

Salt Migration in Granular Media

Abstract

Significant geotechnical problems arise when engineering site activities take place on or within saline soils. This is because the natural processes which allow saline soils to exist at equilibrium are changed. Because natural saline soils are complicated a simplified saline soil is created in the laboratory to understand how salts move under controlled conditions, and when boundary conditions are changed. Experiments comprised instrumented flow columns with siliceous sand as the host soil subjected at its base to a concentrated sodium chloride groundwater. Tests were conducted at constant temperature with a low relative humidity on exposed soil surfaces and with groundwater recharge to a constant level and at a constant salt concentration. Salt presence in aqueous, solid and intermediate states was monitored using electrical conductivity, shear wave propagation, time domain reflectometry (TDR), non-contact proximity and relative humidity sensors.

Auxiliary rising head tests in dry sand using pure water showed a capillarity rise within the height of the sand column, and that both saturated and unsaturated capillary zones could be identified. Moisture contents from weighing samples were consistent with TDR measurements. Comparison between pure water and brine in capillary tubes showed that brine achieves a significantly lower capillary rise height, so that even more space was available for the unsaturated zone in the experiments. Salt migration was observed to take place above the capillary zone by the upward flow of fluid towards the free surface which was subject to evaporation. Salt migration was found to take place by the formation of dendrites which propagate by a process of capillary rise, evaporation, and salt crystallisation which reduces the pore size and enhances the capillary effect inside the dendrite. Photographs and exhumations after the tests revealed the branching pattern of crystallisation which confers the name "dendrite" to this salt structure. The term 'autogenous wicking' was coined to describe this new understanding of heterogeneous salt transport in unsaturated granular media.

The salt migration was detected by monitoring changes in internal relative humidity, and in surface heave due to internal crystallisation. TDR probes showed no change in dielectric constant in the capillary zone but subtle changes in bulk electrical conductivity were used to infer the presence of dendrites. Changes in shear wave velocity were also observed but they could not adequately be interpreted due to the heterogeneity which developed in the columns. The upward spread of dendrites eventually lead to efflorescence of salt at the surface and the creation of a salt crust. Following this covering of the surface, the internal relative humidity was seen to rise with consequential changes observed in TDR measurements. Changing the boundary conditions to simulate engineering activities produced consistent changes within the soil.

The migratory mechanism of autogenous wicking may only be applicable where the capillary zone does not extend to the free surface, the groundwater level remains static and there is no fluid infiltration from above. This study of salt transportation may therefore only be applicable to granular soils under arid conditions where rapid evaporation takes place.