From grain assemblies to plastic softening, a discrete to continuum story.

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Abstract

Even for the most simple geometrical grain shapes and simple contact laws, the micro-origin of plastic strain hardening/softening in granular materials is still an open issue. From a continuum mechanics point of view, irreversible behaviors are intimately linked to the onset of plastic slip lines and shear bands. However from a microscale point of view, such continuum mechanics concepts vanish because of the discrete nature of granular materials. In this study, two dimensional discrete element simulations are performed at the representative elementary volume (REV) scale to simulate the typical dense and loose sand behavior in drained biaxial tests. We bridge the gap between micro discrete and macro continuum descriptions of granular materials by introducing an intermediate mesoscale composed of small structures of a few grains (force chains and grain loops). Mesoscopic definitions for stress and strain are then proposed in order to clearly distinguish slip lines from shear bands in the considered grain assemblies. It is shown that, while the orientation of slip lines is dictated by material properties, the orientation of shear bands is a combination between the local material properties and the structural properties at the scale of the samples. By analyzing geometrical and mechanical characteristics of force chains inside and outside of the shear band area, some of the mesoscale mechanisms responsible for strain hardening/softening are identified. It is also shown in particular that i) the hardening regime is explained by the degradation of the contact network and the concentration of the load on fewer and fewer force chains, and ii) the softening regime is linked with loop dilation and force chain rotation inside the shear band domain.