Lagrangian Mesh-free Particle Method (SPH) for Large Deformation and Post-failure of Geomaterial using Elasto-plastic Constitutive Models

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In this thesis we develop the Lagrangian mesh-free smoothed particle hydrodynamics (SPH) method, which aims to overcome limitations of traditional numerical approaches in handling large deformation and post-failure of geomaterials, using elasto-plastic theory. In the first part, the SPH for fluid dynamics will be briefly overviewed with additional improvement for free surface flow. Based on the SPH equations for fluid dynamics, the general SPH framework for modeling an elastic-perfectly plastic material is first established, and then applied to the Drucker-Prager models with associated and non-associated plastic flow rules. Next, the elastic-plasticity model is generalized to include hardening. In particular, application of the Modified Cam Clay soil model is investigated. In contrast to the previous works of SPH for solid, where the pressure of material was often estimated by using the so-called "*equation of state*", the present study proposes to calculate pressure of soil directly from the constitutive models. Numerical instability of SPH that is often found in applications for elastic dynamics of solid material is also found in this study. In this work, this tensile instability is removed by using the artificial stress method with properly selected parameters. Furthermore, a new boundary condition for elasto-plastic material is also developed in this work to overcome the SPH problem of particle deficiency near the solid boundary. The final issue considered herein for the first time is the interaction between an elasto-plastic structure and geomaterial in the SPH framework.

In the second part of the thesis, the SPH method is developed for a saturated two-phase mixture of fluid and soil by combining the SPH approaches for fluid and for solid that were developed in the first part. New SPH governing equations for two-phase flow of saturated soil are established. The variation of porosity at large deformation of soil is taken into consideration, and the hydraulic conductivity coefficient of soil is assumed to be a function of the porosity. Numerical results obtained in this thesis are then compared to other numerical methods, such as FEM, DEM and to experimental results. Very good agreements have been obtained through these comparisons. This suggests that the development of SPH method for geomaterial presented in this thesis can be extended to general geomechanics problems. Limitations of traditional numerical methods in handling extremely large deformation of geomaterials can be completely resolved by using the proposed method.