Material Point Method to simulate Large Deformation Problems in Fluid-saturated Granular Medium

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Abstract

Large deformation problems in granular soils are of great interest in the field of geotechnical engineering since most of them cause catastrophic damages. Among them, Geophysical and gravity-driven flows such as landslides, avalanches, flowslides, and debris flows; seepage failures in mad-made structures such as levees, embankments, and dams; and liquefaction of loose saturated granular soils have been extensively studied by researchers. Both experimental and numerical investigations are very important to understand the mechanics and to predict failures of these problems. However, the dynamics of these problems during the failure are less explored. Experimental investigations on these types of large scale problems are difficult to perform and require large quantity of resources. Numerical modelling can be used to study these problems, and most of the research related to numerical modelling is mainly focused on identifying the unstable limit due to the limitations of the numerical methods.

The material point method (MPM) is a novel numerical method that combines the best aspects of Lagrangian and Eulerian techniques and can be applied to model large deformation problems. This research consists of four main contributions in the study of large deformation problems in granular soils. First, it investigates the applicability of using continuum approaches to model dry granular flow problems using MPM. Second, a fully coupled formulation is derived for MPM to model large deformation problems in fluid-saturated soils.

Third, the proposed coupled MPM is implemented along with advanced features to apply for a wide range of applications and verified with analytical solutions. Fourth, the coupled MPM is used to model river levee failure problems that involve large deformations.