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New borehole heat exchanger thermal enhanced grout formulations

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In shallow geothermal systems, especially ground source heat pumps (GSHP), cementitious grouts play a decisive role in guaranteeing an efficient heat transfer between the probe and the surrounding ground. Several studies have been devoted to understand the effect of different additives (silica sand, graphite, fluorspar, glass and fly ash …) in improving especially the thermal conductivity of such mixtures, maintaining at the same time physical properties as viscosity and workability suitable for in situ application. In fact, when continuous operation mode is running, thermal conductivity shows a positive effect on the mean heat exchange rate of vertical borehole heat exchangers (BHE). However, when an intermittent operation mode is selected, the BHE performance improves when a high thermal conductivity is coupled with a high specific heat capacity.

This research focus on assessing the contribution of two specific thermal additives (silica sand and molybdenum disulphide powder) to the thermal properties' improvements of a specific commercial cementitious grout. These components are added in different proportion to the grout, up to the creation of 6 different mixtures. For each mixture 3 specimens are prepared, in order to perform the thermo-physical analyses. In addition, other 3 commercial grouts are considered. A total of 10 mixtures, leading to the creation of 30 specimens, have been analyzed. Then, thermal conductivity, thermal diffusivity and specific heat capacity of each specimen measured in anhydrous and saturated conditions are considered.

The commercial grouts prepared as stated by the producers show, as expected, a minimum variation of their thermal properties in wet and anhydrous conditions. Instead, when the additives are used, a noticeable improvement of the thermal properties is observed in saturated conditions, where the effect of silica sand seems dominant. The best thermal properties improvement obtained by combining the two additives is also considered.

However, the grouts suitability to be easily managed on site must be considered because, even if the new mixtures show a general gain of the thermal properties, these can be difficult to apply

going from laboratory to full scale.

Anyway, the characterization of the grouts thermal properties based on composition and saturation variations is important not only in numerical simulations, but also in analytical approaches, typical of the heat exchange probe fields sizing processes. In fact, the cementitious grouts play a key role in determining the shallow geothermal systems efficiency in transient mode operation, often neglected by sizing programs. In fact, those characterized by better thermal performances will contribute to the reduction of the borehole thermal resistances, interposed in the heat exchange processes between the heat transfer fluid and the ground. Finally, this research contributes to fill the gap between numerical simulation and experimental data, providing real data to be used as database for further numerical modelling analysis improvement.

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