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Thermophysical parameters from laboratory measurements and tests in borehole heat exchangers

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Besides the type of thermal regime, the performance of borehole heat exchangers relies on the overall thermal resistance of the borehole. This parameter strongly depends on the underground thermal conductivity, which accounts for most of the heat that can be extracted. The geometric configuration and the increase of thermal conductivity of the grout filling back the bore can yield a non-negligible enhancement in thermal performances. In this paper, we present a study on a pilot geothermal plant consisting of two borehole heat exchangers, 95 m deep and 9 m apart. Laboratory and in situ tests were carried out with the aim of investigating underground thermal properties, mechanisms of heat transfer and thermal characteristics of the filling grouts. Samples of grouting materials were analysed in the lab for assessing the thermal conductivity. An attempt to improve the thermal conductivity was made by doping grouts with alumina. Results showed that alumina large concentrations can increase the thermal conductivity by 25-30%. The in situ experiments included thermal logs under conditions of thermal equilibrium and thermal response tests (TRTs). The analysis of the temperature-depth profiles, based on the mass and energy balance in permeable horizons with uniform thermo-hydraulic and steady-state conditions, revealed that the underground thermal regime is dominated by conduction. TRTs were performed by injecting a constant heat rate per unit length into the boreholes for 60-90 hours. After TRTs, the temperature drop off (TDO) was recorded at 20-m-depth intervals for one week in both holes. The TRT time series were interpreted according to the classical model of the infinite line source (ILS), to infer the underground thermal conductivity. The TDO records allowed the inference of the underground thermal properties variation with depth. The results of thermal conductivity inferred with the ILS method are consistent with the values obtained from the TDO analysis.