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PARTICLE-BASED MODELLING AND COMPUTATIONAL HOMOGENISATION OF GRANULAR MEDIA

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The configuration of many geomaterials is governed by a porous structure, where individual grains form a solid skeleton whose voids may be filled with a pore fluid or a gas. The motion of individual grains plays a significant role for the macroscopic material behaviour and thus justifies the need for modelling approaches, which incorporate a micro-macro transition. An example for micromotion-based material failure is the development of shear zones, as examparily observed in biaxial compression tests, cf. [1]. In this contribution, localisation phenomena are investigated in dry granular media on different size scales. This is done in three basic steps: a particle-based modelling is set up on the microscale, followed by the homogenisation of the obtained information towards continuum quantities, introducing Representative Elementary Volumes (REV) on the mesoscale. Finally, a comparison with a micropolar continuum approach, formulated on the macroscale, is carried out. Figure 1 illustrates the overall modelling procedure.

Choosing a particle-based approach for granular assemblies is probably the most intuitive way to model granular assemblies, as each grain is individually described as a rigid particle. In a numerical framework, this leads to the Discrete-Element Method, introduced by Cundall & Strack [2], wherein the motion of each particle is obtained by solving its Newton's equations. Constitutive relations are formulated for the inter-particle contact forces in normal and tangential directions. In particular, these constitutive formulations have to provide the plastic material behaviour. Initial-boundary-value problems (IBVP) using mono- and polydisperse packings of particles are discussed with special focus on the onset and the development of localisation phenomena in shear zones. A further focus of the contribution lies on the apparent idealisation of the particle shape as well as on the remaining differences in scale and distribution of the generated particle packings with respect to natural grain assemblies.

As engineering problems are regularly described on the macroscale by means of continuum mechanics, a homogenisation strategy transfers the information from the microscale

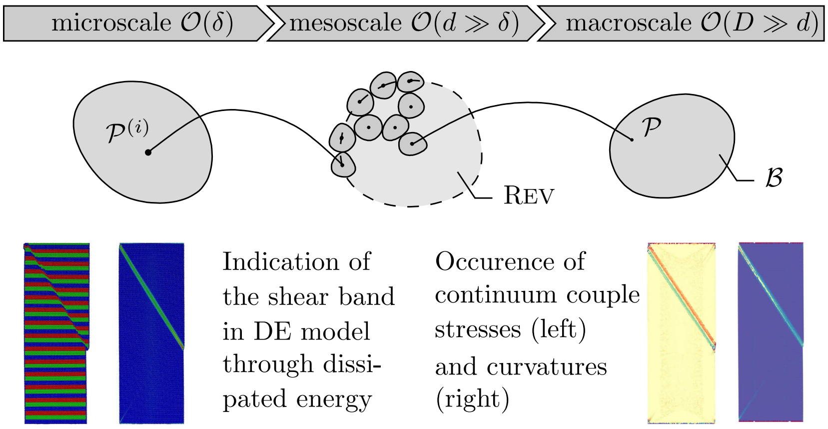

Figure 1: From particle-based to continuum quantities.

towards continuum quantities via volume averaging. Therefore, characteristic REV are constructed by an ensemble of particles, where each particle can be chosen as the centre of the REV, cf. [3]. Proceeding in such a way leads to the loading of the REV boundary by resulting forces and moments, which again results in the existence of non-symmetric stresses and couple stresses in a continuum sense. Consequently, due to particle translation and rotations on the microscopic scale, strains and curvatures are found as kinematic quantities after the homogenisation procedure. An appropriate choice of the REV size leads to averaged macroscopic quantities without loss of the microscopic effects.

The averaged continuum quantities compare to those of a micropolar or Cosserat continuum, which is therefore chosen as a purely macroscopic description of granular material. Herein, in comparison to a standard Cauchy-Boltzmann continuum, a free rotational field is introduced and thus enhances the continuum to account for the above mentioned effects on the microscopic scale. Inhomogeneous IBVP, as the biaxial experiment, are solved using standard Finite-Element Methods and reveal the activation of rotations in the shear zone. Consequently couple stresses and curvatures occur in addition to the non-polar stresses and strains. The homogenisation approach allows for the qualitative comparison of results from both modelling approaches, as the information from particle simulations on the grain scale is bridged to the continuum scale.

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