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Influence of particle shape on packing structure and non-linear hydraulic behavior

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Granular media, exhibiting permeable packing structures, commonly exists in various fields of civil engineering, ranging from soil drainage, oil and gas extraction, to mining, and underground gas storage. The packing structure is dominated by grain features, such as size distributions, general shapes, and fine morphology features. Due to the opaque nature of overwhelming parts of natural grains, instant changes of the porosity and tortuosity reflected by pore geometry are hard to quantify experimentally. To bridge this gap, this numerical study is twofold: i) systematic investigations on influences of initial grain shapes on the fabric tensor during compaction process, and ii) the resultant hydraulic conductivity in transition flow. The first point is accomplished using the discrete element method (DEM), while the latter is conducted by solving Reynolds-Averaged Navier-Stokes (RANS) equations at pore-scale. In this study, DEM can quickly and accurately assemble packing structures consist of mono-dispersed grains in natural shape; meanwhile, the fabric tensor in each assembly is computed from the resulting packing structure. Realistic shaped grains, generated using the inverse analysis of Spherical Harmonics, are imported into DEM for the assembly, in order to systematically study the grain shape effects. The results indicate that the grain rearrangement and deformation from the compaction process could decrease porosity, introduce anisotropic features, and increase the global pore tortuosity, and therefore supress the permeability. Our findings will contribute to the understanding of effects of grain shapes and compaction on permeability, beneficial to the engineering applications concerning the fluid flow in various types of porous materials.

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References

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