Geomechanics and Engineering, *Vol. 6, No. 1 (2014) 79-98*
DOI: http://dx.doi.org/10.12989/gae.2014.6.1.079

Thermal transfer behavior in two types of W-shape ground heat exchangers installed in multilayer soils

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(*Received June 18, 2013, Revised August 29, 2013, Accepted September 16, 2013*)

Abstract. This paper presents an experimental and numerical study on the evaluation of a thermal response test using a precast high-strength concrete (PHC) energy pile and a closed vertical system with W-type ground heat exchangers (GHEs). Field thermal response tests (TRTs) were conducted on a PHC energy pile and on a general vertical GHE installed in a multiple layered soil ground. The equivalent ground thermal conductivity was determined by using the results from TRTs. A simple analytical solution is suggested in this research to derive an equivalent ground thermal conductivity of the multilayered soils for vertically buried GHEs. The PHC energy pile and general vertical system were numerically modeled using a three dimensional finite element method to compare the results with TRTs'. Borehole thermal resistance values were also obtained from the numerical results, and they were compared with various analytical solutions. Additionally, the effect of ground thermal conductivity on the borehole thermal resistance was analyzed.

Keywords: ground thermal conductivity; borehole thermal resistance; ground heat exchanger; thermal response test; numerical analysis

1. Introduction

Recently, the need for renewable energy sources is constantly increasing with the advent of global warming and the depletion of fossil energy. Geothermal energy has great potential as a directly usable type of energy, especially in connection with ground source or ground coupled heat pump (GCHP) systems, to achieve energy-efficient spaces for cooling and heating (Johnston *et al*. 2011). The GCHP systems use the ground as a heat source or reservoir, as it provides a relatively constant temperature. It releases heat energy during winter, while it absorbs heat energy in summer (International Energy Agency 2010). GCHP systems are available as both open and closed systems. The open system exchanges heat to/from aquifer water, while the closed system exchanges heat to/from the ground by a fluid circulating in heat exchange pipes. The closed system can be largely divided into vertical and horizontal types depending on the way that the exchange pipes are installed. The horizontal system requires the installation of a large number of GHEs parallel to the

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http://www.techno-press.org/?journal=gae&subpage=7 ISSN: 2005-307X (Print), 2092-6219 (Online)

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