Emerging properties in geomaterials accross the scales

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Abstract

Geomaterials exhibit a wide range of complex behaviors that are of crucial interest for engineering scale applications or for mitigating natural risk hazards. Such behaviors are often accounted for through continuum mechanics concepts such as constitutive behavior, yield surfaces, hardening law, permeability, shear or compaction bands... Given the complexity of the macroscopic behavior of geomaterials, a current strategy is to use a multi-scale approach either in the lab or in the virtual lab (with DEM, molecular dynamics, X-ray tomography, SEM...), to identify sub-components with simpler behavior. However, in the change of scale, some properties are lost and some emerge.

In the upscaling, we face the issue of emerging properties fundamentally different from those at lower scales. For instance, sand is usually modeled as non-deformable solids interacting through elasto-frictionnal contact laws, but the internal friction angle (macroscale) does not corresponds to the contact friction (micro scale) but incorporate geometrical properties of the microstructure.

On the contrary, the huge number of degrees of freedom that exist at the microscale is compressed into a much more limited number of macroscopic degrees of freedom. For instance, the displacements and the rotations of thousands of sand grains reduce to the strain tensor (and possibly its derivatives for enriched continuum mechanics) at the representative elementary volume scale. For the stress, the well-known Love-Weber formula, compress contact based information into a second order tensor.

Working on the mico to macro link is probably the key for a wise use of phenomenological constitutive models (e.g. physics based justification of the parameters) and for an efficient use of multiscale strategies (e.g. FEMxDEM methods save probably too much microscale information).

In addition, fundamental knowledge on the micro/macro link may prove crucial to anticipate future use of geomaterials subjected to unprecedented loading conditions. Among other conditions, we can think of temperature rises, thawing permafrost, chemical creation or dissolution of bonds, diffusion of pollution, cyclic loadings, recycling materials, varying degrees of saturation...