate the potential for ground improvements due to the influence of vegetation. It will be appreciated if readers could email john.greenwood@ntu.ac.uk of suitably accessible sloping sites, ideally where instability has occurred or is likely to occur and vegetated sections exist alongside non-vegetated sections in the same geology/soil type.

An example of such a site is shown in **Figure 2**, where a non-vegetated length of cutting at the northern end of the M69 motorway has failed, whereas the vegetated sections either side have remained intact. There may well be other factors that have helped to maintain stability. Detailed studies are clearly required.

Bio-engineering is insufficiently understood to be a routine part of geotechnically engineered slope design. But as our understanding of the effects of vegetation increases, we will be able to apply the techniques to prevent shallow slope failures.

John Greenwood is senior lecturer at Nottingham Trent University, where his research interests are slope stability, earthworks, geosynthetics and bio-engineering techniques.

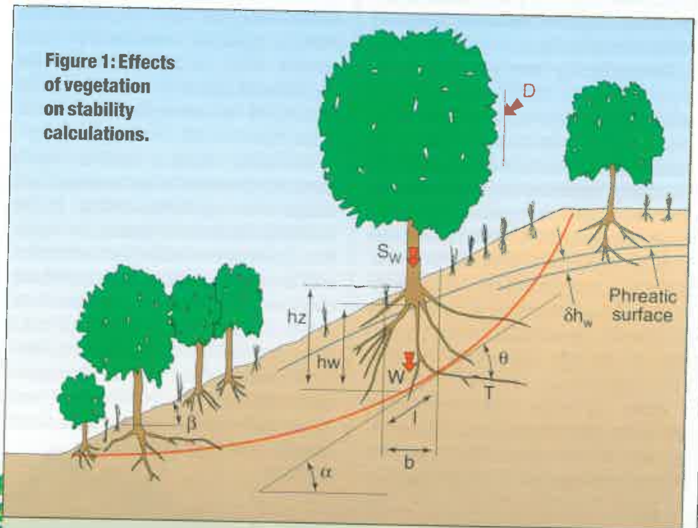

Figure 1: Effects of vegetation on stability calculations.

Parameters applied in slope stability analysis

- **W** Total weight of soil slice, kN/m²
- **c' ϕ'** Effective strength parameters at slip surface
- **l** Length of slip surface with slice, m (b sec α)
- **u** Pore water pressure at slip surface, kN/m² ($\gamma_w h_w$)
- **u_v** Decrease in pore water pressure to evapotranspiration by vegetation at slip surface, kN/m² (2)
- **c'_R** Enhanced effective soil cohesion due to root matrix reinforcement by vegetation along slip surface, kN/m_2
- **S_w** Surcharge due to weight of vegetation, kN/m
- **D** Wind loading force parallel to slope, kN/m
- **T** Tensile root force acting at base of slice, kN/m (assumed angle between roots and slip surface θ

Stability analysis for a circular slip surface using Greenwood's simple method

$$F = \frac{\Sigma\,[c'b \sec\alpha + (W - ub)\cos\alpha \;\tan\phi']}{\Sigma W \sin\alpha} \quad (1)$$

Greenwood's simple equation is easily modified to include the vegetation factors

$$F = \frac{\Sigma\{(c' + c'_R)\, b \sec\alpha + \{((w+s_W) - (u - u_v)b)\cos\alpha - D\sin(\alpha-\beta) + T\sin\theta)\tan\phi' + T\cos\theta}{\Sigma\{(W + Sw)\sin\alpha + D\cos(a - \beta)\}} \quad (2)$$