Comparative methods to determine thermal conductivity of grouting mixtures and 3D simulations in vertical closed-loop system

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Thermo-physical properties of grouting mixtures and 3D simulations in vertical closed-loop geothermal system.

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Knowledge of thermophysical properties of grouting materials is one of the important factors to improve the heat exchange between pipes and the ground in vertical closed-loop geothermal systems. The use of a proper grout is in fact essential in order to guarantee an effective heat transfer between the ground and the heat carrier fluid in the pipe. Generally, the commercial demand is of a workable and cheaper geothermal grout, not always paying attention to the thermal and mechanical characteristics. In particular, since thermal conductivity is a fundamental property to be considered, the main objective of this paper is to study the physical properties of suitable material to be used as geothermal grout. To this regard, different mixtures were investigated and thermal, mechanical, and mineralogical properties were tested after twenty-eight days of hardening. We tested two commercial geothermal grouts adding different quantities of water, and two composed of Portland cement and quartz sand in different percentages. In order to obtain reliable results, thermal properties were evaluated through the use of three devices working on different principles both in steady state and in transient conditions. Moreover, with the aim of characterizing the four mixtures, strength and homogeneity of the analysed materials through ultrasonic pulse velocity (UPV), together with mineralogical determinations through X-ray diffraction (XRD) were determined. The results reveal that commercial geothermal grouts present lower values of thermal conductivity (0.9-1.2 W m-1K-1) compared to that claimed (2.0-2.5 W m-1K-1), and approach those measured on the cement and sand mixtures (0.5-0. 7 W m-1K-1). The slightly differences between the two group of mixtures, are probably related to the different mineralogical composition and to the distinct mechanical characteristics. Moreover, since alumina is an highly conductivity element, two further mixtures consisting on Portland cement, quartz sand and alumina shavings in various proportions were tested, leading to an improvement of both thermal and mechanical properties. Three-dimensional thermal simulations of BHE filled with the different grout mixtures and located in different geological and hydrogeological conditions, were also realized by means of a numerical approach. First results confirm the importance of the thermal properties of grout as well as those of the underground in increasing the efficiency of closed-loop geothermal systems.