A FEM Model For Evaporation And Infiltration In Unsaturated Soils Interacting With The Atmosphere

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Abstract

The pore water pressure in the vadose zone is controlled by the interaction between the soil and the atmosphere through evaporation and infiltration. These processes are strongly influenced by the soil's hydraulic conductivity and water retention properties (Guida et al., 2023). In this contribution, we propose a numerical model based on the mass balance equations of the air and water species by including a storage term accounting for the changes in the liquid degree of saturation and, if necessary, in porosity. Liquid water and vapour mass transport occur via darcian flow and diffusion, respectively. Finally, the thermal energy balance is also considered, including the heat flux due to conduction and convection, in order to obtain the temperature field. The numerical model has been implemented using the Coefficient Form PDE interface available in the Mathematics module of the COMSOL Multiphysics® software. Then, it has been validated by reproducing experimental data from different geomaterials, including sand and cement-bentonite mixtures. As for the sand, experimental data coming from an evaporation test reported by Wilson (1990) has been successfully predicted, not only in terms of evaporation rate (Figure 1a) but also in terms of distribution in time and space of water content (Figure 1b), matric suction, temperature and vapour pressure. As for the cement-bentonite mixture, the model proved able to reproduce the experimental data reported by Musso et al. (2023), both during evaporation and water uptake (Figure 2a) stage via the introduction of the hysteresis of the retention properties of the material in the numerical model (Figure 2b).

Reference

G. Musso et al., Hydro-mechanical behaviour of a cement–bentonite mixture along evaporation and water-uptake controlled paths. Geomechanics for Energy and the Environment, 33, 100413 (2023).
G. Guida et al., The role of hydraulic and thermal properties of soil in evaporation: a numerical insight. Environmental Geotechnics, 40(XXXX), 1-18 (2023).
Wilson, G. W., Soil evaporative fluxes for geotechnical engineering problems (Doctoral dissertation, University of Saskatchewan) (1990).

Figures used in the abstract

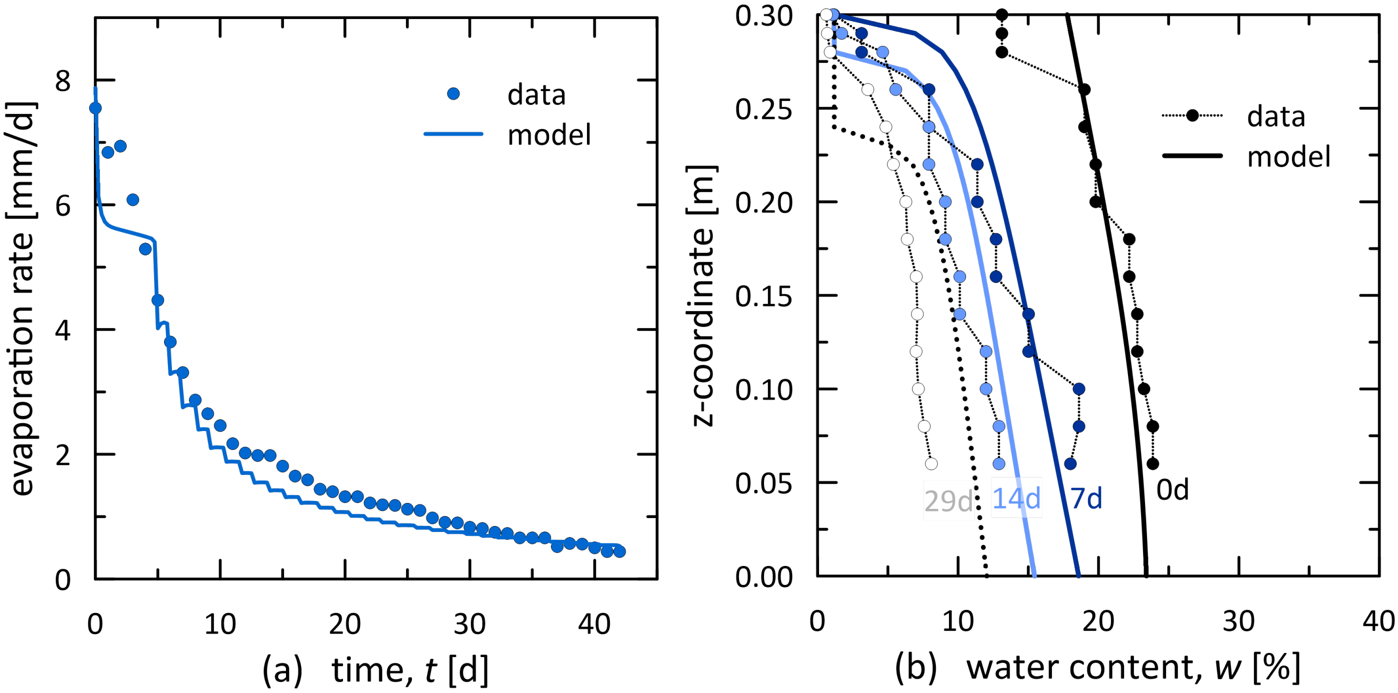

Figure 1 : Results of numerical simulation compared with the experimental data of evaporation on sand (Wilson et al., 1990) in terms of (a) evolution with time of the evaporation rate, and (b) profiles with depth of water content for different times.

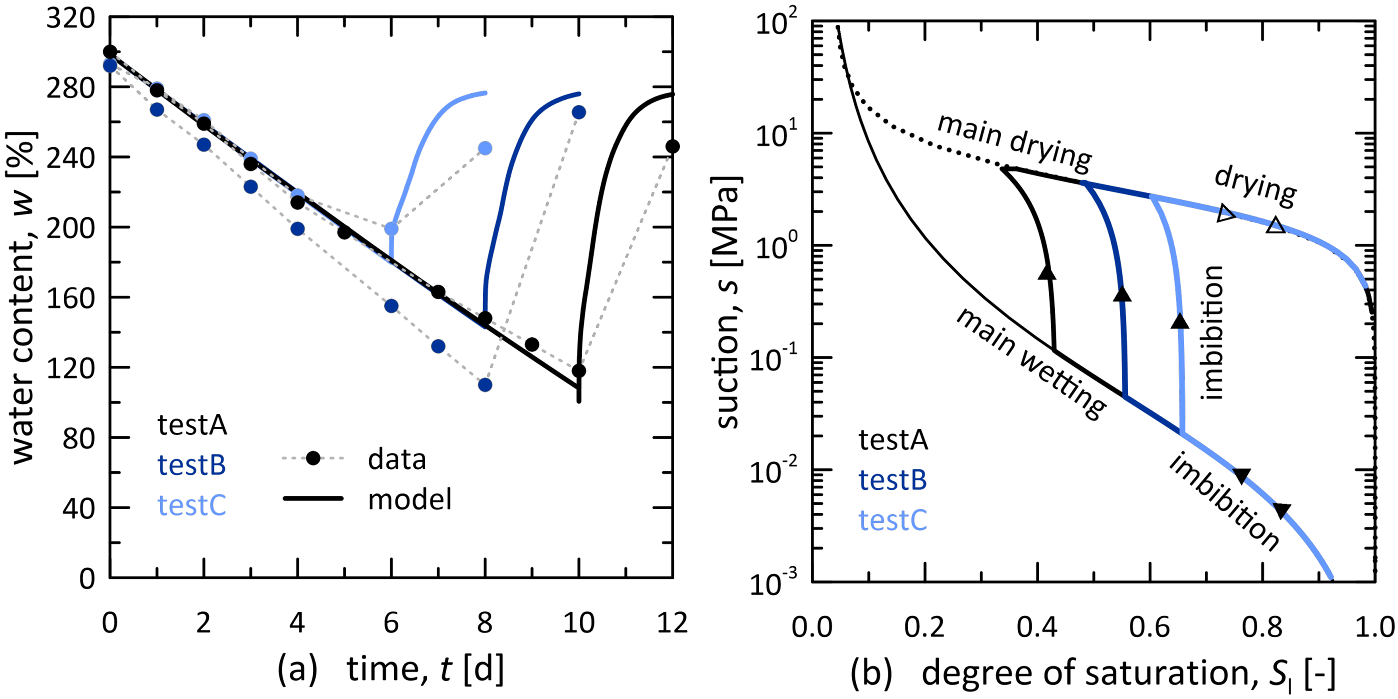

Figure 2 : (a) Evolution with time of the water content of cement-bentonite mixtures: model prediction versus experimental data (Musso et al., 2023). (b) Drying and imbibition paths on the water retention curve accounting for hysteresis.