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APPLICATION OF OPERATOR-SPLIT ALE METHODS TO LARGE DEFORMATION PROBLEMS IN GRANULAR SOIL

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ABSTRACT

Large deformation problems in geomechanics, e.g. pile installation, penetration of sounding tools and slope failure, are usually solved by the application of the finite element method. However, classical Lagrangian and Eulerian viewpoints of finite elements have some shortcomings. In the Lagrangian viewpoint excessive element distortions may occur, which may lead to unstable and inaccurate numerical analyses or even terminates the calculation [1]. In the Eulerian viewpoint the discretised domain is fixed in space and, therefore, following free surfaces and moving material interfaces become a cumbersome task [1]. The Arbitrary Lagrangian-Eulerian (ALE) formulation succeeds in combining the advantages of both classical Lagrangian and Eulerian viewpoints by choosing the element mesh as a time-dependent reference domain different from the material (Lagrange) and spatial (Euler) configurations [2],[3]. For the last two decades the ALE framework has been developed to a powerful analysis tool for large deformation problems, especially metal forming processes and free surface flows. Applications in computational geomechanics are rare because, in particular, modeling the mechanical behaviour of sand is complicated: it depends on the density state as well as on the stress state and stress history. In the context of such path- and state-dependent materials the treatment of the convective terms —which enter the governing equations in the case of ALE— plays a crucial role [4].

In order to bring together the recent developments in both computational mechanics and geomechanics, the ALE framework is combined with an advanced constitutive equation for sand. A commercial FE code is conveniently updated to the ALE formulation by applying an operator-split to the governing equations [5]. The split yields a Lagrangian step, where the constitutive equation is incorporated and an Eulerian step, where the finite element mesh is regularised and the state variables are mapped to this updated mesh. The algorithms needed for the operator-split ALE method are usually simpler and

more robust than algorithms for the fully coupled problem [4]-[6]. The paper gives a brief overview of the basic theory, the calculation steps and the implementation requirements. A couple of numerical examples will be presented and results of ALE calculations will be compared to classical Lagrangian solutions. The results point out the advantages of the ALE framework in conjunction with the use of a stress and density dependent nonlinear soil model applied to the simulation of large deformations problems in granular soil.

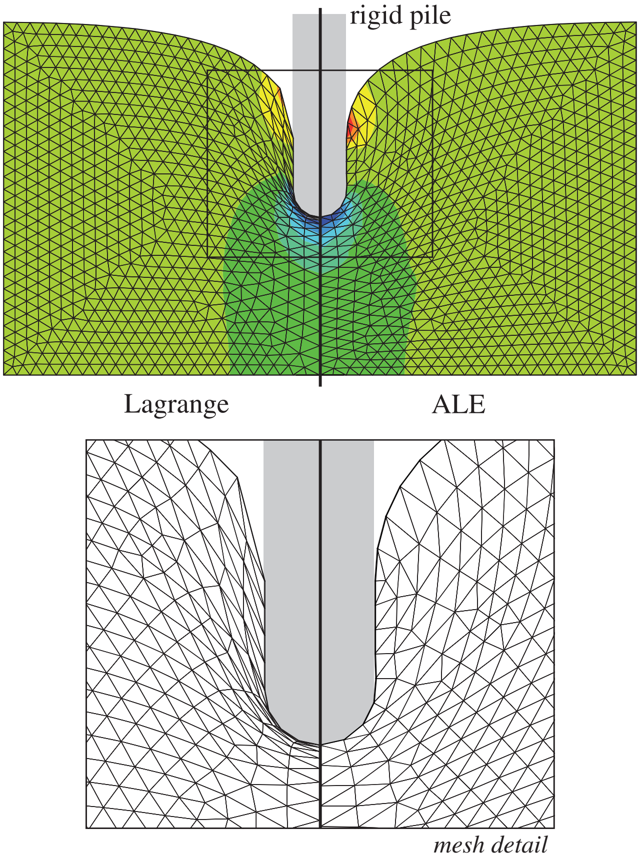

Figure 1: Penetration of a rigid pile. Comparison of Lagrangian and ALE calculations.

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