On predicting pore fluid pressure changes in unsaturated porous media subject to undrained processes

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Predicting the induced change of fluid pressure in an unsaturated porous medium during undrained loading/unloading processes is challenging because two different fluids (a liquid and a gaseous solution) and a mixture of solid particles are involved. The relative presence of the two fluids and solid particles in the medium of interest, their stiffness, and the initial conditions in terms of liquid and gaseous pressure can play a crucial role in dictating the fluid pressures to be expected at the end of an undrained process. Knowledge of these pressure changes is essential because they affect the mechanical behavior of the porous medium, involving, for instance, its shear strength and volume. In this context, the analytical formulations of the so-called "pore pressure coefficients" proves to be a useful tool for making such predictions. A pore pressure coefficient is defined as the change in pressure of a fluid per unit change in total stress (the latter is the stress component of interest) (Lambe and Whitman, 1969). In contrast to existing models (Skempton, 1954; Hasan and Fredlund, 1980), this contribution proposes an analytical approach for determining unsaturated pore pressure coefficients, which adopts the generalized effective stress (Nuth and Laloui, 2008). It refers to an isotropic elastic unsaturated soil, and total stress changes under isotropic and oedometer conditions. It is shown that it is possible to define a unique pore pressure coefficient for an equivalent fluid. This has advantages in ensuring a direct transition between saturated and unsaturated state predictions. The proposed formulation also includes the analytical expression of the liquid-gas mixture stiffness; the latter is a function of the unique pore pressure and individual pore fluid coefficients. The number of constitutive parameters required for the applicability of the approach is lower than that needed to apply the currently existing approach for unsaturated soils (Hasan and Fredlund, 1980; Fredlund and Rahardjo, 1993). The proposed formulation also makes it easy to define the change in the soil water retention state resulting from the undrained process. Existing results in the literature are interpreted or predicted, highlighting the advantages and suitability of the proposed methodology.

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