From Particle Dynamics to Multiphasic Continuous Media:

A research overview including multi-physical approaches
to geomechanical and biomechanical applications

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The lecture highlights selected results obtained at the Institute of Applied Mechanics, which is embedded in the Cluster of Excellence in Simulation Technology through the Research Area B: “Advanced Mechanics of Multi-scale and Multi-field Problems”. Keeping the focus on coupled problems, several applications and numerical examples will be presented. In particular, these will range from discrete particle dynamics to the homogenisation of particle ensembles towards continuum approaches culminating in multi-phasic and multi-component material descriptions of porous solids containing fluids as well as gases or arbitrary pore-fluid mixtures, partly coupled with electro-chemical effects. As a matter of fact, it is obvious that this kind of coupled material behaviour must be based on the Theory of Porous Media (TPM).

The presented examples start with the description of discrete particle ensembles by means of Newton’s equations of momentum and angular momentum in combination with contact laws and neighbouring lists. As a result, a tool is obtained for the computation of dynamical and quasi static problems like the outflow of a hopper and the biaxial test in soil mechanics, respectively, where both approaches are a priori able to describe the development of shear bands. Proceeding from volume averaging techniques, one does not only succeed in transferring contact forces and displacements towards stresses and strains but also in transforming contact moments and rotations towards couple stresses and curvatures. These results clearly demonstrate that a macroscopic description of granular material should include microscopic information through the consideration of micro-polar media. The numerical examples address these effects by exhibiting the computation of slope and base failure problems, the latter also under 3-d assumptions.

Concerning the macroscopic description of these problems, the TPM is applied, which includes a micro-to-macro transition based on a virtual homogenisation process with a distinction of immiscible phases. These phases may consist of either an elastic, elasto-plastic or elasto-viscoplastic solid skeleton, which is saturated by a compressible or an incompressible pore fluid. The fluid itself may be a miscible mixture of components like water, dissolved ions or air, which are embedded in the TPM approach using the Theory of Mixtures. Following this, electro-chemical effects occurring in soft biological tissues or hydrated smart materials, for instance, can be also described. Thus, the presented numerical examples are not only restricted to geotechnical problems but will also cover swelling phenomena as they can be observed in cartilage, intervertebral discs or electro-active polymers.