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Determination of the full permeability tensor

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This work presents a new method of determining the full permeability tensor. We have developed special permeameter allowing three-dimensional flow configuartions and a corresponding numerical program for data analysis. For comparison, we apply magnetic and optimal methods to characterize the anisotropy of the pore space in the samples.

Common permeameter experiments (e.g. according to DIN 18130) use a one–dimensional flow configuration, resulting in a single value of hydraulic conductivity, which is affected by the orientation of the sample in case of anisotropic samples.

The new designed three-dimensional permeameter has the shape of a 10cm$\times$10cm$\times$10cm cube (for consolidated rock) or a cylinder with 10cm height and 10cm diameter (for unconsolidated sediments), respectively. In the center of each site, a 3.3cm$\times$3.3cm filter screen is inserted. These screens can act as inflow, outflow, or may be short-circuited with other screens. This allows performing numerous measurements under different flow conditions with a single installation of the sample. We have selected 22 flow configurations, in which we measure the total flux through the domain and the hydraulic heads at each filter screen.

With 6 independent coefficients in the conductivity tensor to be determined, we arrive at an overdetermined parameter-estimation problem. The latter is done by a Levenberg-Marquardt method coupled to a three-dimensional FEM code for flow simulation. In addition, we compute the sensitivity of the determined conductivity tensor on local fluctuations of the true conductivity distribution by the adjoint-state method.

For comparison, we fill the pore space of the samples with a ferrofluid and measure

the anisotropy of the magnetic susceptibility tensor of the filled sample. Finally, the pore space is analyzed by optical investigations.

Thus, we determine three different tensors: a hydraulic conductivity tensors and two tensors representing the anisotropy of the pore space, which may differ, because hydraulic anisotropy may be controlled by anisotropy in the spatial variation of the pore size, whereas the other two methods measure the anisotropy of the pore shapes.