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Micromechanical basis for the Coulomb failure parameters

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In 1776 Coulomb proposed the simplest and arguably the most important criterion for the macroscopic development of shear fracture in a brittle rock. This linear relation has been found to be applicable to geomaterials over a broad range of pressures, and it is adopted widely in geological and geotechnical applications. The fracture of a brittle rock is characterized by the Coulomb criterion using two empirical parameters, commonly known as the cohesive (shear) strength and coefficient of internal friction. The micromechanical basis for the Coulomb failure parameters remains however obscure and can be established only if a realistic model for the damage mechanics of brittle fracture has been developed.

A model that can capture many of the key micromechanical processes associated with the onset and development of dilatancy and compressive failure in rock is the sliding wing crack model, which has been analyzed in numerous theoretical studies. The model identifies a number of micromechanical parameters (including the friction coefficient for sliding on a preexisting crack, crack density, crack dimension and fracture toughness) that exert significant influence on the development of brittle fracture. The primary objective of this study was to gain insights into the physics of the Coulomb criterion by connecting the Coulomb failure parameters with these micromechanical parameters with reference to the sliding wing crack model.

We first derived analytic approximations for the empirical failure parameters with reference to the sliding wing crack model. These expressions clarify the dependence of the uniaxial compressive strength on micromechanical parameters including the fracture toughness, friction coefficient, crack dimension and density. The internal friction coefficient can be approximated as related linearly to the friction coefficient of the sliding crack, and the difference between the two coefficients has a logarithmic dependence on the square root of the crack density.