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Forced air and water flow in granular media – models and experiments

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The physical processes governing advective and diffusive gas and a counter-current, convective water movement in soil are discussed and described using flow models and in situ measurements in controlled environment experiments. We present several coupled-flow models using analytical solutions to describe simplified physical problems and/or numerical models to describe in more detail the coupled, two-phase flow.
In general, air flow in wet soils is governed by three main forces: capillary, viscous, and gravitation (buoyancy). These forces are characterized by the capillary number (Ca), i.e. the ratio between viscosity and capillary forces, the Bond number (Bo) number, i.e. the ratio between gravitational and capillary forces, by the viscosity ratio of the fluids (M), and by the ratio between these dimensionless numbers.
For the case of gas injection into an unsaturated soil, where a "background"capillary pressure, significantly larger than the air entry value prevails (e.g. a phreatic surface located below the flow domain of interest), the macroscopic air flow is expected to follow the continuum approach formulation (Richards equation) for a much larger span of Ca, Bo and M numbers.
Furthermore, in the case of forced two-phase flow, i.e. independent injection of air and water, the water pressure gradient is expected to alter the effect of these □ numbers on air flow regime and distribution. For example, the role of buoyancy in the vertical water flow depends on the water flux direction (and magnitude), where a downward water flux reduces the effect of buoyancy while an upward water flow increases its effect.
Experiments, describing the effects of water content and forced two-phase flow (gas and water) were conducted in one- (narrow column) and three- (large Plexiglas barrels) dimensional set-up conditions. Measurements of transient and steady-state distributions of O2 concentration, water and air pressure, and volumetric water content for different tracer gas (N2 or air) injection rates (on a large span of Ca numbers), cycle duties, cycle periods, and injection depths are used to study several two-phase flow processes and phenomena, e.g., a counter-current flow of immiscible fluids, unsteady density-driven flow, hydrodynamic hysteresis, intrinsic and relative soil's air and water permeability, buoyancy effect, etc.
Interchanging between air (20.9% O2) and N2 (0% O2) gas injection enabled us to estimate the relative effect of counter O2 diffusion from the atmosphere, and in a complementary manner to evaluate the efficiency and effectiveness of forced soil aeration.
Comparing measurements to the prediction of different models is used to evaluate the applicability of different physical assumptions and of the continuum approach for describing air flow. Furthermore, several non-dimensional numbers and optimization parameters were proposed and evaluated using both measurements and models.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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