# Evaluation of dynamic explicit MPM formulations for unsaturated soils

**F. Ceccato*, V. Girardi*, A. Yerro† and P. Simonini***

* Department of Civil Environmental and Architectural Engineering (DICEA)
University of Padua (UNIPD)
Via Ognissanti 39, 35219, Padua, Italy
e-mail: francesca.ceccato@dicea.unipd.it

† Department of Civil and Environmental Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA, United States

## ABSTRACT

Many applications in geohazards prevention involve large deformations of unsaturated soils, e.g. rainfall induced landslides, embankment collapses due to wetting etc. These phenomena can be investigated with multiphase implementations of the Material Point Method (MPM) able to account for the behaviour of unsaturated soils. Recently, Yerro et al. [1] proposed a three-phase MPM formulation in which the governing equations are derived from the momentum balance and the mass balance equations of solid, liquid and gas phase assuming non-zero gas pressure. This approach takes into account the relative accelerations and relative velocities of the pore fluids and the primary unknowns are the absolute velocities of the phases ($v_s$–$v_l$–$v_g$ formulation). In contrast, Bandara et al. [2] and Wang et al. [3] used a simplified approach assuming zero gas pressure. Under this hypothesis the momentum balance equation of the gas can be neglected, thus reducing the computational cost.

The full three-phase formulation and the simplified approach are briefly presented and compared in this paper in order to highlight their potentialities and limitations with particular attention to engineering applications in soil mechanics. In particular, a 1D infiltration example and a wetting-induced slope stability problem are considered.

Despite the introduced simplifications, the simplified formulation gives reasonably good results in many engineering cases. On the other side, the three-phase formulation is more appropriate in some cases when the gas pressure differs from the atmospheric pressure, e.g. consolidation in confined conditions of gas reservoirs.

**Keywords**: MPM, Unsaturated soil

## REFERENCES

[1] A. Yerro, E. E. Alonso, and N. M. Pinyol, “The material point method for unsaturated soils,” *Géotechnique*, vol. 65, no. 3, pp. 201–217, 2015.

[2] S. S. Bandara, A. Ferrari, and L. Laloui, “Modelling landslides in unsaturated slopes subjected to rainfall infiltration using material point method,” *Int. J. Numer. Anal. Methods Geomech. (published online)*, 2016.

[3] B. Wang, P. J. Vardon, and M. A. Hicks, “Rainfall-induced slope collapse with coupled material point method,” *Eng. Geol.*, vol. 239, no. February, pp. 1–12, 2018.