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Measuring the thermal conductivity of sandstones

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The sandstones of the Middle and Upper Buntsandstein are suitable host rocks for the installation of shallow geothermal systems due to their high thermal conductivities typically ranging between 1.9 to 4.6 W m^{-1} K^{-1} (Verein Deutscher Ingenieure 2010). Knowledge of the effective thermal conductivity is crucial to efficiently dimension borehole heat exchanger (BHE) systems. The standard method for determining effective thermal conductivities at a site is the thermal response test (TRT). However, thermal conductivity can also be analysed in the laboratory from core samples. In addition, various prediction models for the estimation of thermal conductivity based on lithological properties, such as porosity, exist. In this study, depth-specific thermal conductivities of sandstone samples of the Upper and Middle Buntsandstein are comprehensively analysed by applying different methods. First, thermal conductivities of about 140 core samples are analysed in the laboratory, and relations between material properties, such as porosity and mineralogy, and thermal conductivity are investigated. Furthermore, common prediction models are applied, and in addition, the measured and estimated thermal conductivities are compared to the effective thermal conductivities evaluated with an enhanced thermal response test (ETRT). The average effective thermal conductivity analysed with the ETRT is 4.7 W m^{-1} K^{-1}, while the thermal conductivities analysed in the laboratory on saturated core samples range between 2.7 to 6.4 W m^{-1} K^{-1} with an average value of 4.6 W m^{-1} K^{-1}. The best estimate from the prediction models is achieved by the Voigt-Reuss-Hill model with an average error of 13 % and a maximum error of 26 %. Overall, prediction models that assume a random distribution of solid and fluid components can achieve reliable estimates of the thermal conductivity of the sandstone. Thus, the results demonstrate that laboratory analyses can provide representative values of the effective thermal conductivities at a site with negligible or low groundwater flow. However, we also show that in order to achieve a representative value a sufficient number of samples has to be analysed, which entails high expenses for laboratory analyses.

Verein Deutscher Ingeniere. VDI 4640, part 1: Thermal use of the underground, fundamentals, approvals, environmental aspects, 2010.