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An evolving dual porosity model for the study of rainfall infiltration processes in fractured porous swelling soils

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In the last two decades a lot of models have been developed in order to simulate infiltration processes and preferential flow in the vadose zone. Some like dual-porosity/permeability or multi-porosity/permeability models are based on interacting regions (microporous matrix and macropores or fractures) with different hydraulic properties. This kind of models can be used to describe preferential water flow in unsaturated structured porous media. Most of existing models don't take in to account of shrinking-swelling dynamics of clayey soils that cause the closure of fractures and hold water flow. The presence of shrinking effect due to the presence of clay is the main cause of cracks formation in soils, which increases infiltration rate and reduces run-off. Moreover, during infiltration, the porous structure of clayey soils changes with moisture: as a consequence of soil swelling cracks close and there is a reduction in infiltration water flow.

To describe this kind of phenomena, an "evolving" dual-porosity model has been pointed out, in which fractures behave like pipes subjected to progressive narrowing due to water content increase in the swelling matrix. Water transfer from fractures to matrix has been modelled by a modified Richards equations with an interaction term depending on effective saturation gradient, while water diffusion process in matrix has been estimated in terms of adsorption phenomena related to head pressure gradient in soil.

The model has been used to simulate infiltration processes in a loamy soils characterized by shrinking cracks, for different values of rainfall intensity. In the model it has been considered also the presence of a layer of high permeability that create a capillary barrier effect at the interface between the two kind of soils. The application of the model has shown that, for intense precipitations, the water flowing in the fracture reaches significant depth (over 1,5 meters) in few minutes. Instead in the case of weak rains after the same amount of water rainfall, water remains confined in the top soil strata (70 cm) as a consequence of water diffusion in matrix. For severe precipitations there is a quite uniform swelling of soil elements along fracture, which corresponds a uniform closure of fractures. In the case of low intensity rainfall there is a differentiated swelling concentrated to the top of the soil until to create a fracture closure.

In the case of fine soil over coarse one there is a water storage in the upper strata due to capillarity barrier. For severe rainfall, the infiltration in fracture is fast, water is stored in the fracture until the high of water in the fracture is so high that the barrier is braked in a short of time and the break of capillary barrier involves first the fractures and afterwards the matrix. For rainfall of weak intensity there is a closure of cracks and amount of water that reaches the barrier is low so there isn't the break of the barrier for the maximum investigate rainfall time (2 hours and 10 mm).

Additional simulations have shown the effects related to the adoption of different values of key-parameters (swelling percentage, system geometry, etc.) showing that different percentage of swelling doesn't affect considerably the results while the effect of different swelling of matrix is much important for weak rainfalls and when fractures have an initial width very small.