CERIS : Civil Engineering Research and Innovation for Sustainability

Formulation of an advanced effective stress based constitutive model for unsaturated soils

PhD student
Carlos Manuel Pinto Pereira

PhD program
Civil Engineering (IST, University of Lisbon and LNEC)

Supervisor
João Ribas Maranha (LNEC)

Co-supervisor
Rafaela Cardoso (CERIS, IST, University of Lisbon)

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Summary

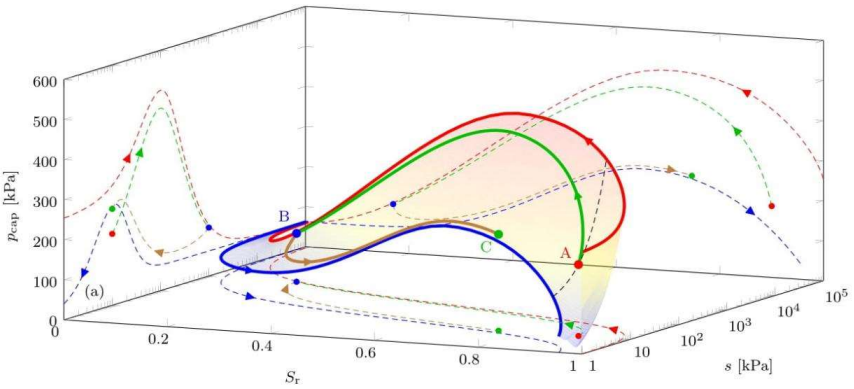
The main purpose of the thesis is to show that it is viable the use of a correct effective stress framework to model the behaviour of unsaturated soils, with the development of an adequate effective stress model being an essential factor. One of the main advantages of this methodology is the separation between the solid skeleton mechanical constitutive models, which can be those developed for saturated soils, and the effect of the partial saturation on the behaviour of the soil, being only influenced by the effective stress model. The effective stress framework consists on the solid skeleton mechanical, the soil-water retention and the effective stress models.

An isotropic effective stress model is proposed based on the main characteristics of the effective stress evolution in cubic spheres arrangements, incorporating hysteretic behaviour between drying and wetting paths and the dependency of specific volume and temperature, and being a function of the degree of saturation. A soil-water retention model is also proposed incorporating the hysteretic behaviour existent in drying and wetting paths, its dependency of specific volume and the incorporation of unsaturated states with zero suction. A rate-dependent (viscoplastic) and a rate-independent (elastoplastic) mechanical constitutive models, formulated with the subloading concept and the same hardening laws, was presented. The mechanical models can reproduce the cyclic, anisotropic and structured behaviour. Additionally, it is presented their expansion to non-isothermal conditions and the convergence of the response of the viscoplastic model to the elastoplastic model, when dealing with rate-independent soil behaviour (the elastoplastic model being more efficient). A generalised mixed stress-strain control for both viscoplastic and elastoplastic models in non-isothermal conditions is given.

The effective stress framework constituted by the proposed mathematical models can reproduce with success diverse and complex unsaturated laboratory tests, reproducing the main aspects of the unsaturated soils behaviour. It is concluded that with an adequate effective stress model, it is not necessary to modify the mechanical constitutive models, previously formulated for saturated soils, introducing dependence of several model parameters on suction, degree of saturation or other similar variables. Also, it is shown that with an adequate evolutionary algorithm, the number of parameters is no longer a relevant issue restraining the use of these complex constitutive models. A new version of the Differential Evolution method is developed to calibrate constitutive models for the laboratory tests available.

Keywords

Unsaturated soils, effective stress model, micromechanical models of spheres, non-isothermal constitutive models, differential evolution method.



Representation of the tridimensional surface of the capillary stress model.