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Application of Finite Element Method of Numerical Modelling to Understand Toe Buckling Deformation in the Southern Alps of New Zealand.

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Toe buckling deformation is a temporal product of induced stresses concentrated at the base of a slope. Prolonged induced stresses may lead to yielding of an anisotropic rock mass, either through rheological creep deformation (flexural toe buckling) or brittle failure (hinge buckling). Progressive deformation can lead to the breakout at the buckled toe and ultimately result in deep seated displacements on a mountain range scale, referred to as deep seated gravitational slope deformation (DSGSD). DSGSD can have a considerable impact on civil infrastructure and should be well understood for hazard identification, to inform civil engineering design and for resource management purposes.

Toe buckling deformation was identified beneath the basal sliding zone of three large (≥50 Mm3) landslides in the Cromwell Gorge, New Zealand. This area was subjected to extensive geotechnical investigations for the Clyde Hydropower Scheme. During these investigations seventeen major landslides were identified in the Cromwell Gorge and subsequently stabilised. The data from the landslide stabilisation project, including 26.7 km of boreholes and 9 km of tunnels, for the three landslides exhibiting toe buckling was made available for this study. This comprehensive database has enabled comparison and validation of numerical simulations carried out for the Cromwell Gorge.

The application of numerical modelling has demonstrated that toe buckling within the Cromwell Gorge is a result of the combination of induced stresses acting on an anisotropic schistose rock mass. The induced stresses comprise: i) topographically-induced gravitational stresses parallel to the slope, associated with the evolution of the Cromwell Gorge from a relatively low relief surface to present day topography (1400 m deep valley), and ii) active far-field tectonic stresses associated with the obliquely convergent stress regime of the Australian-Pacific continent plate boundary.

Finite Element Method (FEM) numerical models were used to model the anisotropic nature of the schist rock mass, and a sequential unloading method was adopted to simulate valley evolution. Far-field tectonics were incorporated into the model by comparing topographically induced gravitational stresses with in situ field stress measurements. The results of sensitivity analyses demonstrate that the dominant parameters governing toe buckling deformation in the Cromwell Gorge are a function of the anisotropy of the schist (foliation orientation and stiffness), and the intersection of the two induced stress fields near the base of the slopes.