Abstract

Analysis of inelastic behaviour of geomaterials during failure process is complex due to the development of microcracks, propagation and interaction of pre-existing discontinuities, existence of inherent defects and flaws. Continuum formulation based on grid based numerical methods cannot effectively simulate large deformation, moving material interface, fractures and fragmentation in geomaterials. The thesis presents a numerical procedure in Smoothed Particle Hydrodynamics (SPH) incorporating pore-water pressure, pre-existing multiple intersecting discontinuities and detonation process of explosive to understand failure processes of geomaterials under static and dynamic loading conditions. The first part of the thesis deals with failure process of geomaterials under static loading conditions and the second part comprises with the detonation mechanism of explosive, whereas last part describes the dynamic failure process of rock materials under blast loading. The thesis provides a detail SPH framework with elasto-plastic softening model that can effectively simulate large deformation, capture the complex failure process and fragmentation pattern. The framework is further extended to include the presence of pore-water pressure in fully/partially submerged geomaterials. A novel numerical procedure in SPH framework is also developed for incorporating multiple pre-existing discontinuities. A discontinuity plane or joint plane is approximated by straight line segments connected with a discrete set of equi-spaced joint particles on which velocity jump and corresponding traction vector across the discontinuity plane are computed. The work is also extended for incorporating detonation mechanism of explosive in SPH framework to generate blast induced loading for dynamic failure of rock medium. A pressure based program burn model is applied with Jones-Wilkins-Lee (JWL) equation of state to describe the burning process of explosive particles. Then, numerical procedures are developed to simulate the dynamic failure process in SPH for application in rock blasting phenomena. The necessary interactions between rock mass, multiple intersecting discontinuities and blast induced high pressure gas is described in detail. An interfacial stress tensor at gas-rock interface is formulated to apply the necessary interface boundary conditions in SPH framework. The procedure is extended in such a way that multiple blast holes with time delay and non-reflecting boundary conditions can easily be employed to simulate large scale rock blasting phenomena. The concept of continuum damage model is applied in the constitutive model to describe the stiffness degradation and failure process in rock mass.

Several numerical examples are illustrated in the thesis to demonstrate the efficacy of the proposed methodologies. The numerical results of the developed procedures are compared with theoretical solution as well as experimental results. The results obtained from this study suggest that the developed methodology in SPH framework has the potential to provide useful information to understand the key physical phenomena that occur in the failure process of rock mass under static and dynamic loading conditions.

Keywords: SPH; rock mass; fracture and failure process; discontinuity plane; detonation of explosive; stress wave; high pressure gas; damage;