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Influence of scale-dependent fracture intensity on block size distribution and rock slope failure mechanisms in a DFN framework

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An accurate characterization of the geometry and intensity of discontinuities in a rock mass is key to assess block size distribution and degree of freedom. These are the main controls on the magnitude and mechanisms of rock slope instabilities (structurally-controlled, step-path or mass failures) and rock mass strength and deformability. Nevertheless, the use of over-simplified discontinuity characterization approaches, unable to capture the stochastic nature of discontinuity features, often hampers a correct identification of dominant rock mass behaviour. Discrete Fracture Network (DFN) modelling tools have provided new opportunities to overcome these caveats. Nevertheless, their ability to provide a representative picture of reality strongly depends on the quality and scale of field data collection.
Here we used DFN modelling with FracmanTM to investigate the influence of fracture intensity, characterized on different scales and with different techniques, on the geometry and size distribution of generated blocks, in a rock slope stability perspective. We focused on a test site near Lecco (Southern Alps, Italy), where 600 m high cliffs in thickly-bedded limestones folded at the slope scale impend on the Lake Como. We characterized the 3D slope geometry by Structure-from-Motion photogrammetry (range: 150-1500m; point cloud density > 50 pts/m2). Since the nature and attributes of discontinuities are controlled by brittle failure processes associated to large-scale folding, we performed a field characterization of meso-structural features (faults and related kinematics, vein and joint associations) in different fold domains. We characterized the discontinuity populations identified by structural geology on different spatial scales ranging from outcrops (field surveys and photo-mapping) to large slope sectors (point cloud and photo-mapping). For each sampling domain, we characterized discontinuity orientation statistics and performed fracture mapping and circular window analyses in order to measure fracture intensity (P21) and persistence (trace length distributions). Then, we calibrated DFN models for different combinations of P21/P32 and trace length distributions, characteristic of data collected on different scale. Comparing fracture patterns and block size distributions obtained from different models, we outline the strong influence of field data quality and scale on the rock mass behaviours predicted by DFN. We show that accounting for small scale features (close but short fractures) results in smaller but more interconnected blocks, eventually characterized by low removability and partly supported by intact rock strength. On the other hand, DFN based on data surveyed on slope scale enhance the structural control of persistent fracture on the kinematic degree-of freedom of medium-sized blocks, with significant impacts on the selection and parametrization of rock slope stability modelling approaches.