Monitoring transient hydro-mechanical processes in porous media using electrical resistivity tomography

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1 Outline

The electrical conductivity of a soil can be related to the electrical conductivity of solid skeleton and interstitial water by means of theoretical and empirical relationships, taking into account the effect of porosity, saturation degree, fabric and clay content. Hence monitoring electrical conductivity inside a soil sample can provide useful information related to the evolution of hydro-chemo-mechanical processes [1, 2]. A laboratory apparatus for electrical resistivity tomography in laboratory has been recently developed [3]. The 3D reconstruction of soil conductivity distribution is obtained with a FEM approach starting from measurements performed using 42 electrodes placed on the external boundary of the sample (Figure 1).

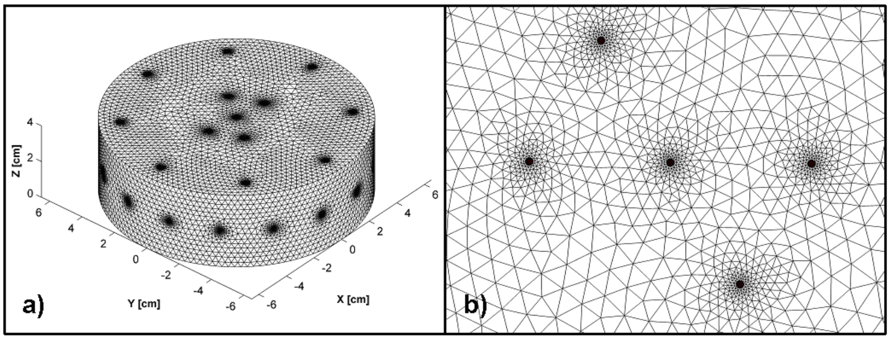

Figure 1: FEM Mesh: a) global view; b) detail showing refinements around the electrodes.

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2 Monitoring of transient phenomena in soils samples

Some results concerning chemical diffusion, mechanical consolidation and water saturation changes are shown in Figure 2. Figure 2a represents the reconstructed distribution of the electrical conductivity in a sand sample undergoing diffusion of sodium chloride, after 75 minutes from the beginning of the process. The sand sample was prepared with distilled water, while grains of NaCl where used as a source of salt at chemical saturation at the upper boundary of the cell. Thus, the increment of conductivity can be related in a straightforward manner to the increased chemical concentration, advancing with hemispherical front. Figure 2b refers to an analogous test, where a kaolinite cylinder having a thickness of 1 cm was placed in the central part of the sample. The image allows appreciating retarding effects due to adsorption in the clay level. As well, a lateral percolation of salt due to a loose contact of kaolinite with the cell walls is evident.

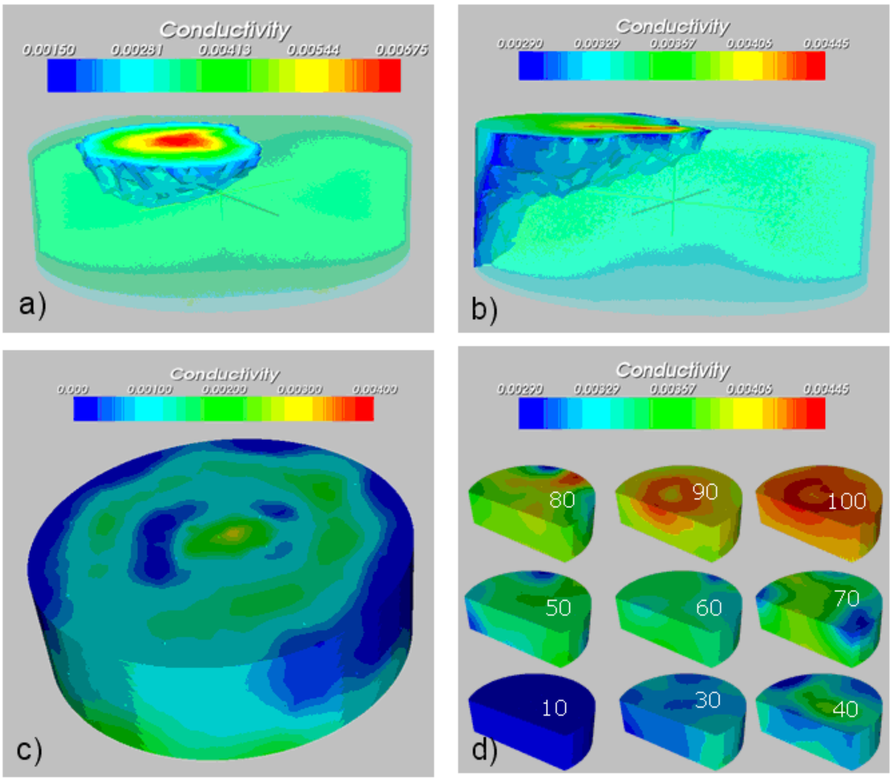

Figure 2: Examples of results (electrical conductivity values in S cm^{-1}).

Figure 2c is a differential image of two reconstructions done during a mechanical consolidation process. The higher values represent higher differences in local conductivities, indicating areas where consolidation increased further in the time span considered. The unusual distribution encountered is dictated by the hydraulic boundary conditions of the cell used, allowing water to flow only from three localized concentric drainages of micrometric thickness on the cell top. Figure 2d refers to images sand samples of equal porosities, prepared at different saturation degrees (data in %). The significant impact of saturation on electrical conductivity can be appreciated. Numerical simulations of the above experiments have been performed by means of an available software based on the Finite Element Method. Hydro-mechanical parameters introduced in the simulations were obtained through characterization tests different from the EIT reconstructions. Simulated salinity, porosity and saturation degree have then been used to estimate local theoretical values of electrical conductivity at different times, to be compared with the reconstructed ones. Very good matches between experiments and simulation have been found, suggesting that the technique could be used as well as a subsidiary tool for indirect determination of transport parameters and/or mechanical parameter, as proposed for in situ experiments [4].

References

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