Discrete element modelling of the effect of disorder on the spatial structure of damage in compressive failure

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ABSTRACT

Compressive failure of brittle heterogeneous materials is accompanied by the spontaneous formation of localized damage bands, where the final slip occurs at global failure. The amount of inherent structural disorder present at the meso- and micro-scale of materials plays a crucial role in the emergence of such damage bands and their properties, including also their final position, orientation, and internal structure.

Here we investigate the effect of the amount of disorder on the spatial structure of damage using a discrete element model of porous rocks. To build numerical rock samples, we simulate the sedimentation process of spherical particles to a cylindrical container. We use a realistic log-normal distribution of the particle radius where the degree of disorder could be varied by tuning the parameters of the distribution. To form a rock sample, the particles are connected by beam elements which represent the cementation between grains. Our model construction has the advantage that the random homogeneous packing of particles is the only source of disorder which determines the physical properties of cohesive elements [1,2].

We performed simulations of the compressive failure of cylindrical samples which are loaded diametrically similar to a Brazilian test, however, the load is applied on a longer cylinder over an extended surface area of the sample which is clamped. In this setup the geometrical constraints give rise to the emergence of extended damage bands in a well controlled way [2].

We show that the orientation angle, the damage bands enclose with the load direction, fluctuates around an average value, which increases linearly with the amount of disorder. The degree of disorder proved to have a strong effect on the structure of the damage band: at low disorder the bands are sharply defined with smooth surfaces, however, increasing disorder leads to gradual broadening which is accompanied by the formation of a diffuse cloud of damage around the bands' connected core. By means of data collapse analysis of the spatial distribution of fragments around the central plane of the damage band we showed that the band width increases as a power law of the disorder amplitude with the exponent $\alpha = 0.78$. Inside the damage band the material undergoes fragmentation creating a large number of pieces with a broad variation of sizes. The majority of fragments form a powder phase comprising only single particles which embed larger pieces. Between the branches of the damage band four fragment wedges are formed which are significantly larger than the debris pieces inside the damage band. In the intermediate range the mass distribution of fragments proved to be a power law with a universal exponent [2].

REFERENCES

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