Feasibility of particle methods in LS-DYNA for unsaturated soil modelling

***†E.A. Flores-Johnson[1], S. Wang[1], F. Maggi[1], A. El Zein[1], G.D. Nguyen[2] and L. Shen[1]**

[1]School of Civil Engineering, The University of Sydney, Sydney, NSW 2006, Australia.
[2]School of Civil, Environmental and Mining Engineering, The University of Adelaide, Adelaide, SA 5005, Australia.

*Presenting author: emmanuel.flores-johnson@sydney.edu.au
†Corresponding author: emmanuel.flores-johnson@sydney.edu.au

Abstract

A clear understanding of the soil mechanical response to extreme events, such as blast, impact or earthquake loadings, is crucial for the design of infrastructure, e.g., roads, government buildings or power plants. Prohibitive costs of large-scale experimental testing of unsaturated soil under extreme loading makes computational approaches necessary not only to save resources but also to gain an understanding of the mechanical behavior at different scales before experiments are set up.

It is well known that the degree of water saturation in soils affects the soil physical properties and mechanical performance. To understand the complex behavior of unsaturated soil, multi-scale modelling can aid in capturing solid-fluid and fluid-gas interactions. An understanding of these interactions as well as contact forces through multi-scale modelling enables us to develop accurate analytical models that can be implemented into continuum constitutive models less computationally costly than micro-scale simulations. Recent developments in fluid-solid interaction (FSI) tools and particle methods that can simulate liquids and gases make modelling of multi-phase media an important tool to advance knowledge in problems related to unsaturated soil.

In this paper, we study the effectiveness of two particle methods in modelling of unsaturated soil, namely: (1) Smoothed-particle hydrodynamics (SPH) and (2) discrete-element methods (DEM) in LS-DYNA software. We focus on the ability of these methods to capture behaviors in solid-fluid interactions such as capillary forces, contact forces and free surfaces. Two tests are simulated and validated with existing experimental data: i) impact of a water droplet on a flat surface due to gravitational load and ii) impact of a solid wedge on water. In both cases, water is simulated with either SPH or DEM and solids and surfaces are modelled using a Lagrangian mesh with the finite-element method (FEM). It was found that our coupled SPH-FEM and DEM-FEM approaches reproduced well the physical behaviour of water subjected to impact loading such as the extension of the splash-up region caused by the entry of the impacting wedge into water, as well as the interaction of water with a solid surface such as the droplet final shape after impact. These results indicate that complex modelling of multi-phase media is feasible with existing numerical tools and should be further investigated to model unsaturated soil applications.

Keywords: Particle methods, SPH, DEM, fluid-solid interaction, LS-DYNA