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INVESTIGATIONS OF DYNAMIC SHEAR LOCALIZATION IN GRANULAR BODIES USING AN UNCOUPLED ALE-FORMULATION

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ABSTRACT

A so-called uncoupled Arbitrary Lagrangian-Eulerian formulation (ALE, in short) [1] was used to describe shear localization in granular bodies during 2 different boundary value problems: plane strain compression and confined granular flow in silos [2], [3]. The deformation process was divided into an updated Lagrangian phase and an Eulerian phase combined with a smoothing phase. First, an updated Lagrangian step was performed which results in calculating the material displacements. In this phase convective effects were neglected. The material body deformed from its material configuration to its spatial one. Secondly, the mesh velocity was calculated during a smoothing phase (called also a remeshing step) performed at each time step in order to reduce mesh distortions. The boundary after the remeshing approximately coincided with boundary obtained with the Lagrangian calculation while the inner nodes were moved (mesh topology remains similar and the number of the nodes and elements through was kept constant). A transfinite mapping method was used for the mesh management. Finally, a remap of state variables of the Lagrangian phase onto new mesh including the calculation of the convective term was carried out. The uncoupled ALE-approach can be successfully used to large deformation problems of bulk solids during flow. It keeps distortions of the spatial mesh under control to ensure the quality of the numerical simulation.

The calculations were carried out with the finite element method using an explicit dynamic approach. The behaviour of dry sand was described with a hypoplastic constitutive [4], [5]. A hypoplastic model is capable of describing a number of significant properties of granular materials: non-linear stress-strain relationship, dilatant and contractant behaviour, pressure dependence, density dependence and material softening. A further feature of a hypoplastic model is the inclusion of critical states, i.e. states in which a grain aggregate can deform continuously be deformed at constant stress and constant volume. In contrast to elasto-plastic models, a decomposition of deformation components into elastic and plastic parts, the formulation of a yield surface, plastic potential, flow rule and hardening rule are not needed. The hallmark of this model is their simple formulation

and procedure for determining material parameters with standard laboratory experiments. The material parameters are related to granulometric properties, viz. size distribution, shape, angularity and hardness of grains [6]. To capture properly shear localization appearing in sand, the constitutive law was extended by a characteristic length of microstructure be means of a non-local theory [7], [8].

In the case of plane strain compression test, the calculations were carried out with a different characteristic length of micro-structure, specimen size and loading velocity. Attention was paid to the load-displacement diagram, deterministic size effect and shear zone thickness. In the case of silo flow, the calculations were performed for a different silo size, wall roughness and initial density. The outflow was controlled and due to gravity. The FE-results were comapred with corresponding laboratory tests.

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