Storing Asphalt Energy into Bedrock Heat Battery System

Hafiz M K U Haq, Birgitta Martinkauppi and Erkki Hiltunen

***Abstract*—** The potential of the ground is very well attested to be a generator of geothermal energy. Though, it varies in terms of magnitude of heat in asphalt or sediment layers depending on the location of the ground. In Northern areas, environmental conditions necessitate to study and develop novel techniques and use every bit of renewable energy sources in order to provide heating system for buildings and houses. This study intended partially to find out the effectiveness and efficiency of a small scale renewable source called Asphalt energy. Plan is to store this small scale asphalt energy into an already developed model of bedrock heat battery system. Arrangement of this model and simulation includes two important parts. First part is to simulate the ground containing asphalt energy and find out the thermal response which is the inlet or the input of the bedrock heat battery. Second part includes simulating model of the bedrock heat battery in which the respective asphalt energy is to be stored. This study uses Comsol software for all simulation and modeling purposes and reports thermal response of the ground.

***Keywords*—**Geothermal energy, Bedrock battery, Asphalt energy, Heat storage.

I. INTRODUCTION

The focus of the study is to find out the thermal behavior of the ground while injection and extraction at the same time before implementing the system. COMSOL is used to determine the behavior of the system by simulating the suitable configuration of the model for this system [1]. Considered ground is 50 meters in radius where the boreholes are located. The basic configuration of the boreholes for this project includes three boreholes for the injection and six boreholes for the extraction of heat energy [4].

Injection boreholes are drilled in the center, surrounded by the extraction boreholes. Polyethylene pipes are used in the U-shape to use the water and ethanol solution as the heat carrier which starts flowing from the ground surface through the length of the boreholes and comes back to the surface. Thermal response of the asphalt is to be determined by a different model presented in the following section. The idea of storing asphalt energy came from one of the test project that has been done in the University of Vaasa. One of the areas in the university has been found to be effectively producing heat energy just 2 to 3 meters below the surface. The intensity of this heat energy is found to be sufficient in order to store and utilize in the heating system. But before doing so, it is necessary to evaluate the thermal response if being stored in the bedrock heat battery system.

The rest of the paper organized in sections. In the next section, a brief configuration of the boreholes is discussed followed by thermal response of the asphalt layer and the behavior of the ground during the injection and the extraction mode. Results and discussions are further scribe in the following section include concluding remarks of the outcome of the study.

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II. CONFIGURATION OF THE BOREHOLE

An optimal configuration of the borehole is required to make a long lasting heat storage system. This means the length of the boreholes and distance among them should be proper so to acquire the optimal thermal resistance among the boreholes [3] & [6].

In order to get the required response, multiple configurations are modeled and simulated. The difference between these configurations is mainly the distance between boreholes. Multiple configurations has been evaluated and attested in order to agree on the most suitable configuration. After a detail study on the configuration of boreholes, the best configuration is found. This configuration includes three injection boreholes in the center surrounded by six extraction boreholes. These boreholes are placed in a way presenting itself a circular architecture shown in Fig 1. The ground is considered to be 25 meters in radius and 200 meters deep. Distance between boreholes is assumed to be 5 to 6 meters. Long legged depicts are the extraction boreholes.

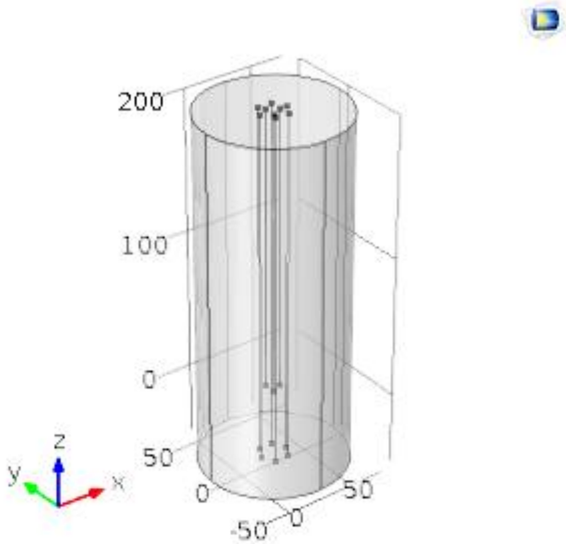

Fig. 1 Model of borehole in the ground

2.1 Thermal response of Asphalt layer

This part of the study belongs to a pilot project that measures the temperature of the asphalt layer in the parking lot in the University of Vaasa. Findings concluded that, with very few meters of digging borehole into the ground provides a significant temperature reading which varies between +1 ^{0}C to +25 ^{0}C during four seasons with the depth of only 1-3 meters in the ground. It is suggested that thermal energy from asphalt layer can be extracted to be stored. Following configuration in Fig. 2 explains how pipe is adjusted within the boreholes so that the carrier fluid flow from one point to another, providing temperature change. Input temperature is considered to be 5 ^{0}C.

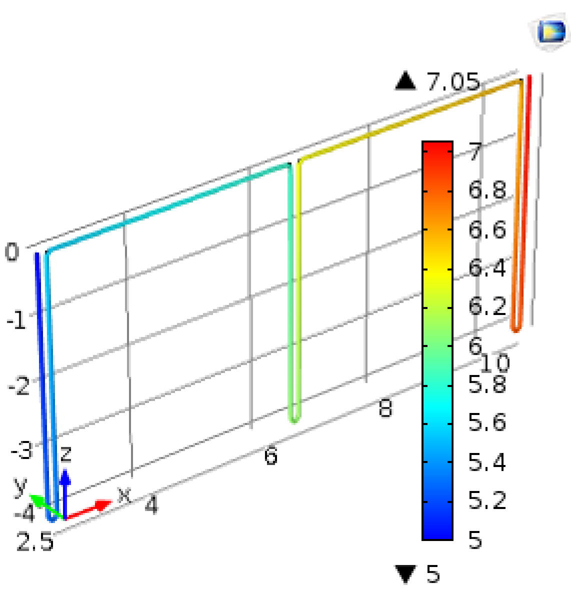

Fig. 2 Configuration of the Asphalt layer

Simulation presented in Fig. 2, 3 & 4 are basic pipe flow model, as the fluid run through the pipe the temperature of the neighboring ground is absorbed by the carrier fluid and hence provided high temperature at the output. Three boreholes are considered for this simulation to make the case easier. Distance between boreholes is assumed to be 5 meters. Fig. 3 & 4 illustrate how fluid flow changes the temperature of during the course of simulation. The depth of the ground is considered to be 4 meters in this model in the z-direction. The average temperature of the ground is 8 ^{0}C. Fig. 4 only represents thermal response of one borehole.

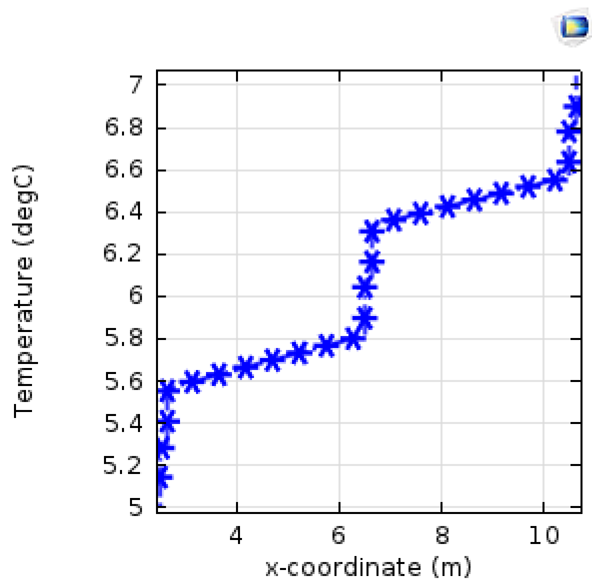

Fig. 3 Thermal response of the fluid flow in asphalt layer

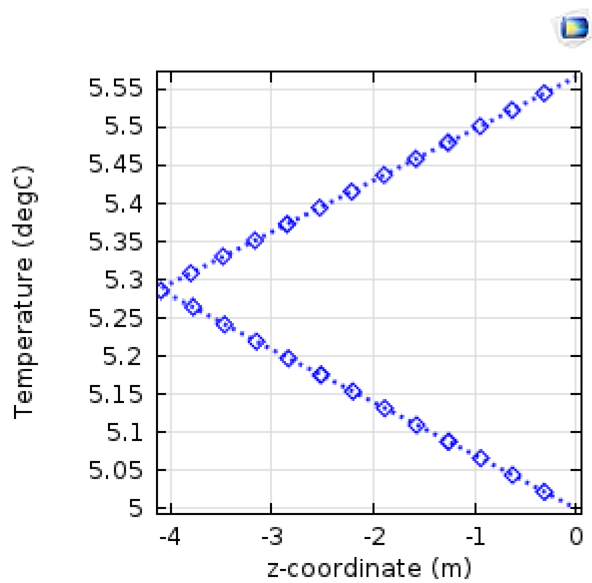

Fig. 4 Thermal response of the fluid flow in a single tube

2.2 Boreholes injection/extraction

The configuration for the injection and extraction boreholes is shown in Fig. 5. There are nine boreholes in total in which three of the boreholes are dedicated for the injection of heat energy in the centre of the ground and the rest of the six boreholes surrounded by the injection boreholes are dedicated to extract the heat energy from the ground. The boreholes are not considered to be filled with the grouting material in the simulation but instead U-shaped pipe is placed inside the ground. More information about grouting is explained in [8].

Polyethylene pipe is used as the standard for this project. The length of the injection pipes are considered to be 200 meters while the length of the extraction pipes is 250 meters as shown in Fig. 8. The considered neighboring ground area has a radius of 50 meters. Water is assumed to be the heat carrier in all the rest of the simulation and the time for simulation is considered to be 90 days for which the thermal response of the ground and the pipe flow is presented in the next section.

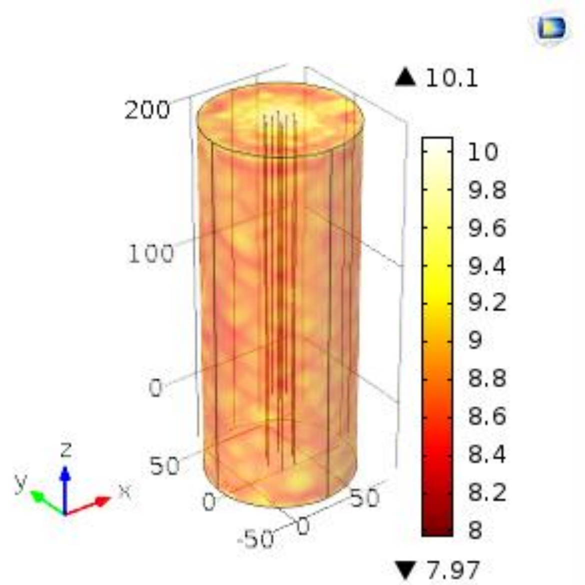

Fig. 5 Thermal response of the ground

One of the important point of this model is to perform different configurations of the borehole and analyze the thermal response of the ground which can be done by adjusting the position of the pipe in the same area of the ground but the practical implementation dictates to find the thermal response by altering the distance between the injection and the extraction pipes. So to achieve this purpose, the configuration of the boreholes are altered by increasing the distance between the injection and the extraction pipes in the same model and then analyze the thermal response of the simulation. Starting with the 2 meters distance between the injection and the extraction boreholes, the thermal response for the pipe flow is noted for distances of 3, 4 and 5 meters.

The model of the boreholes configuration suggests that the surface of the injection pipes starts at 200 meters at the spatial coordinate and goes until 0 meters. While the surface of the extraction pipes starts at 200 meters and goes until – 50 meters at the spatial coordinate axis which makes it 250 meters long. Flow in porous media is explained in [2] & [7]. Fig. 5 also presents thermal response of the ground while injecting asphalt energy into the injection boreholes and at the same time extracting heat energy from the extraction boreholes. Thermal response of the pipe flow is presented in the next section (a comprehensive account of pipe flow in a porous media is depicted in [10] for more details). Simulation time is set to be 72 hours while injection and extraction pipes are working simultaneously. Result of this simulation advances a very impressive response of the ground considering the thermal conductivity as high as 3.1 (Watt / meter. Kelvin)

III. RESULTS AND DISCUSSION

In this section, thermal response of fluid is presented. First, injection of asphalt energy is shown for the time period of 90 days where the carrier fluid is running through the injection pipes and the last time step is plotted in Fig. 6. In the same way, plot in Fig. 7 shows thermal response at the outlet. Carrier fluid in practical is a mixture of ethanol and water but for the simulation purposes, water is only considered for carrier fluid (more detailed fluid behavior is well explained in [5] & [9]). Since thermal response varies slightly in both cases with the mixture of water and ethanol solution or only water [5]. Reason to use the mixture solution is to avoid any hindrance when air temperature is below zero.

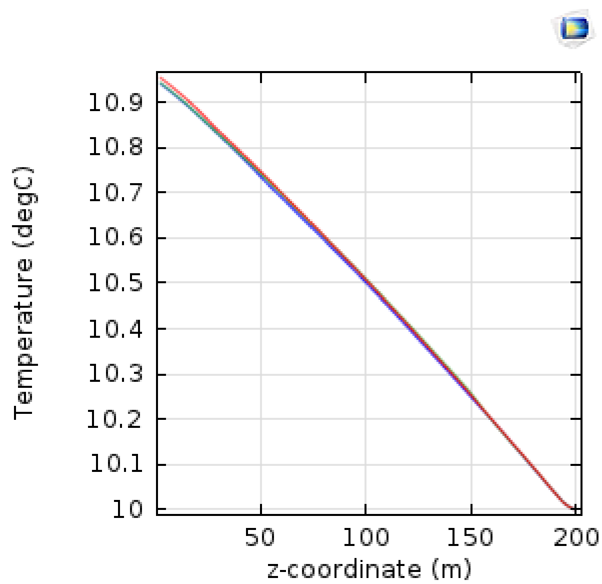

Fig. 6 Thermal response at the inlet of injection boreholes

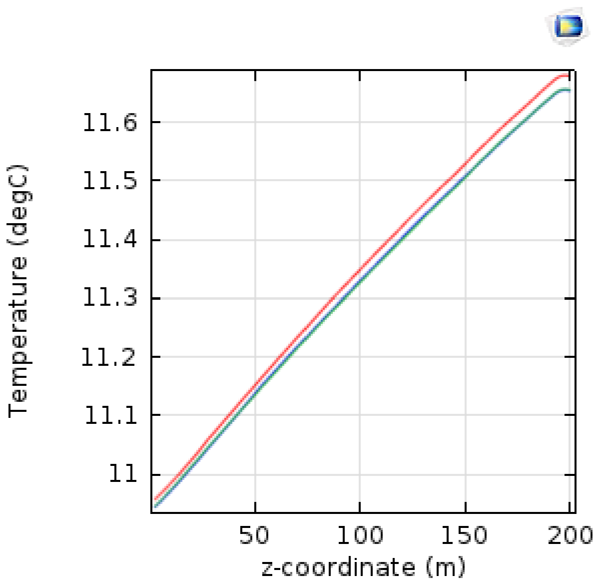

Fig. 7 Thermal response at the outlet of injection boreholes

The rise of temperature in the ground due to the injection of asphalt energy causes a significant change in the temperature at the extraction boreholes presented in Figs. 8 & 9. Same process is chosen to find the temperature rise at the extraction boreholes while asphalt energy is injected into the bedrock at the same time. Temperature of carrier fluid shows rapid change as soon as it introduced in the borehole as shown in Fig. 8. As it reaches the bottom of the ground (bedrock), temperature rises well above 2 ^{0}C. On the other hand, Fig. 9 presents rise of temperature when the carrier fluid is returning back to the surface.

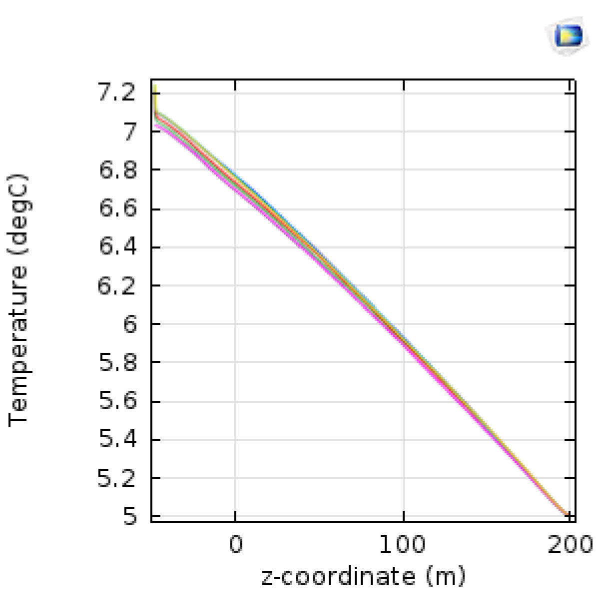

Fig. 8 Thermal response at the inlet of extraction boreholes

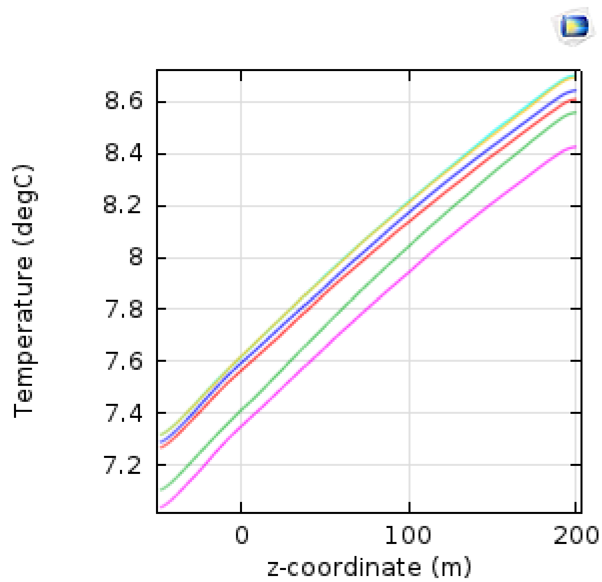

Fig. 9 Thermal response at the outlet of extraction boreholes

Multiple lines in Figs. 8 & 9 show the number of extraction boreholes and the configuration is set up as presented in Fig. 1 showing the individual thermal response of each of the boreholes. Boreholes are connected with each other, though, it can be connected to examine the response with that configuration and probably presents even much better results. But in this case, boreholes are examined separately so to evaluate the potential of the individual borehole.

The air temperature in Finland changes drastically most of the time so the 90 days duration explains the most difficult time in winter where the extraction process could be harder than any other time of the year. In Fig. 6, the thermal response at the inlet is slow and increase exponentially. On the other hand, the thermal response at the outlet of the extraction in Fig. 7 is even slower and gradual. The multiple lines in the Figs. 8 & 9 with different reading imply that the boreholes closer to the injection pipes gathered more heat than the ones that are far from them. Six extraction pipes may have different response.

Neighboring areas of the boreholes increases temperature in the time duration of 90 days presented in Fig. 10. Temperature rise differed from beginning of the first time steps to the last time step represented by multiple lines in the plot. The very ideal assumption that has been taken in the simulation is the outside temperature of the ground to be 20 ^{0}C which simplifies our case but later will be used to find the thermal response using periodic function which will depict the change in the air temperature throughout the year.

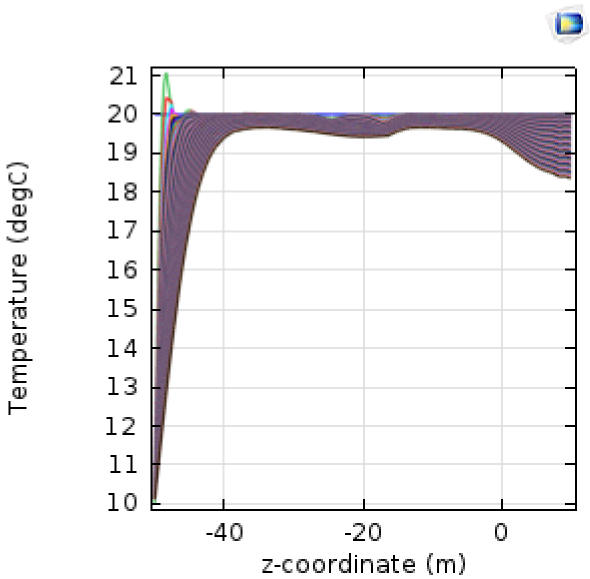

Fig. 10 Temperature distribution at the center of the ground between the bottom edges of the injection boreholes to the bottom of the extraction borehole

IV. Conclusion

Modeling and simulation of asphalt layer in the process of heat exchange is analyzed to further use in the process of heat injection into the bedrock heat battery. Temperature of asphalt has long been measured and the conditions of the ground used in the simulation are taken mechanically through distributed temperature sensing method. A rough model based on the observed site has been considered in the simulation and thermal response of the pipe flow is presented. Furthermore, model of the bedrock heat battery system including six extraction boreholes and three injection boreholes (which can be reverse depending on the need and input thermal energy) are designed and thermal response of the pipe flow and the ground is presented. The assumptions made in the simulation include the density, heat capacity and thermal conductivity of the ground which are largely relative to the regional capacity and characteristics of the ground. The error that might have been important to address is that the characteristics of the ground varies with the variation of the air temperature. The variation in the ground and air temperature are curtailed in the simulation but intended to further study.

Acknowledgment

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