A computational method for piping erosion with hydro-mechanical coupling

Andrea Francesco Rotunno*,†, Carlo Callari◇ and Francesco Froiio†

*Department of of Civil and Computer Science Engineering (DICII)
University of Rome "Tor Vergata"
Via Politecnico 1, 00133 Roma, Italy
e-mail: a.rotunno@ing.uniroma2.it

◇Department of Biosciences and Territory, Engineering Division (DiBT)
University of Molise
Via De Sanctis, 86100 Campobasso, Italy
e-mail: carlo.callari@unimol.it - Web page: http://docenti.unimol.it/index.php?u=carlo.callari

† Laboratoire de Tribologie et Dynamique des Systèmes (LTDS)
École Centrale de Lyon
36 Avenue Guy de Collongue, 69134 Écully, France
e-mail: francesco.froiio@ec-lyon.fr

ABSTRACT

We have recently developed an innovative numerical method for localized erosion in multiphase porous media [1]. Such formulation is able to describe piping erosion, which consists in the upstream-oriented propagation and the simultaneous expansion of conduits in the porous medium. We consider the problem at the scale of civil engineering works (e.g. levees and cofferdams). Accordingly, the pipe is treated as a one-dimensional entity. To account for the exchange of fluid mass through the pipe walls, a lineic discontinuity of the Darcy flow in the porous medium is assumed at the conduit. Further contributions to the mass exchange between the porous medium and the conduit are those due to the erosion-induced pipe front propagation and pipe enlargement. Two kinetic laws are employed to model these two crucial processes, namely the backward erosion of the pipe front due to the normal Darcy flow (propagation) and the tangential erosion of the pipe walls due to the inner turbulent flow (enlargement). In the present work, the relevant erosion models are combined with an existing formulation [2] suited for problems in which the hydro-mechanical coupling plays a crucial role. As a representative example we propose a study of the unstable behaviour of sheet pile cofferdams, in the presence of piping along the sheet pile and of downstream surface heaving [3]. Finite elements with embedded strong discontinuities [4] are employed to simulate localized failure phenomena.

Acknowledgements. Research supported by GIS VOR 2012, LTDS 2012 and PRIN 2010-2011 (2010BFXRHS_004) projects as well as by one PhD fellowship (UniRoma2) and a VINCI mobility programme (Università italo-francese).

REFERENCES

[1] Rotunno, A.F., Callari, C. and Froiio, F. A finite element method for localized erosion in porous media with applications to backward piping in levees. *In preparation* (2017).

[2] Callari, C. and Abati, A. Finite element methods for unsaturated porous solids and their application to dam engineering problems. *Comput. Struct.* (2009) **87**:485–501.

[3] Marsland, A. Model experiments to study the influence of seepage on the stability of a sheeted excavation in sand. *Geotechnique* (1953) **3**:223–241.

[4] Callari, C., Armero, F. and Abati, A. Strong discontinuities in partially saturated poroplastic solids. *Comput. Methods in Appl. Mech. Eng.* (2010) **199**:1513–1535.