Computational methods for localized erosion in porous media

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Abstract

We present two computational methods for the modeling of localized erosion propagating in saturated porous media [1]. In the first part of this work we describe a finite element formulation able to model, at the macro-scale, both the simultaneous processes observed in backward piping, i.e. the upstream oriented propagation and the cross-section enlargement of erosion conduits within the hydraulic work. The numerical formulation is based on a new analytical model for the localized erosion along a line propagating in a poro-elastoplastic porous medium. In this line, a conduit with evolving transverse size is embedded, which conveys a multi-phase flow fed by the solid and fluid masses exchanged by the erosion line with the surrounding porous medium. The two systems, i.e. porous medium and the pipe, share the same displacement- and pressure field. On the contrary, different fields are considered to describe the relevant flows, which are assumed as laminar in the porous medium and turbulent in the pipe. These two flows drive pipe propagation and enlargement, respectively, as modeled by means of proper erosion kinetic laws. The corresponding numerical method is based on the combination of one- and multi-dimensional finite elements [2], to model the erosion conduit and the porous medium, respectively. Some simulations are proposed to demonstrate the ability of the approach to reproduce experimental data of real-scale levee tests [3]. The application of the method in the analysis of the stability of excavations supported by diaphragm walls is presented as well. In the second part of this work we analyze, at the micro-scale, the backward erosion process driving the propagation mechanism of the erosion front. The numerical formulation is based on the coupling of the Discrete Element Method (DEM) with the Lattice Boltzmann Method (LBM) for the modeling of the solid- and the fluid phase, respectively [4]. The implementation of DEM follows a molecular dynamics approach and the interactions between grains are regulated by unilateral contacts and breakable bonds. The coupling with the LBM is based mainly on the implementation of non-slip conditions for moving boundaries (the grain boundaries). The scheme employed for the parallelization of the LBM code is also presented. Finally, we present the DEM-LBM numerical test on a granular soil REV located on the pipe front.

Keywords: **FEM, DEM-LBM coupling, backward piping, hydraulic works**

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