



HAL
open science

Hydrothermal Modeling of Pile Heat Exchangers in the Unsaturated Zone

Charles Maragna, Xavier Rachez

► **To cite this version:**

Charles Maragna, Xavier Rachez. Hydrothermal Modeling of Pile Heat Exchangers in the Unsaturated Zone. 1st Workshop on Numerical Geothermal Simulation, Apr 2015, Munich, Germany. hal-01120945

HAL Id: hal-01120945

<https://hal.science/hal-01120945>

Submitted on 3 Mar 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Hydrothermal Modeling of Pile Heat Exchangers in the Unsaturated Zone

Charles Maragna and Xavier Rachez

BRGM, 3 Avenue Claude-Guillemin, BP 36009 - 45060 Orléans cedex 2 - France

c.maragna@brgm.fr

Abstract

Pile heat exchangers (PHE) are an attractive way to exchange thermal energy with shallow underground since they combine the structural role of geostructures with ground heat exchangers, making it possible to mutualize both investments. PHE are typically 5 to 20 m deep and can be partially located in the unsaturated (vadose) zone. Thermal properties of soil depend on water content, which is heterogeneous in the unsaturated zone. The presented study investigates the influence of groundwater table depth upon the amount of heat transferred by the PHE. It is a part of a research project “GECKO” (*geo-structures and hybrid solar panel coupling for optimized energy storage*) which is supported by a grant from the French National Research Agency (ANR). The authors focused on deriving an effective thermal conductivity of the ground, denoted $\overline{\lambda}_m$, as this value is essential to a consistent PHE sizing. A three-dimensional finite elements (FE) model developed in COMSOL-Multiphysics® of a 10 m deep PHE has been set up. The geometry of the pipes, pile concrete and surrounding ground is discretized. Stationary distribution of matric potential is determined by solving the Richards equation while the resolution of the heat equation leads to the temperature evolution in the heat-carrier fluid, the concrete and the surrounding ground. Several cases were modelled for ground water table depths ranging from 0.5 m to 9.5 m (cf. Figure 1). The two mentioned bounds respectively correspond to situation where the PHE stands in almost saturated or unsaturated soil. The considered soil, a homogenous Fontainebleau sand, is subject to large water content variations which lead to large thermal conductivity variations: The estimated thermal conductivity is $3.01 \text{ W.K}^{-1}.\text{m}^{-1}$ at saturation, i.e. matric potential $\psi = 0 \text{ m}$, and $0.46 \text{ W.K}^{-1}.\text{m}^{-1}$ for $\psi = -10 \text{ m}$. Other soils ranging from clay to sandy loam exhibit a smaller influence of moisture content and matric potential upon thermal conductivity. To determine an effective thermal conductivity of the ground $\overline{\lambda}_m$ the PHE was subject to a thermal response test (TRT) – i.e. a constant power given to the heat-carrier fluid. $\overline{\lambda}_m$ was estimated based on the evolution of fluid temperature, according to state-of-the-art procedures for TRT interpretations. The analytical model used for the interpretation considers that the pile behaves as an infinite line emitting a constant heat flow in a homogenous media. $\overline{\lambda}_m$ is tuned so that the evolutions of inlet/outlet averaged fluid temperatures computed by both models (FE and analytical) match. As a result, $\overline{\lambda}_m$ ranges from $3.01 \pm 0.01 \text{ W.K}^{-1}.\text{m}^{-1}$ for a groundwater level depth of 0.5 m to $1.33 \pm 0.04 \text{ W.K}^{-1}.\text{m}^{-1}$ for a groundwater level depth of 9.5 m. The effective thermal conductivity $\overline{\lambda}_m$ is almost identical to the ground conductivity averaged over the PHE height. These preliminary results suggest that for a single PHE standing in an unsaturated soil the temperature evolution of the heat-carrier fluid can correctly be described by an analytical model considering a homogenous media whose thermal conductivity is equal to the averaged ground conductivity. Further development should focus on similar study for a group of PHE.

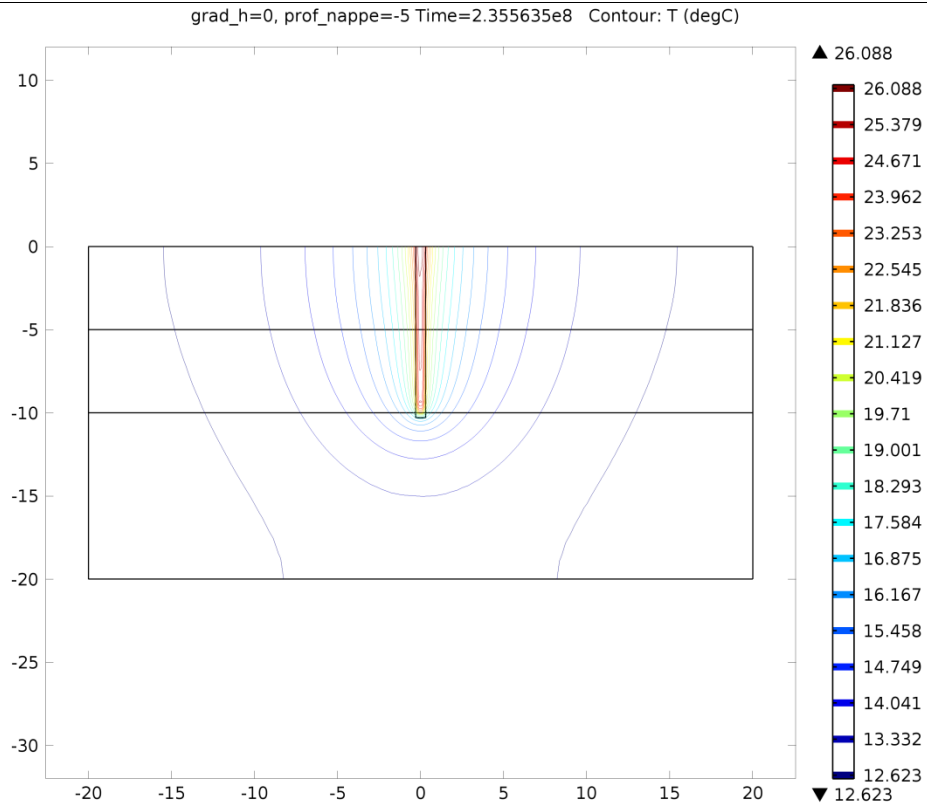


Figure 1 : Cross-sectional view of temperature field (°C) around a 10 m deep pile heat exchanger after 7.4 years with a constant exchanged power at 500 W. The water table is located at 5 m depth.