GROUND-COUPLED COOLING IN HANOI

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Abstract
The energy required for space cooling could be reduced by using ground as a heat sink depending on the weather conditions and the ground characteristics. In this paper the theoretical performance of a closed loop ground coupled cooling system for a commercial building in Hanoi has been investigated as an alternative to the conventional air-to-air cooling system. A theoretical computational model for the prediction of the cooling system performance has been developed. It was found that the ground-coupled cooling system performs better (approximately 30% energy saving) than a conventional air-to-air cooling system.

Keywords: Ground-coupled cooling; heat pump; simulation; Hanoi
Theme: Energy efficiency and advance simulations

1 Introduction

The energy required for space cooling could be reduced by using the ground as a heat sink depending on the weather conditions and the ground characteristics. The ground temperature is relatively constant at few metres below the surface. Yasukawa *et al*. (2009) conducted extensive groundwater temperature surveys in the Red-river plain, Vietnam (Fig. 1). They reported that the temperature of the ground remains fairly constant below summer outside air temperatures in the Hanoi (Fig. 2). A recent study by Tuyen *et al*. (2010) concluded that there is a good prospect for extensive use of the ground-coupled cooling system for space air conditioning in the Hanoi region.

The conducive conditions are: the long time duration of hot weather in summer, large power consumption for air conditioning, and the electricity shortages in summer.

A ground-coupled cooling system uses the ground as a heat sink for reducing the energy consumption of the cooling system. Closed loop ground-coupled cooling systems comprise of either a series of parallel pipes laid out horizontally in the trenches a few metres below the surface or vertically suspended in the boreholes back filled with a good thermal conductance material. A closed loop ground-coupled cooling system uses refrigerant, water or a water-antifreeze solution as a heat transfer fluid in the ground loops. The ground loops reject heat to the earth. Figure 2 shows a schematic of closed loop ground-coupled cooling system with horizontally laid ground heat exchanger loops. The system works with the air handler drawing in hot air from the room.

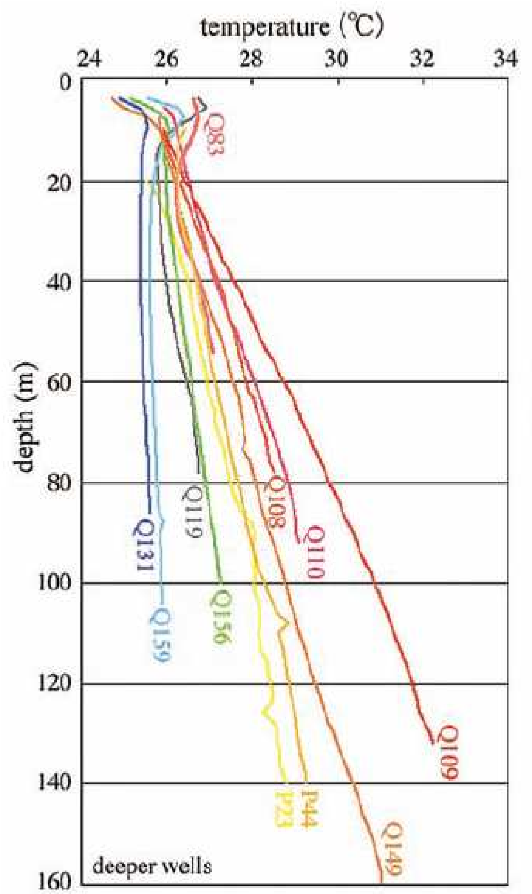

Fig. 1. Temperature profiles of the wells around Hanoi are
(Source: Yasukawa *et al*. 2009)

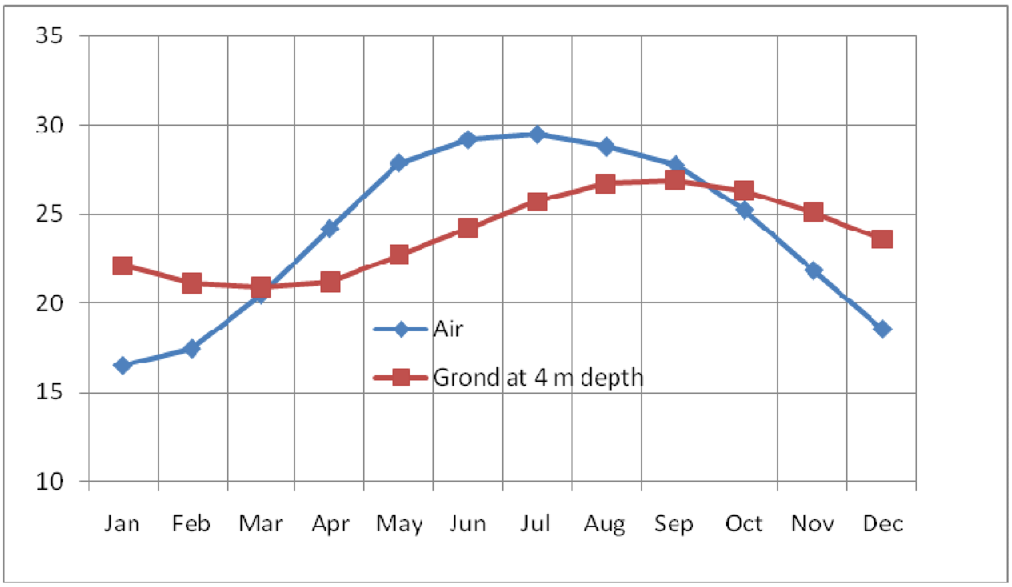

Fig. 2. Monthly calculated "undisturbed" ground temperatures at 4m depth and ambient air temperatures (°C)
(Source: http://apps1.eere.energy.gov/buildings/energyplus/weatherdata)

As the hot air passes over the evaporator coil, the refrigerant being colder than the air, heat flows to the refrigerant thus evaporates the refrigerant. The air becomes colder and flows into the conditioned space. The refrigerant in vapour form flows into the compressor which further increases the temperature and pressure of the vapour refrigerant. As the high pressure and temperature refrigerant arrives at the condenser, the heat from the refrigerant is transferred to the water due to which the refrigerant temperature drops and condenses to liquid. The liquid refrigerant is further cooled as it passes through an expansion valve decreasing both the pressure. This low temperature and pressure refrigerant flows to the evaporator and the cycle is repeated.

In this paper the theoretical performance of a closed loop ground-coupled cooling system for a commercial building in Hanoi was investigated as an alternative to a conventional air-to-air cooling system. The aim of this paper is to compare the effectiveness of ground-coupled cooling system and conventional air-to-air system for commercial building applications in Hanoi. A theoretical computational model for the prediction of the system performance was developed for the vapour compression cooling. Then this was used to compare the performance of ground-coupled cooling system and conventional air-to-air cooling system in Hanoi. The model developed and the results obtained for Hanoi are presented and discussed.

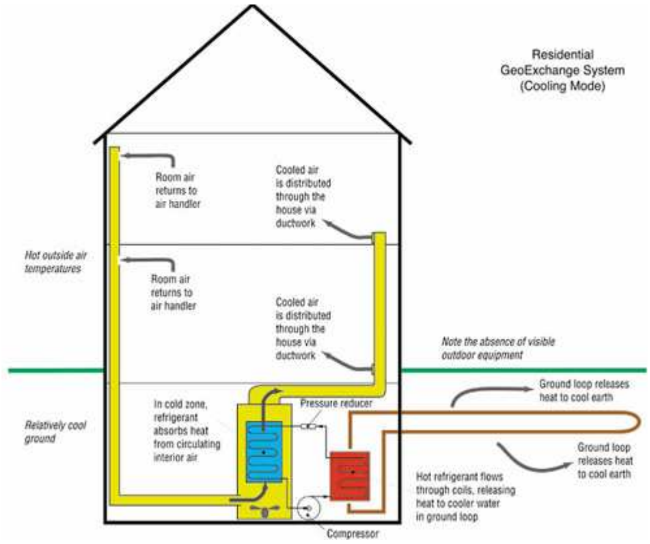

Fig. 2. Schematic of a close loop ground-coupled cooling system
(Source: http://www.greenbuilder.com/sourcebook/groundsource/images/geoexchange_cooling.jpg)

2 Cooling and Heating Requirements in Hanoi

Hanoi is the capital and second largest city of Vietnam. It is located on the bank of the Red River. The climatological information of Hanoi, based on monthly averages for the 93-year period (1898-1990), is shown in Table 1. The Hanoi region is hot in summer and warm in winter. There are over 200 days of cooling demand in a year (Tuyen *et al*. 2010).

It should noted that annual average number of rain days is approximately 150, which make the ground high moisture content and high thermal conductivity and favouring good ground heat exchange.

Figure 3 shows the annual heating and cooling energy requirement for one floor of a typical 50-storey concrete building in Hanoi. The annual heating and cooling are estimated to be 14 MWh and 117 MWh respectively. The peak heating load is 33 kW and the peak cooling load is 64 kW. The heating and cooling demand of this office building was estimated by running a TRNSYS model with Hanoi hourly climatic data provided by Building Technologies Program, US DOE (2010).

The following assumptions were used:

- number of occupants – 54 based on 25 m^2 per person,
- about one third of the occupants have computers,
- the building is occupied from 9 am to 5 pm on weekdays,
- the building is unoccupied at weekends.

Table 1. Climatological information of Hanoi
(Source: World Weather Information Service 2010)

Month	Mean Temperature (C) Daily Minimum	Mean Temperature (C) Daily Maximum	Mean Total Rainfall (mm)	Mean Number of Rain (Days)
Jan	13.7	19.3	18.6	8.4
Feb	15.0	19.9	26.2	11.3
Mar	18.1	22.8	43.8	15.0
Apr	21.4	27.0	90.1	13.3
May	24.3	31.5	188.5	14.2
Jun	25.8	32.6	239.9	14.7
Jul	26.1	32.9	288.2	15.7
Aug	25.7	31.9	318.0	16.7
Sep	24.7	30.9	265.4	13.7
Oct	21.9	28.6	130.7	9.0
Nov	18.5	25.2	43.4	6.5
Dec	15.3	21.8	23.4	6.0

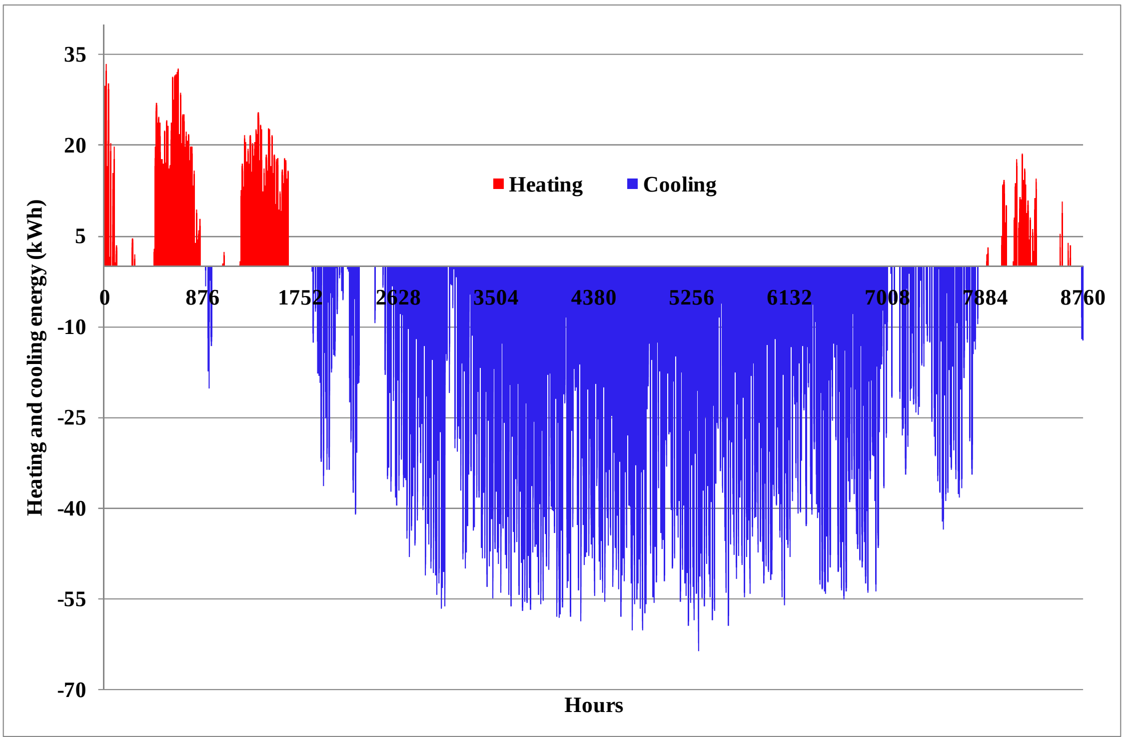

Fig. 3. Heating and cooling demand

3 Performance of the Vapour Compression Cooling System

The cooling coefficient of performance (*CCOP*) of the cooling system is a performance parameter which is defined as the ratio between cooling output (Q_L) and the work input (W) (Fig. 4).

$$CCOP = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L} \quad (Eq.1)$$

$$Q_L = \frac{UA_e \times (T_{ei} - t_e + T_{eo} - t_e)}{\ln[(t_e - T_{ei})/(t_e - T_{eo})]} \quad (Eq.2)$$

$$Q_H = \frac{UA_c \times (t_c - T_{ci} + t_c - T_{co})}{\ln[(t_c - T_{ci})/(t_c - T_{co})]} \quad (Eq.3)$$

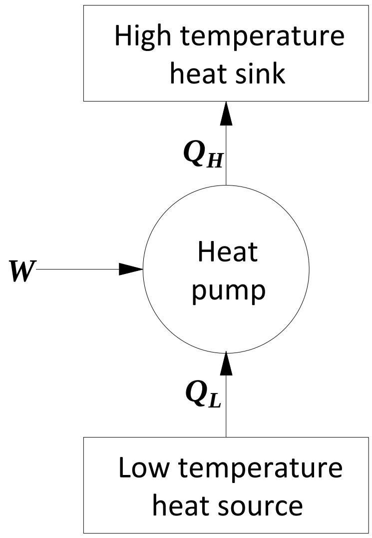

Fig. 4. Energy flow of a cooling system (Source: Lu Aye 2010)

Where *UA* = overall heat transfer coefficient (kW/C)
t_e = refrigerant evaporating temperature (C)
t_c = refrigerant condensing temperature (C)
T_{ei} = evaporator side entering air temperature (C)
T_{eo} = evaporator side leaving air temperature (C)
T_{ci} = condenser side entering air or fluid temperature (C)
T_{co} = condenser side leaving air or fluid temperature (C)

4 Results and Discussion

By using the set of equations (Eq. 1 to 3) (performance prediction model) presented in the previous section and using the following assumptions, the average *CCOP*s for the conventional air-to-air cooling system and the ground coupled cooling system were estimated (Table 2).

- Overall heat transfer coefficient ratio between condenser and evaporator is 1.5 [-]
- Average ambient air temperature is 29.5°C
- Average ground temperature is 26°C
- The evaporating temperature is 10°C
- The supply air temperature is 14°C
- The condensing temperature for the conventional air-to-air cooling system is 50°C
- The condensing temperature for the ground-coupled cooling system is 47°C

Table 2. Performance comparison

	Air-to-air system	Ground coupled system
CCOP	3.2	4.5
Annual electricity used for cooling	37 MWh	26 MWh
Energy saving (%)	-	~30%

By using the performance prediction model it is estimated that for the same air supply and evaporating temperatures the ground-coupled cooling system has about 3°C lower condensing temperatures. This makes the energy efficiency of the ground coupled system better than the conventional air-to-air cooling system.

5 Conclusion

A theoretical computational model for the prediction of the system performance of vapour compression cooling systems has been presented. The model has been used to compare the performance of a conventional air-to-air cooling system and a ground-coupled cooling system for a commercial building in Hanoi. It was found that the potential electricity saving of the ground-coupled cooling system is about 30 % compared to the conventional system. It is recommended that further detailed transient analysis should be done to confirm this finding.

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