THERMAL PROPERTIES DEPENDENCE OF BOREHOLE HEAT EXCHANGERS FOR HEAT PUMPS ON GROUTING MATERIAL

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Introduction

Currently, in Poland, there is a continuous development of the heat pump market. The main increase in the heat pump market is observed in terms of air-to-water heat pumps, both for domestic hot water as well as those for heating and domestic hot water. Nevertheless, the market of ground heat pumps is also growing, however, although its dynamics is lower than the dynamics of the increase in sales of air heat pumps.

In case of ground source heat pumps, apart from the quality of the device, it is extremely important to design and construct proper heat source. For borehole heat exchangers which are the most popular form of ground source, thermal response tests (TRT) are performed (Śliwa et al., 2017). The test results, properly developed, provide information on the average undisturbed ground temperature, as well as the effective thermal conductivity of the ground and the thermal resistance of the borehole heat exchanger. Thermal conductivity depends mainly on the thermal parameters of the rock, and the borehole thermal resistance depends on the quality and technology of borehole heat exchanger construction.

The Centre of Sustainable Development and Energy Saving WGGiOŚ AGH in Miękinia, conducts educational, research and development activities in the field of heat pumps and ground sources. On the area of the Centre there are several borehole heat exchangers for heating, cooling and testing. To broaden the spectrum of both educational and research activities, it was necessary to expand the activity by testing borehole heat exchangers (BHE). For this purpose the thermal response test rig was developed.

Materials and methods

The most popular method on interpretation of TRT test results is the line-source model. This method has been adopted to describe the heat transfer in the lower heat source by Ingersoll and Plass (Liu et al., 2017; Nordell, 2011). This model defines a vertical exchanger as an infinite linear source and skip the heat flow from the ground surface and the heat flow from the depths of the Earth. The ground is defined as an infinite medium with a uniform temperature. The heat conduction process is simplified to one-dimensional, skipping the heat flow along the axis of the hole.

To make a tests a mobile equipment for TRT constructed in the Centre in Miekinia was used(Fig.1). The TRT test was done on two borehole heat exchangers each 100m depth. In the boreholes profile are:

- from 0 to 15m depth – fine-grained sand,
- from 15 to 24m depth – gravel with clay addition
- from 24 to 100m depth – grey loam

One of the borehole heat exchanger (BHE1) was filled by bentonite and water mixture and the second (BHE2) was backfilled by drilling cuttings from the borehole (grey loam). Each borehole was grouted from the bottom to top.

Figure 1. *TRT device during borehole heat exchanger testing*

Results

The conducted thermal response tests conditions and results are in the table 1.

Table 1. *Conditions and results of conducted thermal response test for two BHE*

	BHE 1	BHE 2
Lenght of the BHE (m)	100	100
Diameter of BHE (mm)	153	153
Type of the pipe	U-pipe PE 40x3 mm SDR13.6	U-pipe PE 40x3 mm SDR13.6
Backfilling material	Bentonite (100 kg bentonite per 1000 kg of water)	Drilling cuttings from borehole (grey loam mixed with water)
Medium (carrier fluid)	Propylene glycol and water solution (crystallization temperature : -15°C)	Propylene glycol and water solution (crystallization temperature : -15°C)
Flow rate (l/h)	630	780
Test conditions	Turbulent flow	Turbulent flow
Undisturbed ground temeprature (°C)	12.99	12.88
Average heating power (W)	3979	4070
Effecitve thermal conductivity λ_{eff} (W/mK)	1,92	1.92
Borehole thermal resistance R_b (mK/W)	0,179	0.157

Conclusions

The grouting material has an important role. It seals up the surface between the pipes and natural ground. This protects from uncontrolled underground water mixing and provide the heat transfer between the ground and the carrier fluid. Properties of grouting material influence on borehole heat exchanger thermal resistance. Realized tests show that for both BHE's, the undisturbed ground temperature and effective thermal conductivity was almost the same. But borehole thermal resistance for BHE filled with native ground (grey loam) was lower, which let for better heat transfer. It was the special case because the drilling cutting were plastic and which allowed them to be pumped.

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