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Master Thesis Abstract

of Prakash Satenahalli

Streaming potential in variably saturated porous media

Streaming potential is the electric potential generated by fluid flow in a charged porous medium. The streaming potentials are related to pore-water velocity, bulk electrical conductivity, pore water excess charge, and soil water content. Although streaming potential in saturated conditions is well understood, there still is considerable debate about the adequate modelling of streaming potential signals in unsaturated soil because different concepts are available to estimate the effective excess charge in these conditions. Some studies have relied on a simple estimate of volume-based excess charge, whereas others proposed to use the flux-averaged excess charge derived from the water retention or the relative permeability function. The aim of this study is twofold. First, a coupled model for SP is developed to investigate the different models for the effective excess charge in unsaturated conditions, and to evaluate to what extent these models provide different predictions for SP during a dynamic infiltration and drainage event. For this, a coupled model to simulate SP for 1D flow problems was implemented with different concepts to calculate the effective volumetric excess charge. Second, laboratory experiments were performed to measure SP for infiltration and drainage of a 1-m long soil column using a new type of SP electrode that was expected to provide more reliable SP measurements. In addition, several SP electrode designs all based on the novel SP electrode design were evaluated with respect to electrode leakage, stability, and their response to a variation in pressure. The electrode types used were i) non-polarizing Ag-AgCl electrode with crystalline KCl solution in chambers ii) non-polarizing Ag-AgCl electrode that has the same water in the chamber as in the sample iii) bare Ag-AgCl electrodes without chambers. The experimental results were compared to the modelling results to identify the most appropriate model for the effective excess charge. The modelling results showed that the flux-averaged approaches for the effective excess charge predicted measurable SP at lower saturation, whereas the volume-averaged approach predicted negligible SP. Hence, previous studies which used drift corrections for the SP measurements may not be applicable. It was concluded that accurate SP measurements that do not need drift correction are required to identify the most appropriate concept to describe the effective excess charge in unsaturated conditions. The electrode tests showed that the novel SP electrode type was susceptible to leaking. It was also observed that the leaking rate varied considerably between electrodes, indicating a high variability in the properties of the electrode membrane. The electrodes were also found to be sensitive to pressure changes, which led to long-term drift and permanent potential offsets in electrodes with salt solution in the chamber. This is likely related to flow in and out of the membrane and resulting changes in the water composition in the membrane. The results of the infiltration and

drainage experiment with the 1-m long sand column using Ag-AgCl electrodes with salt solution in chambers also showed the long-term drift and delayed response observed in the electrode tests. Hence, the evaluation of different SP model concepts for unsaturated conditions was not feasible using these electrodes. The experiment with a reduced pressure gradient over the same electrode type used in the first experiment showed an improvement in drift as well as in response, but still a too wide spread of SP values for different electrode pairs was observed. The bare Ag-AgCl electrodes without chambers showed the most promising results in saturated conditions, although the range of SP differences for different electrode pairs was still high. The electrode behavior in unsaturated conditions was not consistent, perhaps due to a loss of contact with the medium. It was concluded that reliable measurements of self-potential in unsaturated conditions remains a challenging task. Future work should focus on the selection of electrodes that do not respond to pressure variation and have a small diaphragm limiting the leakage of electrolyte.