Geophysical Research Abstracts
Vol. 15, EGU2013-11704, 2013
EGU General Assembly 2013

Spatial structure and temporal fluctuations of damage in a discrete element model of geomaterials

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We present a discrete element model of geomaterials and investigate the uniaxial compression of cylindrical specimens. In order to capture the heterogeneous micro-structure of materials the sample is generated by sedimenting randomly sized spherical particles inside a cylindrical container. The cohesive interaction of particles is represented by beam elements which can break when they get overstressed. The breaking rule takes into account the stretching and shear of particle contacts. The time evolution of the system is generated by molecular dynamics simulations.

Computer simulations revealed that under strain controlled uniaxial loading of the system first micro-cracks nucleate in an uncorrelated way all over the sample. As loading proceeds localization occurs, i.e. the damage concentrates into a narrow band which has an angle of 30-45 degrees with the load direction.
Inside the damage band fragments are obtained with a power law mass distribution embedded into fine powder of single particles.

Analyzing the temporal evolution of the breaking process we show that local breaking events form correlated trails which are analogous to acoustic bursts of experiments. Characteristic quantities of bursts such as size (crack surface), energy, and duration, furthermore, the waiting times between consecutive events are characterized by power law distributions over a broad range. We show that the energy and duration of bursts have power law dependence on the crack surface created by bursts. As the system approaches macroscopic failure we pointed out that consecutive bursts get correlated: the average waiting time to the next event proved to be an increasing function of the burst size, furthermore, the formation of the damage band is marked by the decrease of the average distance of consecutive bursts.

The simulation results are in reasonable agreement with the experimental findings on sedimentary rocks.