Geophysical Research Abstracts
Vol. 14, EGU2012-8294, 2012
EGU General Assembly 2012

Numerical investigations on the role of micro-cracks in determining the compressive and tensile strength of rocks

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Bonded particle models implemented using the Discrete Element Method (DEM [1]) have proven a useful numerical laboratory to investigate the interplay between geological structure and mechanical response of rock specimens [4]. However, it is well-known that such bonded particle models fail to reproduce the ratios of compressive:tensile strength of rocks (typically ranging between 10:1 and 50:1). Since this strength ratio is a critical geotechnical engineering design parameter, it is important to resolve this discrepancy between rock and their DEM analogues.

To date, the largest compressive:tensile strength ratio achieved in DEM rock analogue models ranges between 10:1 and 12:1 [3]. In said studies, the compressive:tensile strength ratio was found to depend on the number of particle bonds removed from the specimen prior to testing; a modelling analogy for changing the micro-crack density within the specimen. These results are consistent with the popular conjecture that the compressive and tensile strengths of rock are impacted by the opening (or closure) of micro-cracks oriented parallel (or perpendicular) to the loading direction.

The current research consists of a rigorous analysis of the role of micro-cracks in governing the compressive:tensile strength ratio of DEM rock specimens. Micro-cracks are geometrically represented as planar surfaces of variable size and orientation. Spherical particles are packed around each planar micro-crack forming a surface that is flat on scales larger than the particle scale. This geometrical approach permits prescription of the sizes and orientations of micro-cracks, as well as the crack density. A series of cylindrical DEM rock specimens are prepared with varying micro-crack densities and orientations. Specimens with either or both micro-cracks sub-parallel to, or sub-perpendicular to the cylinder axis are consided.

Each DEM rock specimen is subjected to both a numerical uniaxial compression test and a numerical direct tension test. From these tests, four macroscopic material properties are measured for each specimen: Young's modulus, Poisson's ratio, uniaxial compressive strength and unixial tensile strength. Fracture mechanisms are also examined. Preliminary results indicate that both micro-crack density and micro-crack orientation significantly impact the macroscopic mechanical properties of DEM rock specimens. Quantitative results will be presented at the meeting.

The software employed for these experiments is ESyS-Particle [2], an Open Source DEM simulation package for multi-core PCs or supercomputers.

References

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