Analysis of Multiphysics Problems Related to Energy Piles

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Abstract

Geothermal energy is used for space heating and cooling in buildings. One way of achieving this goal is to make use of the foundations of buildings. Deep foundations which transfer the mechanical loads from buildings to the ground and also serve as energy exchangers are called energy piles (Brandl, 1998). These piles contain tubes to circulate fluid that accelerates the heat transfer. The thermal energy coming from the building is transferred into the ground for cooling purposes in the summer. The process is reversed in the winter for heating the building. The schematic view of an energy pile is shown in Figure 1. The efficiency of energy piles depends on their dimensions, the heat and moisture transfer characteristics of the soil and the type of pile material. Heat transfer also takes place between the pile and the soil. This process can be divided into (1) heat conduction between the pile material and the soil, (2) heat conduction within the soil mass, and (3) heat convection via subsurface fluid flow. Heat transfer and fluid flow in soils are strongly coupled processes. The authors (Infante et al. 2011, COMSOL Conference) published the results of an investigation on the heat and moisture transfer problems around an energy pile without including the mechanical aspects of the problem. The changes in moisture content strongly affect the mechanical behavior of soils. In other words, mechanical behavior and fluid flow are coupled processes. Therefore, the load transfer function of an energy pile is not independent from its heat transfer function. A full investigation of the behavior of an energy pile requires an analysis that takes into consideration the mechanical, thermal, and fluid flow aspects of the problem simultaneously. Piles transfer the building loads to the ground (1) at the surface of the pile shaft and (2) at their toes (Figure 1). In the calculations of these two components, the following physics needs to be considered: the temperature changes which cause moisture movement in the soil, and the mechanical behavior, including adhesion and friction angle at the interface, which is affected by the moisture content. This problem is investigated with interface experiments between a soil mixture and a steel plate representing the pile shaft. In the numerical analysis, the soil mass and the "contact zone" between the soil and the pile need to have mechanical properties specified as a function of soil moisture content. In the present analysis using COMSOL Multiphysics Code, the building load versus the displacement response of an energy pile will be investigated numerically. The thermal and hydraulic effects on the soil behavior will be taken into consideration. The properties of the contact zone between the soil and the energy pile will be expressed as a function of moisture content of the soil. A simultaneous solution of this Multiphysics problem requires the use of Structural Mechanics, Heat Transfer, Geomechanics and Subsurface Flow Modules.

Figures used in the abstract

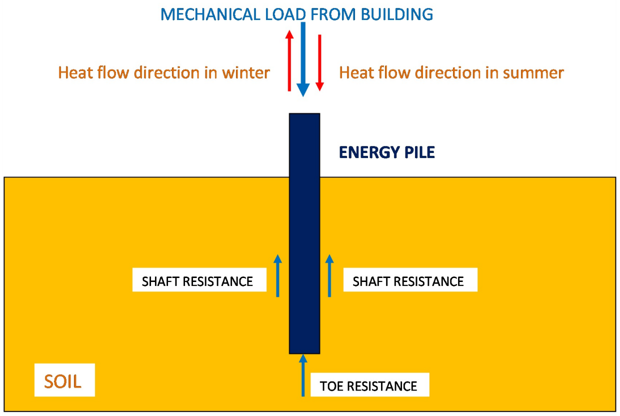

Figure1. Dual function of an energy pile: Heat transfer and the transfer of building load to soil mass.

Figure 1

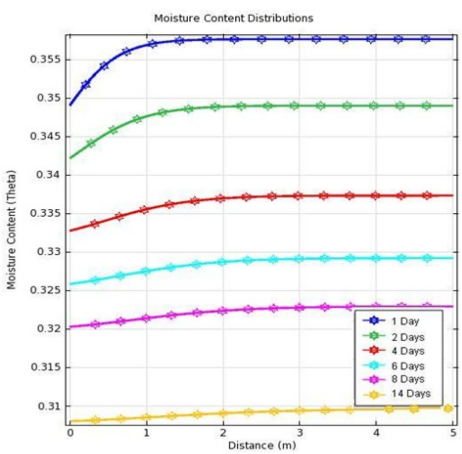

Figure 2. Moisture content distribution in the soil mass as a function of time. The changes in the moisture content is the result of heat transfer. The pile shaft is located at Distance=0 m. Analysis was carried out using COMSOL Multiphysics Code.

Figure 2

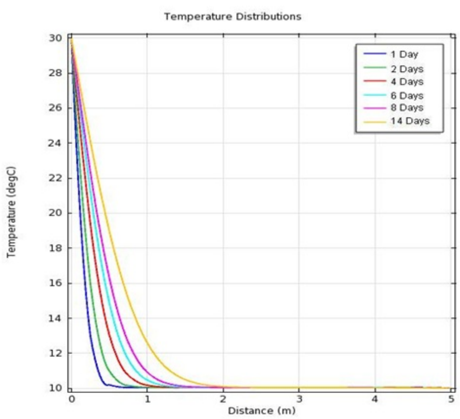

Figure 3. Temperature distribution in the soil mass as a function of time. The pile shaft is located at Distance=0 m. Analysis was carried out using COMSOL Multiphysics Code.

Figure 3