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Development of a spiral type heat exchanger for ground source heat pump system

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Abstract

In Japan, net Zero Energy Buildings are crucial for reducing energy use and environmental load to realize a sustainable society. Ground-source heat pump systems are a key technology for reducing energy consumption by air conditioning systems. There are two types of ground-source heat pump systems: “closed loop type” and “open loop type”. In general, open loop type ground-source heat pump systems have better relative performance than closed loop type systems. However, pumping up underground water is prohibited in urban areas of Japan to prevent the ground surface level from sinking. Therefore, closed loop type systems are used more extensively in Japan. The typical and conventional heat exchangers used for closed loop type heat pump systems are of the “U tube” or “double U tube” types. However, neither type has a high heat exchange capacity per unit length. Thus, in this study, a spiral-type heat exchanger for a ground-source heat pump system is developed. The aim of the heat exchanger is to perform intensive heat-exchange in the aquifer layer near the ground surface (ten to twenty meters in depth). To use the underground water flow in order to facilitate intensive heat exchange, the length of the heat exchanger is planned to be inserted between ten and twenty meters below the surface into the upper part of the aquifer. The diameter of the spiral-type heat exchanger is determined such that a borehole machine for piles can be used for settlement of heat exchangers to reduce the construction cost. The performance of the heat exchanger is simulated under various flow rates and soil conditions using the numerical simulator “TOUGH2/EOS1.” Based on the simulation and construction cost study, the cost-effectiveness of the spiral-type exchanger is made clear.

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Keywords: ground source heat pump system; ground heat exchanger; spiral type

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1. Introduction

In Japan, nZEB (net Zero Energy Building) is crucial for reduction of energy use and environmental load in order to realize a sustainable society.

Ground source heat pump system (GSHP) is one of the key technologies to reduce energy consumption for air conditioning system. There are two types of ground source heat pump system, one of those is closed loop type heat pump system and another type is open loop type heat pump system.

Generally, open loop type ground source heat pump system has relatively higher performance compared to that of closed loop type. However, it is prohibited to pump up the underground water in urban area in Japan to avoid ground surface level sinking.

Therefore, closed loop type system is spread in Japan. The typical and conventional heat exchanger used for closed loop type heat pump system is "U tube" type or "double U tube" type. However, both "U tube" and "double U tube" type do not have high heat exchange capacity per its length.

In Japan, there are many place where aquifer layer is near the ground surface. It is often observed that the areas in which rich underground water exist, the flow rate of groundwater is relatively high in shallow underground (ten to twenty meters depth).

Purpose of this study is to develop a high performing and low cost heat exchanger for GSHP in order to accelerate the introduction of GSHP in Japan.

The aim of newly developed spiral type heat exchanger is to intensive heat exchange in the aquifer layer near the ground surface (ten to twenty meters in depth). In order to use the underground water flow to intensive heat exchange, length of the heat exchanger is planned between ten to twenty meters to insert the top aquifer from the surface. Diameter of the spiral type heat exchanger is determined so that borehole machine for piles can be used for settlement of heat exchangers to reduce the construction cost. Performance of heat exchanger is simulated in various flow rate and soil conditions used numerical simulator "TOUGH2/EOS1" (see Note1). Based on the simulation and construction cost study, cost effectiveness of the spiral type is made clear.

2. Overview of Spiral Type Heat Exchanger

High performance polyethylene PE100, the material having high, long term durability mainly used for U-tube, is used for the exchanger, and bending of small diameters which used to be impossible to be conducted is applied to the exchanger (see Figure 1). As the foundation construction and installation of the new ground heat exchangers may be conducted during the same period, it can be expected that using an excavator which is normally used for piling works for installing the ground heat exchangers into the ground will reduce the cost of installation. Therefore, we assumed that the spiral pipes made of high performance polyethylene were installed in the small-diameter boreholes drilled by a piling machine. As shown in Figure 1, the spiral type heat exchangers with 10 - 20 m in depth, 100 - 200 mm in pitch and slightly less than 400 - slightly less than 600 mm in diameter are commercialized.

3. Results of Measurement and Comparison of Simulated Values

3.1. Overview of Installation of Ground Heat Exchangers

The ground heat exchangers were installed as the heat source of the research institute building which was newly built in Tokyo. High performance polyethylene PE100 with high, long term durability was used for all the heat exchangers. The spiral type heat exchanger has 21 mm in inside diameter of the pipe, and single-U-tube and double-U-tube heat exchangers have 27 mm in inside diameter of the pipe. A diameter of a spiral is 385mm.

Figure 2 shows the illustration of the arrangement of the heat exchangers and temperature measurement points. Two spiral type heat exchangers (20m in length) and three single-U-tube and three double-U-tube heat exchangers