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Numerical analysis of granular soil fabrics

L. Torbahn and K. Huhn
MARUM, University of Bremen, Bremen, Germany (ltorbahn@marum.de)

Soil stability strongly depends on the material strength that is in general influenced by deformation processes and vice versa. Hence, investigation of material strength is of great interest in many geoscientific studies where soil deformations occur, e.g. the destabilization of slopes or the evolution of fault gouges. Particularly in the former case, slope failure occurs if the applied forces exceed the shear strength of slope material. Hence, the soil resistance or respectively the material strength acts contrary to deformation processes.

Besides, geotechnical experiments, e.g. direct shear or ring shear tests, suggest that shear resistance mainly depends on properties of soil structure, texture and fabric. Although laboratory tests enable investigations of soil structure and texture during shear, detailed observations inside the sheared specimen during the failure processes as well as fabric effects are very limited. So, high-resolution information in space and time regarding texture evolution and/or grain behavior during shear is refused. However, such data is essential to gain a deeper insight into the key role of soil structure, texture, etc. on material strength and the physical processes occurring during material deformation on a micro-scaled level. Additionally, laboratory tests are not completely reproducible enabling a detailed statistical investigation of fabric during shear. So, almost identical setups to run methodical tests investigating the impact of fabric on soil resistance are hard to archive under laboratory conditions.
Hence, we used numerical shear test experiments utilizing the Discrete Element Method to quantify the impact of different material fabrics on the shear resistance of soil as this granular model approach enables to investigate failure processes on a grain-scaled level. Our numerical setup adapts general settings from laboratory tests while the model characteristics are fixed except for the soil structure particularly the used grain shapes. So, ideal round or stick- and plate-shaped grains were utilized to represent natural silts or clays to test two end-members. To quantify texture influences on soil strength, physical parameters, e.g. soil resistance, were calculated during deformation process. Furthermore, fabric analysis during shear reveals new information on detailed pore space regarding distribution and shape of voids. For this, a three-dimensional visualization of pore space is realized with the Visualization Toolkit (VTK) that allows the volume calculation and hence a quantification of single voids with progressive deformation.

As a result, imaging of particle contact distribution and particle orientations within samples show significant changes with ongoing strain such as strong variations in material fabric and particle re-organization and therewith significant structural changes. These findings confirm that in general grain shape and its factor of soil fabric is not negligible for soil resistance and hence soil strength. This is notably affected by the deformation behavior of granular matter. With the broad investigation of the three most important factors that specify fabric behavior, this study attains a comprehensive view evaluating the impact of fabric on soil strength.