

Development of a stable two-phase contact MPM algorithm for saturated soil-structure interaction using a semi-implicit solver with the projection method

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ABSTRACT

Numerical simulation of the soil-structure interaction problems with the soil as a two-phase material has been a challenging topic in geotechnical engineering due to the differences in material stiffnesses and interaction between multiple phases, the high bulk modulus of pore fluid, and low permeability. The conventional explicit time integration scheme is conditionally stable, thus requiring a limited time step size, and causes pressure oscillations in rapid loading conditions. As a solution, we develop a stable two-phase contact algorithm in the framework of the Material Point Method (MPM) to study soil-structure interaction problems. We model the soil as a fully saturated porous media and the pore fluid is modeled as incompressible. The algorithm has three main advances over the conventional MPM: (1) We solve the coupled formulations with Chorin's projection method to reduce the numerical oscillation. (2) By handling a diffusion term implicitly, the proposed contact algorithm allows a larger stable time step size which is independent of the bulk modulus and permeability of the pore fluid. (3) To deal with the single-phase material with relatively high stiffness to the soil, we introduce a rigid algorithm in the model. We present detailed formulations and the time increment process of the two-phase contact MPM algorithm. We compare the proposed algorithm with the FEM and the explicit MPM in simulating coupled hydro-mechanical problems to evaluate the accuracy and performance of the algorithm.