A preliminary test for using a borehole as cool storage

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ABSTRACT

This paper describes a preliminary test for using a borehole as a cool storage. The testing was done using a dry borehole in Vaasa area. The cooling was done using a special trailer in period of 9 days after which the borehole was allowed to warm naturally up. Temperature data was collected both cooling and warming periods. The temperature of undisturbed ground had not reached the original bedrock temperature even after 12 days. The temperature data collected also indicate that one can store cool in a similar way as the heat around a borehole. This test did not cause any visible damage to bedrock that is important when making a cool storage.

KEYWORDS

Borehole, storage, cool storage, thermal response test, TRT, distributed temperature sensing, DTS

INTRODUCTION

There are a lot of news about heat waves and high temperatures. Both increase need for cooling in residual, public and commercial buildings. There are district cooling solutions, but they typically require long pipelines (see e.g. [1]). Cold and cool storages make possible local cooling solutions. One option to build this kind of storage would be the use of boreholes and bedrock. So far, there are only few studies in this area, e.g. [2-3].

The first step before building actual cold or cool storage is naturally test the behaviour of bedrock. The cool storages should also use renewable sources and thus reduce fossil fuel usages. The cold can be obtained due to natural conditions (during wintertime e.g. in Finland) or produced via excess renewable electricity.

Testing of bedrock includes thermal response test (TRT) and temperature measurement with distributed temperature sensing (DTS). The TRT test will be made in this study with a unique TRT trailer built in the University of Vaasa. The TRT trailer has a heat pump system for two-way thermal response testing (heating and cooling) [4].

In this paper, we first describe the test area and measurement settings installed. Results and their analysis are shown after this. Finally, conclusions are drawn on the basis of obtained results.

TEST AREA AND MEASUREMENT SETTINGS

The test area is located in Laajametsä industrial area in Vaasa, Finland. The City of Vaasa has drilled a 200 m deep well in this area when it made a survey of available energy. The purpose of the borehole was to explore the potential of the groundwater for heating and / or cooling (so-called aquifer energy storage). The borehole turned out to be dry due to which it was here chosen for test place. The dryness is, of course, a negative property for the conventional systems. For a heat storage, this is a wanted property since the groundwater flows do not transfer the loaded energy away from the well. When storing cold or cool to bedrock, the minimal groundwater flows and water are essential property. Freezing water change its volume due to its thermal expansion behavior. When the water melts, the volume is smaller. This behavior of water can cause crumbling of bedrock.

Ordinary polyethylene pipes (PE-pipes) were installed inside the borehole since they are cheap and can withstand thermal expansions. The heat transfer fluid was a mix of ethanol (40 %) and water which should withstand cold conditions without freezing or congealing. The criteria for the fluid selection was suitability, price and safety. For DTS measurements, an optical cable was installed inside the borehole. The TRT trailer was connected to the borehole pipeline. The trailer was first used to do the ordinary TRT test after which the borehole was left to return its undisturbed state. After the recovery period, the cooling was done with the heat pump of the trailer. Fig. 1 shows the trailer used for cooling test. Data was collected during cooling period as well as during time of natural warming. More details can be found in the report by Martinkauppi et al. (in Finnish) [5].

Figure 1. TRT trailer is shown in the left-hand figure. The right-hand figure shows the environment around the borehole About 15 m long pipes go to the borehole as shown in middle of the figure.

RESULTS AND ANALYSIS

The ordinary TRT test gave the basic temperature of bedrock to be 5.6 ºC or 278.8 K. The data collected during this test was used to calculate three parameters: thermal conductivity 3.844

W/m·K,, diffusion coefficient $1.697\cdot10^{-6}$ m^2/s and thermal resistance 0.0833 m·K/W. The values are used to characterize the bedrock borehole.

After the ordinary TRT test, the bedrock was allowed to stay undisturbed 13 days. During this time the temperature data of fluid was collected (Fig. 2). The borehole is returned to its undisturbed state when the fluid temperature reaches the original basic temperature.

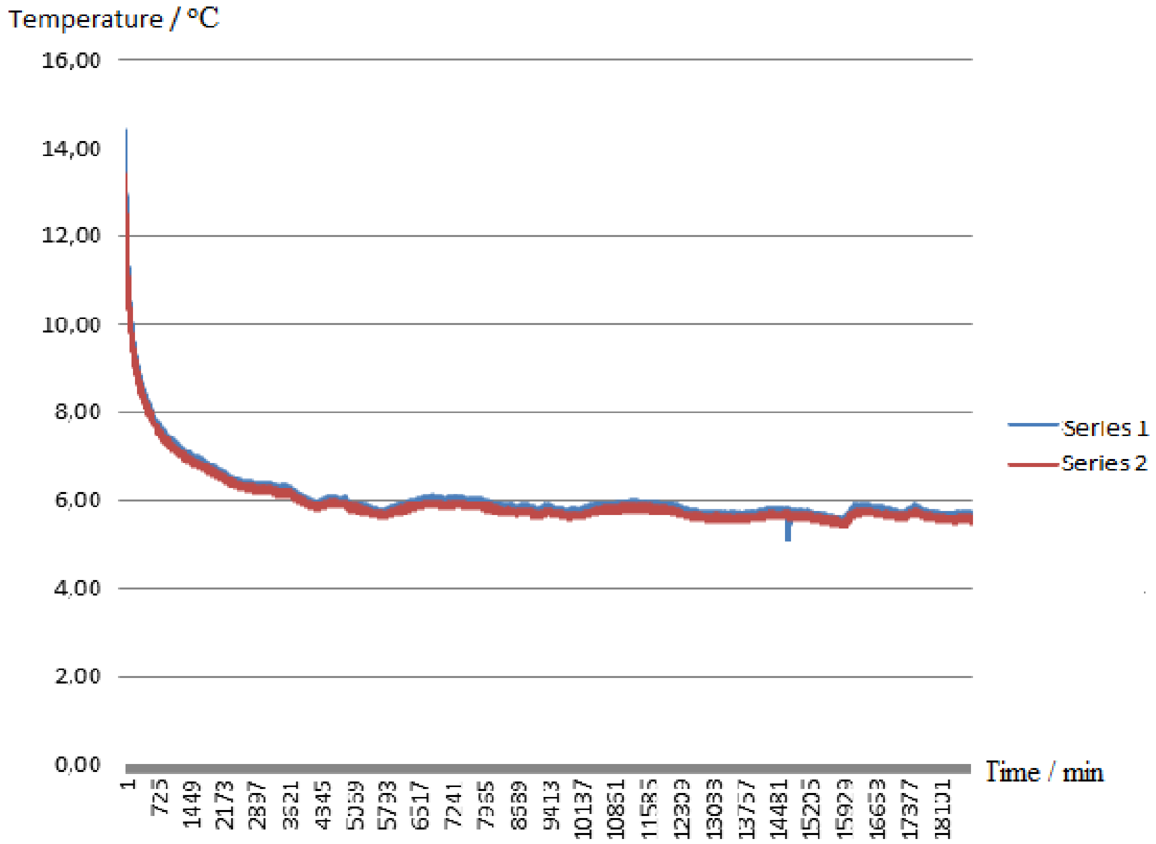

Figure 2. Temperature during recovery phase.

After recovery the TRT trailer was used to cool the borehole for a period of 9 days. After the cooling period, warming of borehole was recorder for a period of over 10 days. The average cooling power was 9.4 kW and energy transferred out of the borehole was 2.07 MWh. The temperature from DTS measurement is shown at depth of 40 m in Fig. 3. As the figure shows, the cooling is relative fast up to 0 ºC. After reaching 0 ºC, decrease in temperature slows. Temperature at the end of cooling period is around -5.5 °C. When the cooling is stopped, the temperature returns almost immediately near to 0 ºC. Then the temperature stays under 1 ºC some time before it slowly starts to increase back to the original temperature. One can speculate that the first part of the behaviour is due to phase change of water from ice to liquid.

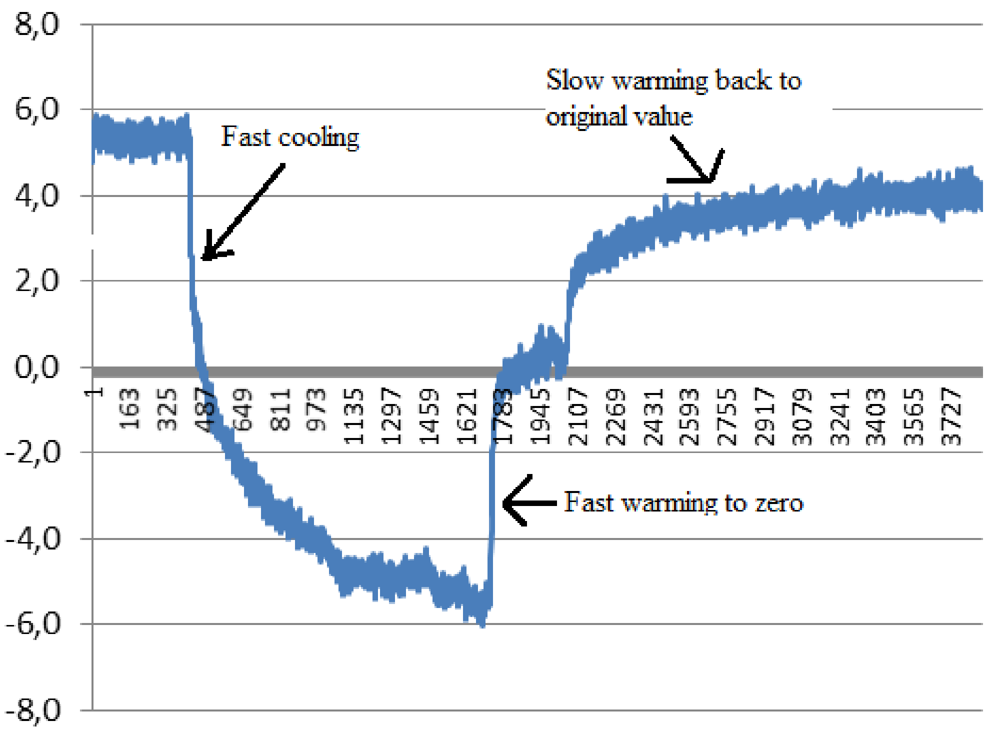

Figure 3. DTS data for cooling and warming periods

Fig. 4 illustrates cooling and warming changes. The blue part of the figure is related to energy transferred out of the borehole (2.07 MWh). The orange part indicates warming during the first 220 h period. The energy in this period is around 690 kWh or approximately 1/3 of the discharged. The borehole has still not returned its undisturbed temperature, so there is some cool to be used later. The test time was relatively short. A longer loading time (i.e. years) can make a bigger storage where more cold stays longer period available.

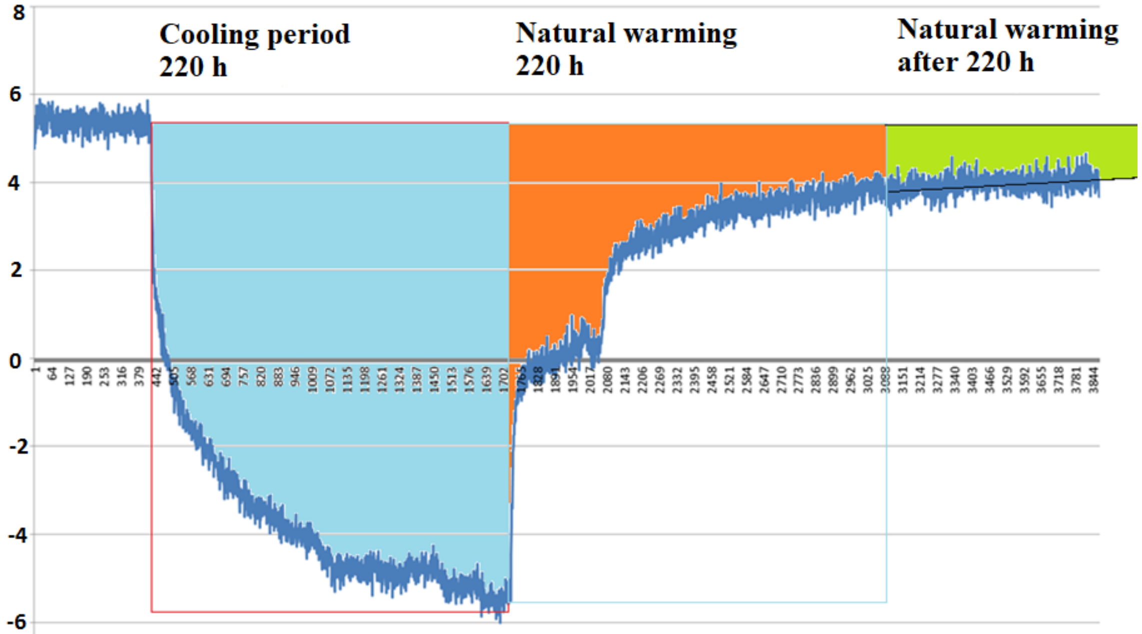

Figure 4. Cooling and warming data.

The ground and borehole were visually inspected after the test (summertime). No crumbling or structural changes was observed.

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CONCLUSION

This paper describes a borehole cooling test done in Vaasa area. The results indicate that cool can be loaded into a borehole similar way as heat. The temperature of the borehole and bedrock after cooling was below the original temperature longer time than 9 days (the cooling period). The bedrock and borehole stayed undamaged. The test was relatively short but it indicates the possibilities of storing cool with boreholes. Longer loading time and more boreholes for cooling is needed to create longer lasting cool storage.

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