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Ground Source heat Pump Application in Tropical Countries

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ABSTRACT

In this paper we discuss the performance data of Ground Source Heat Pumps (GSHP) installed in Tropical countries, in this case in South East Asia (Thailand and Vietnam). Unlike the application of GSHP in four-seasons countries in which rejection (cooling) and heat uptake (heating) are balance, the use of GSHP in tropical country is mostly for cooling only (heat rejection). Also, the difference between ground and atmospheric temperature is essentially low. The ground water flow, on the other hand, can potentially increase the heat exchange rate by mean of natural convective heat transfer. Moreover, the groundwater temperature in recharge zone is generally lower than that of the other zone, allowing greater difference with the atmosphere temperature. The results of test data show the significant advantages in energy saving compared to those normal Air Source Heat Pump (ASHP). Moreover, in Hanoi, the GSHP can be used for heating purpose during low temperature season (December-January).

1. INTRODUCTION

Ground Source Heat Pump (GSHP) has been widely used in many subtropical countries in which seasonal heating and cooling are required. The GSHP system takes advantage of the relatively constant ground temperature against seasonal temperature variations. The tropical countries, however, have less seasonal temperature variations, besides, the underground temperatures in some location may significantly high to the extend the use of GSHP may not provide better efficiency compared to normal ASHP. Moreover, the intensive use of GSHP merely for heat rejection may create underground heat island problem. Figure 1 shows the average ground temperature in comparison with atmospheric temperature. The presence of groundwater flow in other hand, has several benefits. Shallow groundwater recharge area generally has lower temperature. Also, the groundwater flow provides convective heat transfer which increase the heat exchange rate and dispersing the heat away from heat exchanger, reducing the risk of underground heat island formation.

2. BACKGROUND AND OBJECTIVES

Yasukawa et al. 2009 provided important information on general groundwater condition in Chao-Phraya plain, Thailand and Red river plain, Vietnam by conducting ground water temperature surveys. The study identified several locations in Thailand where the use of GSHP as cooling may have greater advantages. In Hanoi, Vietnam, on the other hand, where the climate is humid subtropical, characterized by humid and hot summers and mild winters, the heating may also be applied.

Southeast Asian countries are experiencing rapid economic growth in an average of 5.2% per year since 2000. The rapid growth is followed by the significant increase of energy demand. In 2015, the region's total primary energy consumption reached 621 Mtoe. The total electricity generation of the region has increased from 370TWh to 868TWh from 2000 to 2015. By 2015, 83.4% of electricity was generated by burning the fossil fuel (coal, natural gas, oil). While Southeast Asian countries may not be considered as major global CO2 contributor, however, the data trend shows significant increment of CO2 emission from 711Mt in 2000 to 1288Mt in 2015.

Based on the report World Air Conditioner Demand by Region, published by The Japan Refrigeration and Air Conditioning Industry Association (JRAIA), national total air conditioner demand in 2016 was 1.56million units, the third largest in southeast Asia after Indonesia and Vietnam (Japan Refrigeration and Air Conditioning Industry Association (JRAIA) 2018)

South east Asian countries, as one of the region with the fastest economic growth rate where most of its countries are in tropical regions, are among the major contributor to global (Green House Gasses) GHG emissions. At the 2015 United Nations Climate Change Conference (COP21) held in Paris, the panel of 190 countries agreed upon a framework for global warming countermeasures from 2020 onward. It implies that, reducing the emission of CO2 into the atmosphere become the main issue that requires immediate action.

The application of GSHP in the tropical countries can potentially be applied to reduces GHG emission reduction. The application of GSHP in the tropical countries can potentially reduce GHG emission.

This research is carried out mainly to study the applicability of GSHP system in tropical countries. From the installed GSHP systems, important heat pump's thermal performance data, utilizing both vertical and shallow-horizontal heat exchanger can be evaluated. Also, the installed systems served as educational purpose for public awareness on the GSHP technology and renewable energy technology application.

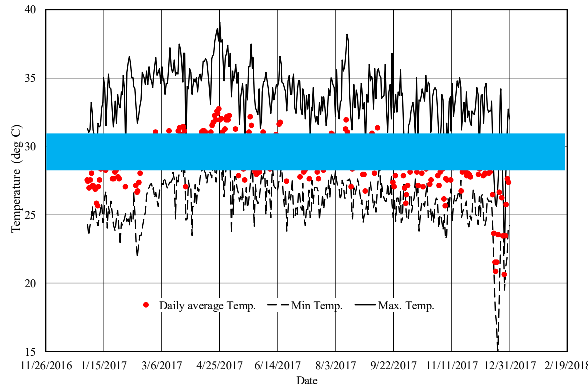

Figure 1. Average atmospheric temperature and average underground temperature in Bangkok.

3. INSTALLATION SITES

We have installed four GSHP systems in total. All of those have 4kW and 5kW capacity of cooling and heating respectively.

3.1 Thailand sites

Currently, we have three installed GSHP systems in Thailand.

3.1.1 Chulalongkon University Bangkok Campus

The Chulalongkorn University GSHP at Bangkok campus has two vertical boreholes with single u-tube arrangement. Both boreholes were supposed to have 50m depth, however, due to one of the borehole collapsed; only one borehole can be installed as planned while the other one has only 20m depth. The Fan Coil Unit (FCU) of the system is used for cooling purpose in one of the room of Parot Racha building.

3.1.2 Chulalongkon University Saraburi Campus

The Saraburi system installed at Chulalongkorn University Saraburi campus is using horizontal heat exchangers (carpet type and slinky coils). The FCU is used to provide room cooling in one of the laboratory offices. In this site,two GSHP were installed. One of which is an original GSHP with heating and cooling modes while another one is locally modified ASHP, by changing its refrigerant-air heat exchanger to refrigerant-fluid heat exchanger. For energy saving comparison, a normal ASHP was also installed. Figure 2 show the installation of heat exchangers in this site.

Figure 2. Installation of horizontal ground heat exchangers in Saraburi campus, Chulalongkorn University, Thailand.

3.1.3 Department of Mineral Resources of Thailand

The Department of Mineral Resources (DMR) GSHP at Pathum-Thani Province has two vertical 50m boreholes with double u-tube arrangement. The fan coil unit is used for cooling purpose of the museum's souvenir shop. Figure 3 shows the installation of GSHP at DMR geological museum, Thailand.

Figure 3. Installation of ground heat exchangers in Geological Museum, Department of Mineral Resources of Thailand

4. RESULTS AND DISCUSSIONS

Figure 4 shows the recorded CoP of GSHP installed in Bangkok campus, Chulalongkorn University. The CoP are presented for both 20^0C and 25^0C temperature setting. Detail of the experimental result of this site can be further found in other published paper (Chokchai et al. 2018).

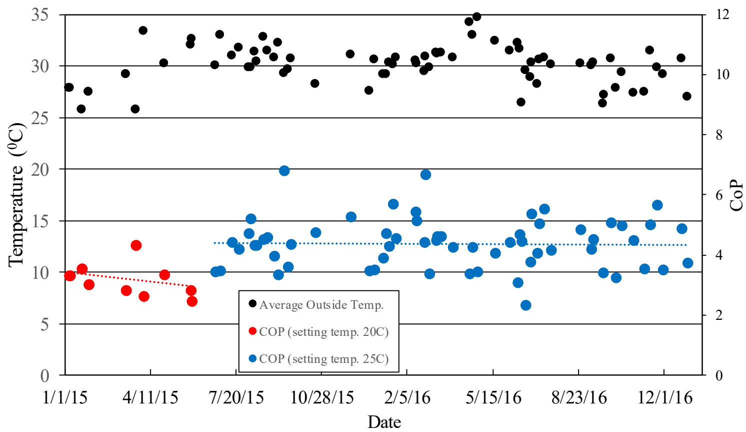

Figure 4. Cooling performances of GSHP system installed at Chulalongkorn University, Bangkok Campus

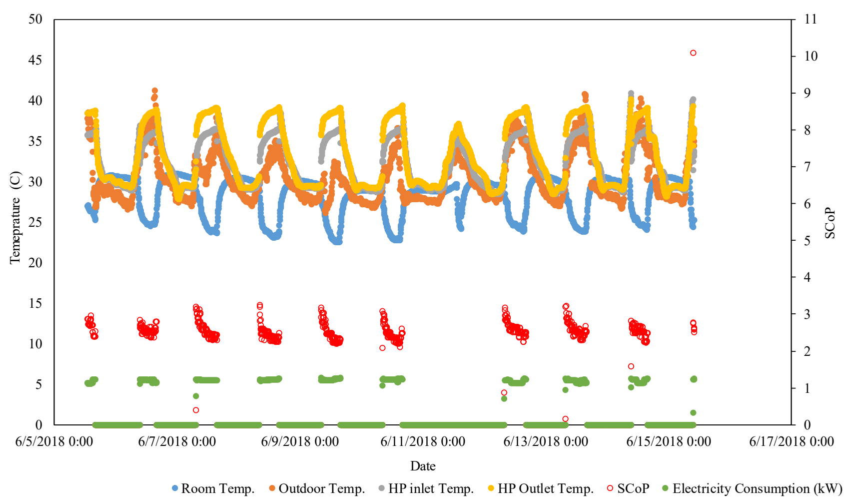

Figure 5. Cooling performances of GSHP system installed at DMR museum

Figure 5 shows one of the observation data and calculated System-CoP of Thai DMR museum. The recorded temperatures were outside temperature, room temperature, heat exchange fluid inlet and outlet temperature. The electrical consumption and heat exchanger fluid flowrate were also recorded from which, the CoP can be calculated. The average temperature difference between outside and room temperature were 9.7^{0}C while average temperature difference between outlet and inlet were 3-4^{0}C. Due to the high thermal load that is almost similar to the HP's cooling capacity, and improper positioning of fan coil unit, the CoPs were found to be low. At the beginning of daily operation, the average CoP was around 3 and decreases with time. This is attributed to the increasing HP return temperature followed by increasing HP outlet temperature which lead to the higher demand compressor works.

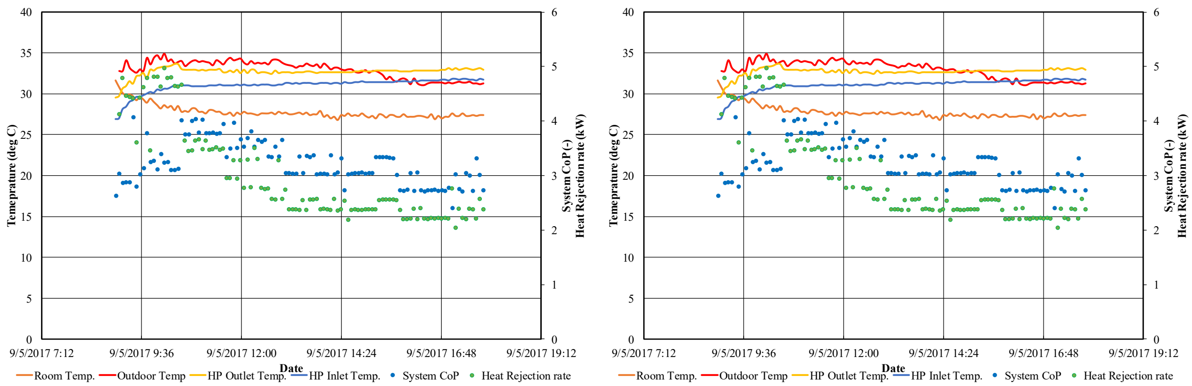

Figure 6. Performance of GSHP systems, cooling and heating respectively

On December 2017 heating test for Vietnam GSHP was carried out. The minimum atmospheric temperature was 130C and the setting temperature was 23. The obtained average system CoP was 3.7. Figure 6 shows the Vietnam GSHP system performance during cooling and heating respectively. The average CoP is 3.1 and 3.6 respectively.

The accuracy of the recorded data has been one of the major issues in the experiment. It includes the use of standard thermocouples, sensors and proper installations. The standard power logger was just installed this year to ensure the precision of the power consumption.

In 2018, we also carried out the Thermal Response Test (TRT) in Bangkok and Hanoi site. These were the first TRT to be carried out in South-east Asian countries. The effective thermal conductivity of Bangkok was found, 1.82 W/mK due to the fact that most of ground layer in upper 50m are consist of high permeability sandstones as part of Bangkok upper aquifers. Furthermore, existence of pumping wells in Bangkok city have possibly increase the groundwater flow that enhance the effective thermal conductivity. The effective thermal conductivity of Hanoi site was found to be lower than that of Bangkok site (1.44W/mK). The reason is that 80% layer are consist of clay and clayey-silt, which have low permeability. Thus, it has lower advective heat transfer effects. However, it has to be noted initial ground (background) temperature of Hanoi is 27.2^{0}C while Bangkok was 29.3^{0}C. The TRT measurement in Hanoi was carried out in July, during the hottest season while Bangkok test was done in February. Figure 7 and 8 show the TRT measurements and results in Bangkok and Hanoi respectively

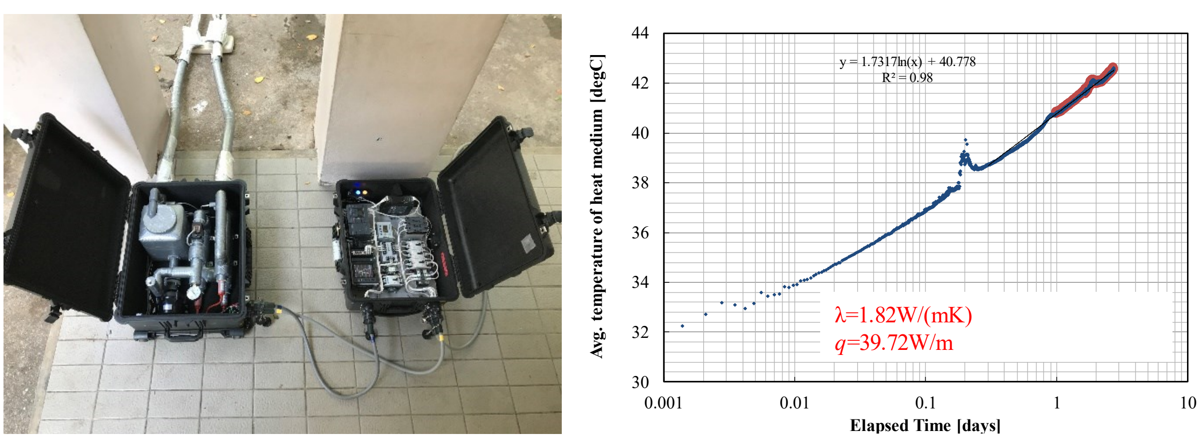

Figure 7.TRT measurement in Bangkok GSHP site

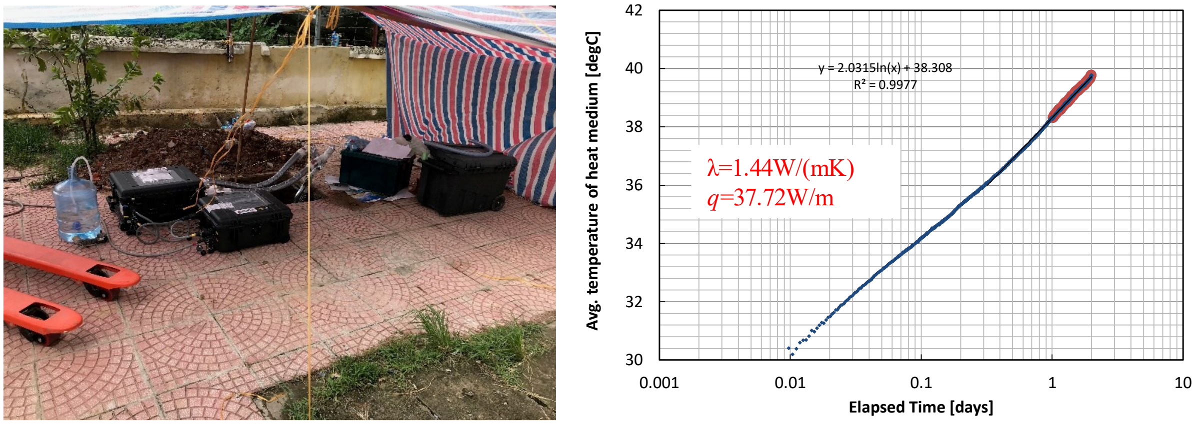

Figure 8.TRT measurement in Bangkok GSHP site

5. CONCLUDING REMARKS

The GSHP systems have been installed in Thailand (3 sites) and Vietnam (1 sites). These systems were used to obtain important thermal parameters that are required to assess the potential applicability of GSHP in tropical countries, especially South-east Asian countries. Furthermore, TRT measurements have been also carried out in two sites. The results signify the importance of groundwater flow as advective heat transport that could enhance the thermal performance of heat pump, despite in fact the temperature differences between ground and air is significantly low. For Bangkok site and Saraburi site, the GSHPs require less electrical power to run the relatively similar cooling load as those of normal AC (ASHP). For the DMR museum site, rapid temperature build-up was observed during daily operation. Despite the background temperature tend to return to the initial temperature in the next day, the CoP can be observed on the daily basis operation. The installed GSHP also serve for educational purpose for local people.

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