Thermo-mechanical behavior of geothermal PHC pile

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Field test design of geothermal PHC pile

Thermo-mechanical behavior is a basic issue for the design of energy pile (Amatya, 2012; Laloui, 2013). However, most of the researches are focused on the cast-in-place piles. Experiments on geothermal PHC pile in the field is introduced. Heat exchanger pipes were inserted into the hollow section of the PHC pile and the hollow section was backfilled with sand to create a geothermal PHC pile. In order to understand the characteristics of temperature and strain distribution along the PHC pile, the distributed optical fiber sensing technology, including Brillouin optical time domain reflectometer (BOTDR) and Raman optical time domain reflectometer (ROTDR) were applied to monitoring the mechanical and thermal behavior of the PHC pile during thermal response tests (TRTs). The construction technique of geothermal PHC pile as well as the installation method of the optic sensing cables were presented in detail. TRT on ground heat exchanger was conducted for comparison.

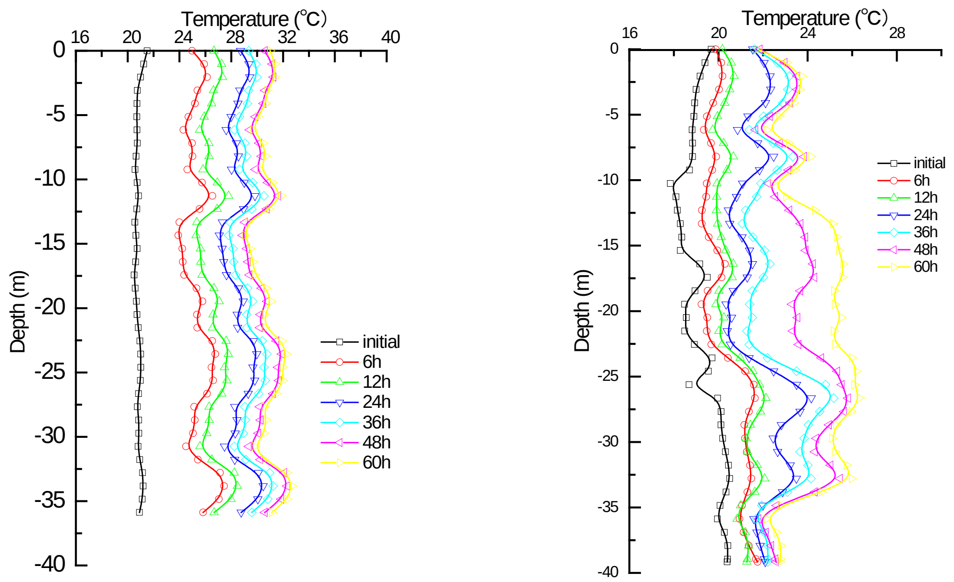
Temperature and strain distribution along the PHC pile

The initial temperature distribution of the soil was measured using the optical fiber sensors in the borehole. It was found that the temperature was between 18℃-19℃ and increased gradually within the depth of 36m. The average temperature is 18.4℃, which is close to the outlet temperature of 18.3℃ by TRT. The ground thermal conductivity was 1.53W/(m·K), which was obtained by TRT of the ground heat exchanger based on the line heat source model. Simultaneously, the borehole temperature was measured by distributed optical fiber sensor. During the heating process, the borehole temperature increased gradually and the temperature distribution was uneven along the borehole. The rate of temperature changes at different depth was not the same, which had a good correspondence with the soil profile.

TRTs of the single U-tube and double U-tube installed in a PHC pile were conducted to investigate the performance of geothermal PHC pile. According to the measurement of ROTDR, the initial temperature in the backfilled hollow section of the PHC pile was about 19℃, which was consistent with the temperature of the borehole below the seasonally varying temperature zone. Resistance thermometers were installed at different depth for comparison with the optical temperature sensing cable. They had a good agreement, by which the reliability of ROTDR was verified. The temperature distributions in and on the PHC pile are shown in Fig.1. In the first 24h, the temperature in the PHC pile increased quickly because the thermal conductivity of the backfilled and is small. The heat cannot transfer through PHC pile and into the surrounding soil. The temperature on the outer surface of pile increased slowly at early stage of heating and accelerated after heating 36h. The temperature in the pile increased 11.6℃, whereas the temperature on the pile surface increased only 4.4℃. It can be concluded that the heat transfer was very slow at the condition of backfill with sand in the hollow section. In addition, the temperature in the pile presented a relatively uniform distribution. With the increase of temperature, uneven distribution can be observed along the pile because of the difference in the density of the backfill sand.

Similar results can be found from the double U-tube TRT. Because the heating power was increase to 4kW, the temperature in the pile increased 19.5℃ and the temperature on the pile surface increased 6.75℃. We can conclude that the performance of heat transfer is not satisfactory with sand backfilled in the hollow section of the PHC pile.

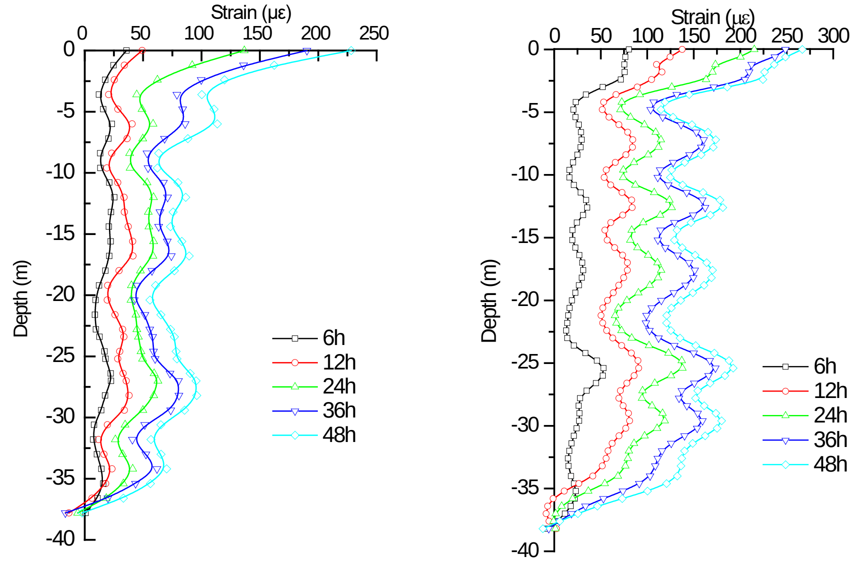
The heat transfer per unit length of the traditional ground heat exchanger and the geothermal PHC pile were calculated. It was found that the heat transfer of the single U-tube geothermal PHC pile was improved 15.4% than that of ground heat exchanger, and the double U-tube was improved 6.4% than the single U-tube.



(a) in the PHC pile (b) on the surface of PHC Pile

Fig. 1: Temperature distributions of PHC pile in single U-tube TRT

According to the stain sensing cables on the outer surface of PHC pile, the strain distribution was investigated during the TRT, as shown in Fig.2. It can be concluded that the strain increase with the temperature. The strain of double U-tube TRT was larger than that of single U-tube. The strain distribution along the pile had a good correlation with the temperature distribution, which may be related to the soil profile. The maximum strain appears on the top of the pile because of there was no loading on the pile head.



(a) Single U-tube TRT (b) Double U-tube TRT

Fig. 2: Strain distributions of PHC pile

It was found that the heat exchange performance is not ideal and the heat transfer efficiency was affected by the density of backfill in the hollow section and the configuration of the heat exchangers, which need to be designed carefully to improve the performance of geothermal PHC pile.

References

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