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Direct simulation of resistivity on porous model obtained from high-resolution X-ray CT

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Resistivity imaging is widely used to estimate both the class ofgeo-materials (e.g., rock, sand, etc.) and the state variables of geo-materials (e.g., porosity, degree of saturation, etc.) on a cross-sectional plane (survey area) placed in the underground. For engineering use, the resistivity imaging of underground is adopted to observe the behavior of groundwater flow and to comprehend the changes of ground state caused by ground improvement. In order to increase the accuracy in the estimation of geological properties derived from resistivity imaging, we need to reveal the relationship between the resistivity and several physical parameters such as porosity, degree of saturation, and electrical conductivity of pore fluid. In other words, the resistivity has the dependency with those physical parameters.

Here, we have conducted a series of finite element simulations with above physical parameters to discuss the relationship between the resistivity of porous media and those physical parameters. The three-dimensional porous models are created by a series of sectional images obtained from the high-resolution X-ray CT. Although this method requires a precise micro-structure of porous media before the consideration, we can quantitatively estimate the resistivity of the porous model. This method also enables us to discuss the anisotropic properties on the resistivity by changing the direction of energization along the x, y, and z-axis.

Subsequently, the simulation results are compared with those obtained from experiments and with those derived from the empirical law, i.e., Archie's equation. According to the comparison, the simulation results are in good agreements with experimental results and indicate similar function form that proposed in Archie's equation being available for unsaturated state. Also, we have tried to extract the micro-scopic physical parameter such as the tortuosity. The tortuosity is one of the key parameters to characterize the transport properties of porous media, but it is difficult to measure the tortuosity through experiments.

Finally, we discuss the limitation of Archie's equation and infer that Archie's equation is applicable to geo-materials having a degree of saturation exceeding 40%.

Keywords: resistivity, porous media, finite element method, X-ray CT, Tortuosity