Seasonal Thermal Performance of Geothermal Piles

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Abstract

The use of foundation piles as ground heat exchangers coupled to a geothermal heat pump is considered of interest for possible savings in installation costs, compared to conventional borehole heat exchangers. We refer to them as "geothermal piles" or "energy piles". The main purpose of the foundation structure is to transmit the load of the building to the lower layers of the soil, best suited to support it. Its additional use for energy purposes has been tested for about 20 years.
Current design methodologies are based on a few technical standards [1-2] and the use of dedicated software [3]; yet, detailed heat transfer models are still under development and validation. Further refinement is necessary to obtain improved accuracy. In fact, to ensure an optimal design of the energy piles, it is necessary to take into account a considerable number of factors, such as:
- type and geometry of the structure;
- convective-conductive 3D heat exchange phenomena within pipeline, concrete, and soil;
- composition and thermophysical properties of different ground layers;
- precise knowledge of boundary conditions at the interface between the foundation piles and the building basement and at the ground surface.
Transient conduction is simulated in the concrete structure of the pile and in the surrounding soil. The analytical solutions of the line-source and cylindrical-source models are compared to the computational results at different distances from the pile and as a function of time. Forced convection heat transfer in the pipeline is separately modeled and imposed as a heat-sink boundary condition for the solid domain.
The thermal performance of the geothermal pile is evaluated for four types of ground heat exchangers: single U-shaped, double U-shaped, W-shaped and triple U-shaped.
The decay of ground heat exchange performance is observed during four months of continuous operation, corresponding to a typical heating season in Mediterranean countries. Heat removal from the pipeline is then arrested and residual thermal gradients are monitored in the subsequent months, to reach a one-year cycle and evaluate the ground temperature drift.
The results of the simulations are expected to provide preliminary guidance for the design process of such ground heat exchangers.

Reference

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[3] Daniel Pahud, PILESIM2 – Simulation Tool for Heating/Cooling Systems with Energy Piles or Multiple Borehole Heat Exchangers, Institute for Applied Sustainability to the Built Environment, SUPSI, Switzerland.