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# Deformations and permeability variations in fine sediments induced by freezing-thawing cycles caused by borehole heat exchangers

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In closed-loop Ground Source Heat Pump system, the circulation of a heat-carrier fluid into the heat exchanger provides the thermal exchange with the underground.

In order to improve the heat extraction from the ground, the fluid temperature is often lowered down to subzero temperatures; as a consequence, the thermal alteration induced in the ground is more intense and can cause freezing processes in the surroundings. In sediments with significant clay fraction, the inner structure and the pore size distribution are irreversibly altered by freezing-thawing cycles.

A wide laboratory program has been performed in order to measure the induced deformations and the permeability variations under different conditions of mechanical loads/depth [1], interstitial water salinity [2] and soil plasticity [3]. In addition, vertical deformations and permeability variations induced by freeze-thaw cycles have been measured also in Over-Consolidated silty clays at different OCR [4].

The results suggest that, despite the induced frozen condition is quite confined close to the borehole [5], in Normal-Consolidated silty clay layers the freezing-thawing-cycles induce an irreversible settlement up to 16%, gathered cycle-after cycle depending on sediment plasticity, pore fluid salinity and applied load. In addition, despite the overall contraction of the soil, the vertical hydraulic conductivity may increase by about 8 times due to a remarkable modification of the soil fabric with increases in pore size, pores connectivity and orientation [6].

The OC silty-clays show an opposite behavior. Experimental results point out that, in case of OC deposits, higher the OCR lower the freeze-thaw induced settlement. In case of OCR > 15, the settlement turns to a slight expansion. Conversely, the observed augment in vertical permeability increases with the OCR degree [4].

These occurrences are significant and irreversible and could affect the functionality of the system as well as lead to environmental effects such as local settlements, negative friction on the borehole heat exchangers or interconnection among aquifers in the probe surroundings.

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