Discrete element modelling of rupture in granular materials

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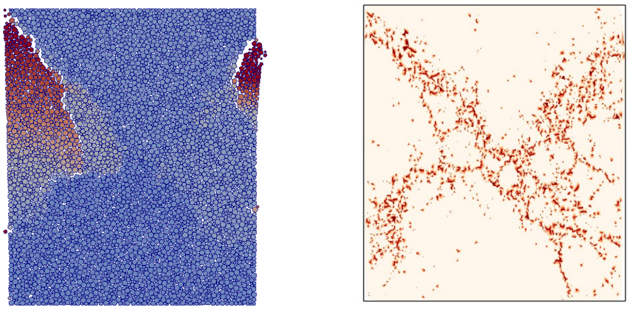
ABSTRACT

We study the fracture mechanisms of granular materials under quasi-static stress by means of Discrete Elements Method (DEM), which is widely accepted as an effective numerical method to simulate the mechanical behavior of such materials [1]. Although gaining attention in recent decades, fracture mechanisms are not yet fully understood and establishing a relation between interactions at micro-scale and resulting macroscopic behavior is still a challenge. The micro-structure of materials such as natural rocks often shows grains surrounded by a binding paste. The complex distribution of this paste, including voids, induces a heterogeneous set of force chains in the material, making the macroscopic behavior difficult to predict.

We represent such a material by an assembly of rigid particles with cohesive contacts to model the rigidity of the assembly. In order to allow cohesion even when particles are not geometrically in contact, we introduce an interaction range [2] below which cohesion is active. To account for particle shape effect, we use non isotropic (polygonal and polyhedral) elements in our simulations. Forces at geometric contacts between particles are calculated using the Non Smooth Contact Dynamics (NSCD) method [3]. The cohesive behavior of the binding paste is mimicked by two linear springs (three or more in 3D) attached to the particles. Rather than derived from fitting relations, spring stiffnesses are computed from the assessment of the microscopic Young's modulus and Poisson's ratio of the modeled binding paste.

After describing precisely the contact and cohesive model used, we discuss numerical simulation results for the modeled material under quasi-static loading (compression / direct traction / indirect traction - Brazilian test). First, sample preparation and samples characteristics are described. Then, the simulation process is presented and simulation results are detailed. Influences of microscopic, grain-scale parameters on the macroscopic response of the material (elastic moduli, strengths...) are investigated, with the aim of establishing micro/macro relations. Finally, the initiation of the rupture and its propagation are examined, together with its microscopic origin. The relevance of using such a model to study rupture in granular materials is also evidenced.



Left : Rupture under uniaxial compression stress of a sample of
5000 regular pentagons. Right : Map of broken cohesive contacts at rupture.

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