

Experimental Study on Underground Heat Exchanger with Different Types

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Abstract: The design and application of Ground Coupled Heat Pump (GCHP) was mainly based on the heat transfer performance of underground heat exchanger. An experimental system with different types of U-vertical ground coupled heat exchanger (UGCHE) in situ was set up, for example, single or double UGCHE with sandstone backfilled, and single UGCHE with cement backfilled. The research on the thermal behaviour of UGCHE in different types, and in various conditions, such as different soil properties, backfill material, number of borehole exchangers, and different operation modes was carried out in the paper.

Keyword: U-vertical ground coupled heat exchanger (UGCHE); Heat transfer performance; Different types of UGCHE

1. INTRODUCTION

The underground heat exchanger has various types, such as U-vertical, horizontal, spiral and double pipe. And the types of backfill materials are also different: sand rock, bentonite and concrete. An experimental system was set up in situ to obtain the operation performances of these kinds of underground heat exchangers above. For example, single or double U-vertical ground coupled heat exchanger (UGCHE) with sandstone backfills or with cement backfills. The influence on the thermal behaviour in various conditions was studied, including soil property, backfill materials, the number of heat exchangers and operation modes. The results drawn from this paper would be useful for the design and application for GCHP engineering.

2. INTRODUCTION OF EXPERIMENTAL SYSTEM

The experimental system with U-vertical ground coupled heat exchanger (UGCHE) was set up in Tianjin in Jan, 2002 and in Shengyang in July, 2003 respectively. The UGCHE has two types: U-vertical borehole heat exchanger with sandstone backfills and U-vertical pipe buried in building's foundation piles with cement backfills. The borehole heat exchanger has single U or double U-vertical pipes in it.

The experiment system included UGCHE and measuring system. The heat exchanger was made of DN32 high-density polyethylene plastic and backfilled with sand rock or concrete. Measuring system was composed of a water-source heat pump, a water tank, a cycle pump, and a water collector and distributor. The cooling and heating loads in the system were controlled to be balanced by the heat pump, and the water temperature in tank was controlled by a thermo regulator so that the inlet temperature could be kept

stable in both heat extracted and heat emitted modes. The experimental system is shown in Fig 1.

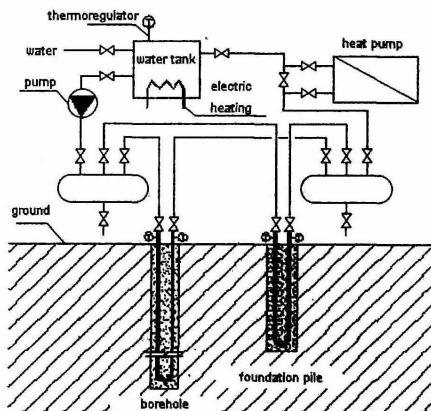


Fig 1: Experimental system of underground heat exchangers

In the experimental system, the inlet and outlet temperature of UGCHE was gained through a mercury thermometer with the accuracy of 0.1 and the flux was measured by a float-type flowmeter, using weight method to verify the results.

In heat extracted or heat emitted mode, the experiment was carried out in different water flow rate and inlet temperature, using the thermo regulator to keep the temperature at setting value. In heat emitted mode the inlet temperature was kept at 30°C or 35°C, and the water flow rate was changing from 760L/h to 1500L/h for single UGCHE and from 1500L/h to 3000L/h for double UGCHE. In heat extracted mode,

the inlet temperature was kept at 3°C or 5°C, and the flow rate kept as the same as the heat emitted mode.

3. EXPERIMENT RESULTS AND ANALYSES

3.1 Heat emitted experiment

3.1.1 Experiment in Tianjin

In Feb, 2002, the heat emitted experiments were carried out for foundation pile's UGCHE with cement backfills and for borehole UGCHE with sandstone backfills in Tianjin. The results are shown in Fig.2. The inlet temperature for both patterns was maintained at 30°C, with the water flow rate changing from 800L/h to 1200L/h gradually. For foundation pile's UGCHE with cement backfills, qL (the heat flow rate per depth of borehole) descended gradually from the initial 210W/m to the final 130W/m, had a decline of about 40% after continuously running of 24 hours. In the experiment, the water flow rate varied small, so it had little influence on the thermal behaviour of UGCHE. The situation was similar for the borehole UGCHE with sandstone backfills, that is, the qL stayed at 80W/m after running of 20 hours. Obviously, the qL of the former type was about 50% higher than that of the latter in heat emitted mode.

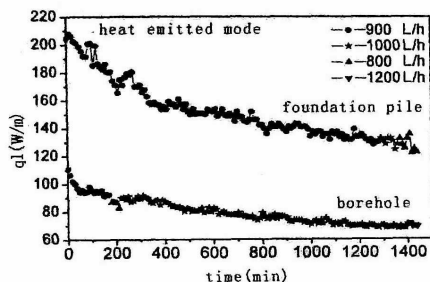


Fig 2: Heat emitted performance with different types of single UGCHE in Tianjin

3.1.2 Experiment in Shenyang

In July, 2003, the heat emitted experiments were performed for single and double UGCHE at the condition of different water flow rate and different inlet temperature in Shenyang.

As shown in Fig 3 and Fig 4, the qL increased with the rise of inlet temperature for both single and double UGCHE when the flow rate maintained stable. With the increment from 30°C to 35°C, the augment of qL was about 20% for the single UGCHE and almost 100% for the double UGCHE. Obviously, the inlet temperature had a stronger influence on the double UGCHE than that for the single UGCHE. However, with the time, the heat transfer went more and more stable, and the qL decreased gradually, and tend to a stable value for both patterns at either 30°C or 35°C.

At the same condition of water flow rate and inlet temperature, the qL of double UGCHE was about 50% higher than that of the single UGCHE, as shown in Fig 5. And the qL will increase by about 10% for both kinds of heat exchangers when the flow rate doubled.

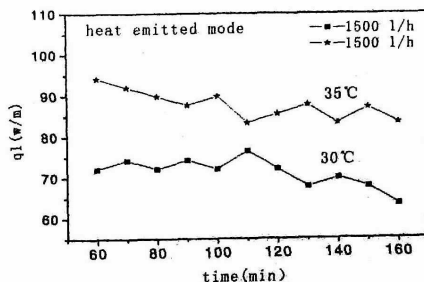


Fig 3: Heat emitted performance of single UGCHE at different inlet temperature in Shenyang

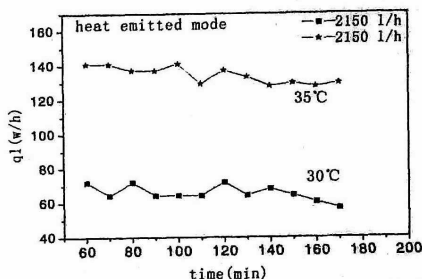


Fig 4: Heat emitted performance of double UGCHE at different inlet temperature in Shenyang

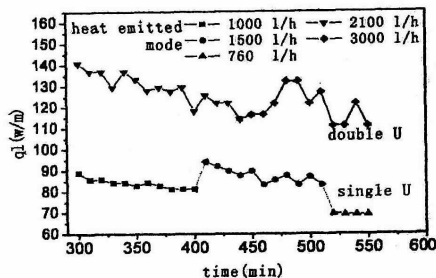


Fig 5: Heat emitted performance of single and double UGCHE at inlet temperature of 35°C in Shenyang

3.2 Heat extracted experiment

3.2.1 Experiment in Tianjin

In Jan, 2002, the heat extracted experiments were carried out for the foundation pile's UGCHE and the borehole UGCHE in Tianjin. Fig.6 shows the results. Experimental conditions were similar for the both patterns. After running of 24 hours continuously, the qL of the foundation pile's UGCHE declined slowly from the initial 70 W/m and stayed at 60 W/m at last. The case was similar for the borehole UGCHE, after 20 hours running, the qL kept at about 52W/m. Obviously, the thermal behaviour of the former

pattern is superior to the latter one by 16% in heat extracted mode. The reason can be concerned on two aspects: the higher thermal conductivity and higher density of concrete, which cause the higher heat transfer performance of it in turn compared with sand rock or soil. This was the actual heat extracted experiment in winter, so it can offer references for practical application for GHSP engineering in Tianjin.

3.2.2 Experiment in Shenyang

In July, 2003, the heat extracted experiments were carried out on the single and double UGCH in Shenyang. The results is given in Fig 7. The qL of double UGCH was 45% higher than that for single UGCH at inlet temperature of 3 °C and with a proximate water flow rate. At the same flow rate, the qL decreased with the rise of inlet temperature for the double UGCH and had a almost 50% drop with the temperature change from 3 °C to 5 °C, as shown in Fig 8. As time went on, the qL declined gradually and tend to a stable value finally.

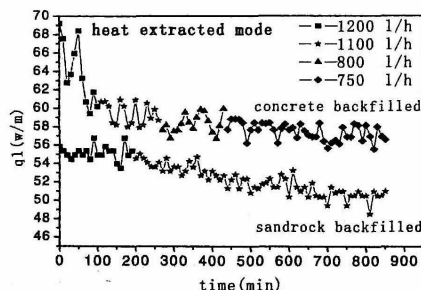


Fig 6: Heat extracted performance of UGCH with different backfill materials in Tianjin

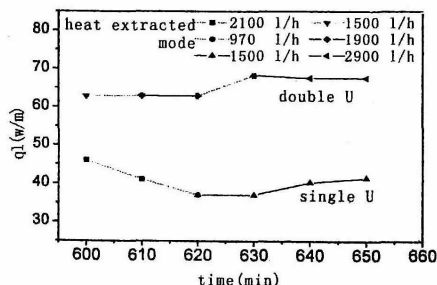


Fig 7: Heat extracted performance of single and double UGCH at inlet temperature of 3 °C in Shenyang

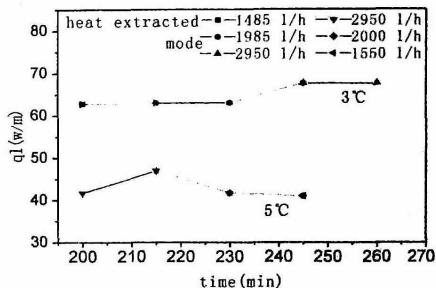


Fig 8: Heat extracted performance of double UGCH at different inlet temperature in Shenyang

4. CONCLUSION

- 1) An experimental system with different types of UGCH, i.e. UGCH buried in foundation piles and borehole heat exchanger was founded for GSHP engineering.
- 2) In heat emitted mode, the qL of foundation pile's UGCH with concrete backfills was about 50% higher than that of borehole UGCH with sandrock backfills, and 16% in heat extracted mode. The qL of single UGCH was almost 50% lower than that of the double UGCH in heat emitted mode, and 45% in heat extracted mode.
- 3) In heat emitted mode, the qL is increased by 20% for single UGCH and almost 100% for double UGCH when inlet temperature increased from 30 °C to 35 °C. In heat extracted mode, the qL of double UGCH dropped by about 50% with the change of inlet temperature from 3 °C to 5 °C.

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