

The characteristics of soil temperature field variation of ground source heat pump in severe cold area

Bai Li^{1, a}, Li Yang^{2, b *}

^{1,2}Xingcheng street 5088, Jilin Jianzhu University, Changchun, China

^abaili0308@163.com, ^bleahlee43@163.com

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Abstract. To monitor the soil temperature field of a ground source heat pump project in Changchun and research their variation and influencing factors. Research showed that: the soil temperature field with the heat pump heating/cooling alternate operation present a periodic variation. The impact of outdoor temperature on the soil temperature field gradually weakened with the increase of the depth and after -10m the change tend to be the same. In transition season soil self-recovery capability is very limited, ground source heat pump system under the condition of cold and hot load imbalance to run for a long time inevitable emergence of thermal imbalance phenomenon.

Introduction

Ground source heat pump as a new energy has been widely used, but the cold and heat load imbalance lead to thermal imbalance of soil temperature field has been the bottleneck of its development. In recent years, many scholars dedicated to research in this area. Wei Jing to take Shanghai(the hot summer and cold winter area) as an example to conduct a simulation study, studies show that, in the cooling and heating load unbalance rate of 10%, and after five years of operation it was an overall upward trend in soil temperature, but not impact the system heat transfer performance, and the larger soil temperature is in the first three years of operation[1]. Lu You to monitor soil temperature field of a ground source heat pump in Tianjin (the cold area), come to the conclusion that the heat and ground temperature reduction is not positive correlation[2]. Wang Pengxuan and Li Shurui were simulated a ground source heat pump system in severe cold area under two kinds of conditions, one is with compensation, another is without compensation [3,4]. But from the exploration of soil source heat pump long-running temperature balance, to establish the soil source heat pump temperature real-time monitoring system is more meaningful. In this study we set up a real-time monitoring system for soil temperature field use of the ground source heat pump demonstration project in severe cold area, aimed at study of the change rule and influence factors of soil temperature field for heat pump long-running in severe cold area.

Introduction of heat project and monitoring system

Select a university teaching museum in Changchun for the ground source heat pump (heating / cooling) demonstration project, the construction area is 34882.24 m². It is equipped with a central pump room with 2 heat pump units and 6 circulating pump, it adopts double u-shaped vertical buried tube, set depth of 100m, and there is 120 Heat exchanger which diameter of 180mm, Heat well arrangement diagram is shown in Figure 1. According to soil thermal response test, the calculated integrated soil thermal conductivity coefficient is 2.573W / (m • K), and under the test conditions per linear meter heat exchange as 25 W/m.

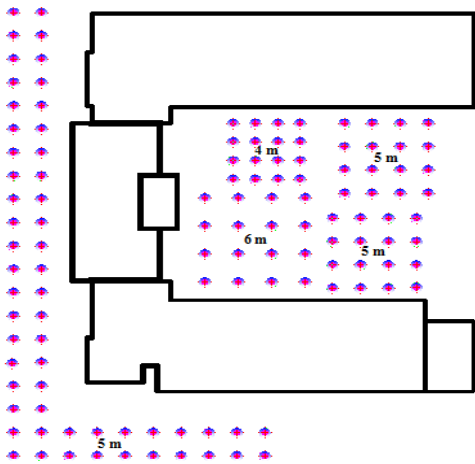


Figure 1 Heat well arrangement diagram

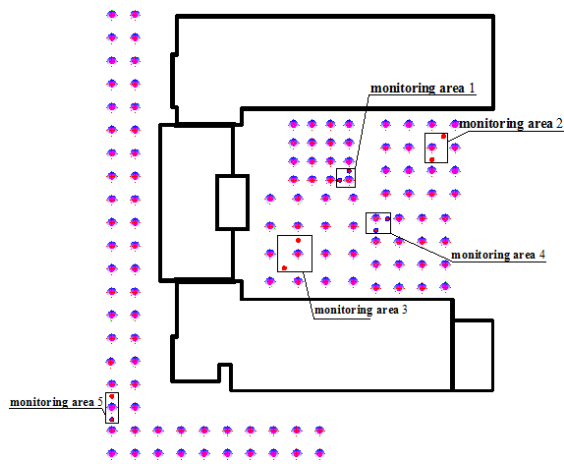


Figure 2 monitoring well distribution diagram

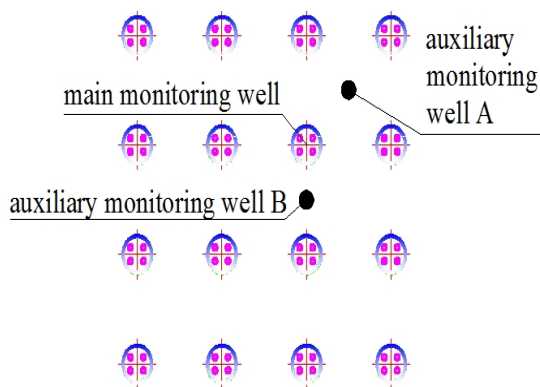


Figure 3 monitoring well arrangement detail

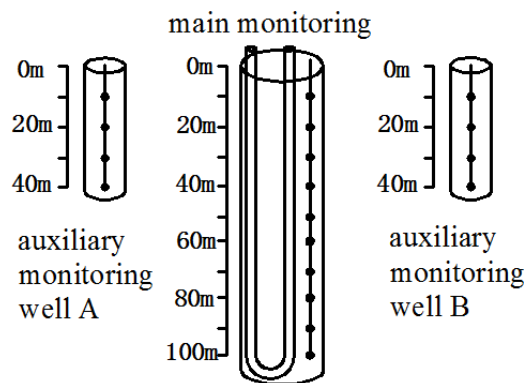


Figure 4 monitoring well temperature sensor arrangement

In order to study the real-time variation of soil temperature field in different well spacing, it is set up 5 groups of monitoring well area in different well spacing, the monitoring well distribution diagram is shown in figure 2. Each group of monitoring well set a main monitoring well and two auxiliary monitoring wells, monitoring well arrangement detail as shown in figure 3. The main monitoring well depth -100m, there are 11 set temperature measuring points, the most shallow layer is -2.5m then 10 m interval set another . Two auxiliary monitoring well depth 40 m then 10 m interval set another, they are set up on both sides of main monitoring well, far away from the main monitoring well 1m and 2m. The main monitoring well is the heat well, during construction fixed three wire system PT1000 temperature sensor on the PE pipe, and put in the heat well together., the monitoring well temperature sensor arrangement is shown in figure 4. This monitoring system can realize the soil of different depth on the longitudinal change of the temperature field, it also can master the lateral of the same rock and soil layer soil temperature field and the mutual influence between heat transfer well.

Monitoring Results and Analysis

Winter condition. Figure 5 to 7 is October 2014 to March 2015 for soil temperature field changes of ground source heat pump in winter operation condition. As can be seen from the figures, since the winter condition exchanger get heat from the soil, the soil temperature field in a downward trend. Figure 5 is -2.5m to -40m shallow soil temperature changes, figure 5 is shows that the change of soil temperature in -2.5m is the largest and after -10m the changes is gradually reduced. This is due to the shallow soil temperature are greatly influenced by solar radiation, and under the combined effect of outdoor temperature and soil heat transfer so that the soil temperature showed

significant downward trend, but with the increasing of the monitoring depth(-10m later), the influence of outdoor temperature on soil temperature field is gradually decreased.

Figure 6 and 7 is the variation of soil temperature field from -10m to -100m. Figure 6 and 7 shows that the soil temperature decreased less in the initial operation, but from December to February the rate of decline of soil temperature is increased, then the rate of decline is back slowly in March and April. This changes of soil temperature are entirely consistent with heat load. December to February is the coldest month in severe cold area, so the demand for heating load is greatest, and at the beginning and the end of the heating, the heating load is small so the soil temperature change slowly. Thus, the changes in soil temperature field is directly affected by the outdoor temperature or heating load is the determining factor of soil temperature field change.

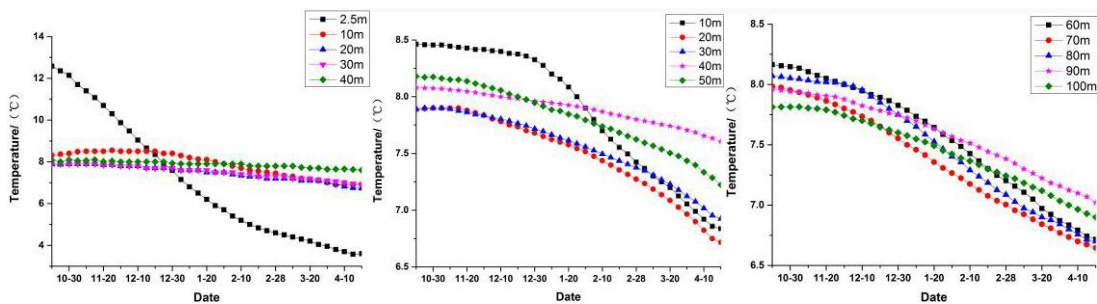


Figure 5 shallow soil Temperature

Figure 6 underground-10m to-50m soil temperature

Figure 7 underground-60m to-100m soil temperature

Observe the entire heating period of each layer soil temperature changes, it can be seen: all layers have different degrees of decline, the decline is between 0.44°C to 1.32°C , which change the smallest is -40m and the biggest is -10m, the drop rate of each layer at the same period is also inconsistent. Research on these measured data, can not find out such a direct relationship between the depth of the soil heat transfer with amplitude and rate change. There are two main reasons for this phenomenon: one is due to difference geological conditions in each layer of soil heat transfer performance is uneven, so the heat transfer of thermal diffusion response is different, resulting in the layers of soil temperature changes appear different degree of delay. On the other hand, the instantaneous fluctuation heating load and hydraulic imbalance are also lead to the change of soil temperature field in each layer is not consistent.

summer condition. Figure 8 and 9 is July 2014 to September 2014 for soil temperature field changes of ground source heat pump in summer operation condition. Can be seen from the diagram, the summer condition releases heat to the soil, therefore present a increasing tendency of soil temperature field. The increased rate of each layer is slightly different, above -50m soil temperature differs slightly larger and below -50m soil temperature and the rate of change is basically the same. It is shows that under -50m heat transfer is more stable. Figure 8 and 9 shows that after July 30 the rise rate of soil temperature field is increases, it is directly related to the outdoor climate characteristics. We can conclusion that the cooling load increases positively influenced changes in soil temperature field. According to statistics, the layers of variation in temperature is 0.21°C - 0.75°C , analysis that in Changchun the amount of cooling demand is relatively small, so there is small changes of soil temperature field in summer. It also suggests that cold and hot load imbalance will directly influence the change of soil temperature field, and leading to cold accumulation problems, thus affecting the efficiency of ground source heat pump.

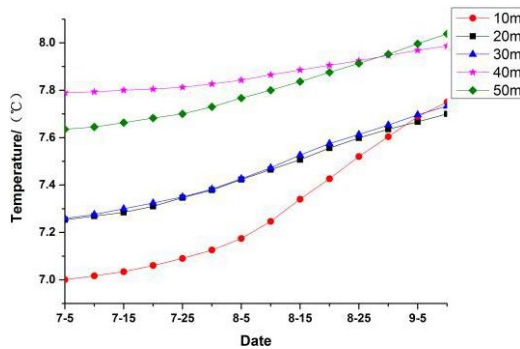


Figure 8 summer -10m to-50m soil temperature

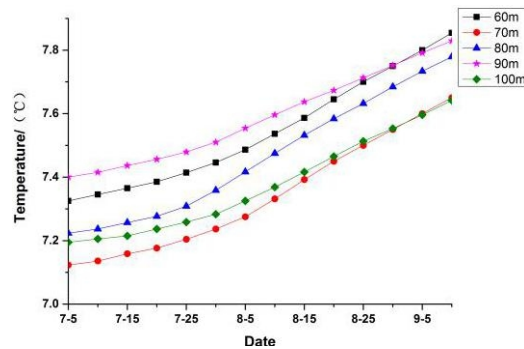


Figure 9 summer -60m to -100m soil temperature

Transition season. Figure 10 and 11 is the change of soil temperature filed in transition season. It is shown in figure10, during the summer-winter transition season, the soil temperature field did not recover and still keep a slowly rising trend. As can be seen in figure 11, during the winter-summer transition season, soil temperature remains slow decline even the heat pump was shutdown. We can conclusion that the soil recovery ability in transition season is not significantly positive effect on soil temperature filed balance. It is has a relationship with the local geological conditions which is more sand and less moisture, restricted by geological conditions, the soil temperature field has certain hysteresis response and make the soil temperature field self-recovery effect is not obvious. Therefore, the balance of the soil temperature field must rely on heating/cooling alternating operation, and the best condition of soil temperature field balance is cold and hot load balance.

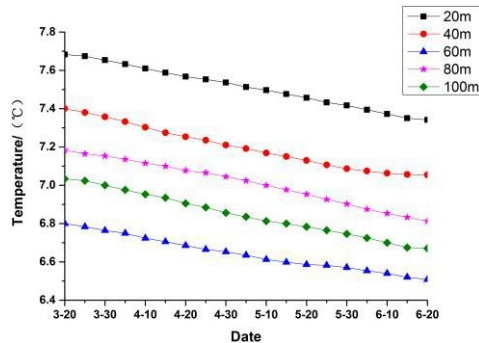
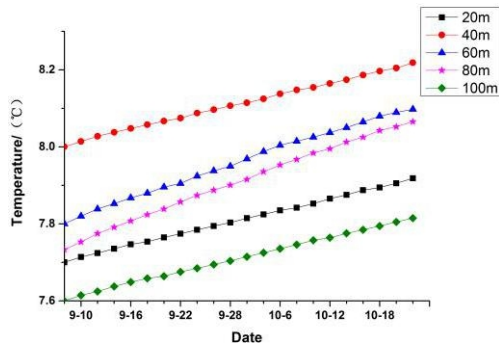


Figure 10 summer-winter soil temperature Figure 11 winter - summer soil temperature

Summary

- (1) With the change of the soil source heat pump heating / cooling condition, the soil temperature field presents a periodic variation of the sine law, and the variation range is mainly determined by three factors, first is the local climatic conditions, second is the soil thermal parameters, third is the heating / cooling load. Recommended for the design and operation of the ground source heat pump to take full account of the local climate environment and geological conditions and load characteristics of the building.
- (2) The change of soil temperature field during the transition season is small. It is indicated that the soil thermal diffusivity is very weak, and there is a delay in the response to the thermal diffusion. Therefore, in the severe cold area can not rely on the transition season soil self recovery ability to achieve the balance of the soil temperature field.
- (3) In severe cold area the underground cooling accumulation of soil source heat pump system is a long-term effect. Therefore, to establish the monitoring system of soil source heat pump is

beneficial to control the variation law of soil temperature field and the influencing factors, and it is active to make a comprehensive and reasonable system operation control scheme, which can ensure system's long-term reliability and energy saving.

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