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# Hydro-mechanical coupling of deformable porous solids with two immiscible phases

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Soils and rocks are amongst all, the most challenging construction materials to be studied. Currently, the elastoplastic theory has become popular when it comes to modelling their stress-strain behavior. This is because this theory is capable of considering the material strengthening, softening, ultimate strength and residual strength. In this paper, we present an elastoplastic constitutive model capable of predicting volume strains, strength and transport properties of deformable porous materials such as rocks and soils where internal pressure gradients exist.
To homogenize pore pressures arising from different fluids, it is proposed to formulate the model using the effective stress concept. To compute such effective stress, an elementary representative volume of the material is analyzed under mechanical equilibrium. This representative volume considers the most general case where three fractions may be found: a dry fraction f1, a saturated fraction f2 and an unsaturated fraction f3. The mechanical equilibrium of this elementary representative volume allows retrieving the following closed-form equation for the effective stress:

p' = pnet + (f1*Sr1+f2*Sr2+f3*Sr3)(u1-u2) (1)

Here, f1+f2+f3 = 1. Moreover, in Equation (1) , the effective stress is a function of the all-around stress applied to the material pnet (better known as net stress), the pressure difference between two immiscible phases and a product between each fraction and its corresponding degree of saturation.

The product (f1*Sr1+f2*Sr2+f3*Sr3) is closely related to the fluid transport properties of the porous medium. For the case of materials containing air and water, the extent to which water is allowed to flow through a porous solid is a function of the suction-degree of saturation relationship; this relationship is called soil-water characteristic curve. Now, these ideas highlight the importance of implementing an explicit model to predict the soil-water characteristic curve. This is performed with a mathematical model that simulates a porous network through which, the wetting and drying processes occur.

Finally, under the elastoplastic theory, the stress-strain equations are derived using the effective stress p' in Equation (1). It is important to point out that, because the effective stress depends on the degree of saturation of the three fractions, this approach naturally couples fluid transport properties and mechanical behavior. Moreover, a suitable yielding surface is imposed to account for the limit between elastic and elastoplastic strains that arise from the applied shearing and isotropic stresses to the porous solid.
The model predictions are confronted with experimental data where it can be shown that it can simulate stress-strain characteristics of porous materials subjected to variable regimes of saturation as well as the implications that the material strains have on its fluid transport properties.

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