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Quantifying the impact of lithology upon the mechanical properties of rock

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The physical characteristics of rock, its lithology, undoubtedly influences its deformation under natural or engineering loads. Mineral texture, micro-damage, joints, bedding planes, inclusions, unconformities and faults are all postulated to alter the mechanical response of rock on different scales and under different stressing conditions. Whilst laboratory studies have elucidated some aspects of the relationship between lithology and mechanical properties, these small-scale results are difficult to extrapolate to lithospheric scales. To augment laboratory-derived knowledge, physics-based numerical modelling is a promising avenue [3]. Bonded particle models implemented using the Discrete Element Method (DEM [1]) are a practical numerical laboratory to investigate the interplay between lithology and the mechanical response of rock specimens [4].

Numerical rock specimens are represented as an assembly of indivisible spherical particles connected to nearest neighbours via brittle-elastic beams which impart forces and moments upon one-another as particles move relative to each other. By applying boundary forces and solving Newton's Laws for each particle, elastic deformation and brittle failure may be simulated [2]. Each beam interaction is defined by four model parameters: Young's modulus, Poisson's ratio, cohesive strength and internal friction angle. Beam interactions in different subvolumes of the specimen are assigned different parameters to model different rock types or mineral assemblages. Micro-cracks, joints, unconformities and faults are geometrically incorporated by fitting particles to either side of triangulated surfaces [5]. The utility of this modelling approach is verified by reproducing analytical results from fracture mechanics (Griffith crack propagation and wing-crack formation) and results of controlled laboratory investigations.

To quantify the impact of particular lithologic structures on mechanical response, a range of control experiments are conducted in which samples with differing structure are subjected to triaxial compression tests to measure the mechanical response. By systematically varying the geometry and statistical properties of the structures, insight is obtained on how such structures influence mechanical response. The goal of this research is to develop constitutive relations for the mechanical response of rock that are functions of measurable lithological characteristics. Such relations will find utility in tectonic stress field reconstructions, seismic hazard assessment and underground mine engineering.

References

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