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Estimating the hydraulic apertures in fractured rocks using different methods

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Fractures represent the main flow paths in crystalline and many sedimentary rocks and therefore govern the hydraulic properties of fissured aquifers and reservoirs. Hence, the knowledge of hydraulic fracture apertures is crucial for modelling flow and solute transport in fractured rocks. In this study we therefore analyzed and compared three distinct methods for the determination of the hydraulic aperture using a syringe air permeameter (1), a microscope camera (2), and a 3D laser scanner (3) by applying them to a natural bedding joint of a Permian sandstone.

With the air permeameter, a mean hydraulic bedding joint aperture of 82 μm could be obtained. A similar hydraulic aperture of 89 μm could be derived from microscope camera pictures using relative roughness and a rock specific empirical equation for conversion of the measured mechanical aperture. With the 3D laser scanning, we encountered problems with identifying clear fracture edges due to a thinning of the captured point cloud caused by breakouts and reflection phenomena, consequently producing mean mechanical apertures 167 μm larger than those obtained by the microscope camera. While laser scanning yielded realistic mean values for the joint roughness coefficient of the bedding joint that could be obtained by extracting two dimensional profiles from point clouds, overestimation of the mechanical aperture also led to a higher mean hydraulic aperture. The mean hydraulic aperture obtained by laser scanning deviates on average by 173 μm from the apertures measured by air permeameter and by 170 μm from the aperture derived from microscope camera pictures.

With regard to the high costs, extensive data processing and elaborate handling of 3D laser scanning, this method did not provide valuable results. Furthermore, comparability of the laser scanning measurements with the other two methods is low. Due to its easy application and mobility, the air permeameter proved to be a practical and efficient tool for the determination of the hydraulic fracture aperture both in the laboratory and field, as large amounts of data can be acquired fast with only minor effort. Alternatively, the use of a microscope camera can be recommended if application of the air permeameter is difficult due to strongly uneven or curved surfaces of outcrops or drilling cores.