From Polygonal Particles to a Continuum Representation
- An Application of the Discrete Element Method -

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ABSTRACT

The failure mechanisms of cohesive granular materials like concrete, ceramics or marl are characterized by complex failure modes due to their inhomogeneous microstructure. Behaving quasi-brittle under load, these materials are characterized by a typical failure mode localization in narrow zones. From the point on a localization phenomenon like a crack occurs the material cannot be treated as continuous any longer. This means that the range of validity of continuum models has been left since these models cannot account for the discrete nature of material failure in a natural way [1].

In order to obtain an anisotropic damage evolution in a natural and conceptually simple way geomaterials are modeled in the context of the Discrete Element Method (DEM) as a discrete granular particle assembly composed of convex polygons [2,3]. These particles are additionally linked together by simple force-deformation interactions accounting for a limited cohesion. Either beams between the centers of mass [2,3] of neighboring polygons or interfaces at the boundaries of neighboring polygons [1] serve as additional cohesive interaction component [1]. This treatment, on the one hand, includes the contact description for the particles and on the other hand a simple beam formulation or a bond formulation based on a simple Mohr-Coulomb plasticity law between the particles. Resulting forces are inserted into the equations of motion which are numerically solved based on the Discrete Element Methodology. A homogenization approach for the transition from a particle assembly to continuum mechanical quantities supplements the theoretical description of the model. Via an introduction of representative particle assemblies a computation of average quantities like stresses and strains are possible [4]. Additionally, the analysis of energetical quantities shows the generality of the procedure. Therewith, it is possible to bridge effects on the particle scale to a higher scale.

The failure evolution of basic loading scenarios in the framework of solid mechanics, will be used in order to verify the presented numerical scheme and the effects taking place at the microstructural level. Through the simulation results it becomes evident that the interaction of the material particles through contact gains an increasing influence on the global behavior during material degradation with respect to the cohesive component. Thus, a transition from a continuous to a discontinuous state of the material results as a naturally output of the simulation. Different failure related characteristic quantities for the description of the failure within the material will be investigated and their relation to continuum–based formulations will be pointed out. It will be demonstrated that this simulation method along with the applied homogenization procedure allows us to monitor quantities which are hard to measure or are not measurable at all in experiments. Hence, the discrete models presented herein provide a deeper understanding of the fracture and fragmentation processes well beyond the description of the final state.

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