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Evaluation of two earth–air heat exchangers efficiency of different pipe materials within a warm temperate climate

Mohammed Cherif LEKHAL[1,*], *Abderahmane Mejedoub* MOKHTARI[1] and *Rafik* BELARBI[2]

[1]LMST Laboratory, University of Sciences and Technology, Mohamed Boudiaf, Oran, Algeria
[2]LaSIE Laboratory, UMR-7356 CNRS, University of La Rochelle 17042, La Rochelle, France

Abstract. The Earth-Air Heat Exchanger (EAHE) system was used for many years for both primary heating and cooling applications, especially in the building sector. Its energy performance can be influenced by three principal factors: the EAHE pipe material, the airflow rate, the soil characteristics and the moisture content. The state of the art shows a divergence about the effect of the pipe material on the performance of the EAHE. The aim of this study is to provide an adequate response to this problematic based on experimental analysis. In this regard, we tested two EAHEX of different materials: PVC and Zinc. The comparative study was conducted under a warm temperate climate in the north of Algeria. The data analyses showed that the pipe material can significantly affect the EAHE performance during periods when the EAHE passes from heating to cooling mode. Furthermore, the air outlet temperature differences provided by EAHE Zinc and those of PVC up to about 7.5°C.

1 Introduction

Nowadays, the high building energy consumption in the world requires new solutions, among which the integration of geothermal resource. This later is considered as an environmental alternative to ensure an acceptable level of thermal comfort while reducing building heating and cooling loads. In this context, several geothermal systems can be found, among which the Earth-Air heat exchanger [1]. In fact, the performance of an EAHE depends on the climate, the nature of the ground, the type of pipe, the pipe configuration and the dynamic conditions (air velocity and airflow rate). In this context, several researchers have studied the effect of operating parameters such as pipe length, pipe radius, air velocity, burial depth, relative air humidity, and pipe material on the thermal performance of the EAHE [2,3]. Among this research, we mention those which take into account the effect of the pipe material, Badescu et al. [4] examined the heating and cooling potential of an EAHE under the real climatic conditions of Pirmasens (PH) in Germany. The results showed that the energy provided by the EAHE significantly depends on the pipe material. Bansal et al. [5, 6] analyzed the thermal performance and evaluated the heating and cooling capacity of two EAHEX (PVC and Steel) installed in Ajmar, India. A numerical model based on the Computational Fluid Dynamics (CFD) was developed to examine the effect of operating parameters such as pipe material and air velocity on the thermal performance of EAHE. The authors concluded that the EAHE performance is not affected by the pipe material. In the study presented by Abbaspour-Fard et al. [7], the performance of an EAHE installed in the North-East of Iran was studied and the effect of the main parameters such as air velocity, burial depth, length and pipe material was examined. The results show that all parameters had significant effect of system performance except pipe material.

Most cited works above shows a divergence concerning the impact of pipe material on the EAHE efficiency. That's why, the present study investigates the effect of PVC (Polyvinyl Chloride) and Zinc (Zn) materials on the performance of the EAHE. This comparative study was conducted under a warm temperate climate of the North-West of Algeria. Then, some suggestions and recommendations were provided based on the analysis of the presented results.

2 experimental system with its operating condition

The studied system represents two EAHEX of different pipe materials, PVC and Zinc. They are composed of two cylindrical tubes of 0.118 m in internal diameter, 0.2 m in external diameter and 20 m in length buried horizontally at 2 m under a clay loam soil. Table 1 gives the thermos-physical characteristics of two EAHEX and the soil.

The EAHE are coupled to an experimental cell located at the Institute of Civil and Mechanical Engineering (IGCMO) of Oran University, Algeria, where the coordinates are: 35.65 ° North Latitude, 0.62 ° North west longitude. Fig. 1 shows an overview of the test cell coupled to both EAHEX.

* Corresponding author: lekhal.med.cherif@gmail.com

Table 1. Thermos-physical characteristics of two EAHEX and the soil.

Material	Thermal conductivity (W/m K)	Density (Kg/m^3)	Thermal capacity (J/kg K)
Soil	1.5	1530	1300
PVC	0.17	1400	1046
Zinc	16	7200	380

Fig. 1. Test cell equipped with both EAHE (PVC and Zinc).

The air inlet is an external mouth with a height of 1 m and the air outlet is inside the room to provide air supply. The Zinc EAHE has the same dimensional configuration as the PVC EAHE. Fig. 2. shows the design and implementation phase of the two EAHEX.

The experimental tests were taken during the heating and cooling period from November 2013 to August 2014. The outdoor air temperature and the air temperature at the outlet of the two EAHEX were measured every hour using a K-type thermocouple connected to a data acquisition chain (KEITHLEY 7700).

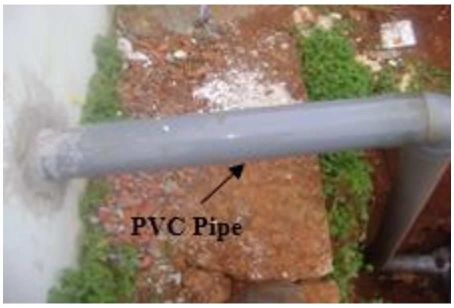

Fig. 2. Sizing and coupling phase of the two EAHEX with the test cell.

3 Results and discussion

In order to assess the impact of the pipe material on the two EAHEX performance's, comparisons were performed under the same climatic conditions, geographical, topological, the same dimensions (length, diameter, thickness and depth) and the same dynamic conditions (air velocity and mass flow).

The measurements were performed during the summer and winter periods of the year 2013-2014; the representative measurements of our study were presented in a 48 hours' sequence distributed over the months of the year to better monitor the temperature differences provided by both EAHEX systems.

The effect of the pipe material on the performance of EAHEX was analysed, as shown in Fig. 3. Fig. 3 (a) shows air temperatures provided by PVC and Zinc EAHE in a 48 hours' sequence with a total of 336 hours distributed in December, November, January, February and March. It was observed that the ambient temperature (measured at the inlet of the EAHE) varied between 9.5°C and 25°C during these months, whereas the air temperature at outlet of the Zinc EAHE varied from 13°C to 22°C and between 12°C and 19.5°C for PVC EAHE. The maximum difference between the air temperature provided by the Zinc and PVC EAHE can reach a value of 5.5°C in November 20 and 21, 2013. This temperature difference decreases during the winter season until it becomes almost zero in March 20 and 21, 2014 (End of the heating season). In fact, the EAHE with Zinc pipe presents high performance compared to the PVC due to its considerable thermal capacity.

Fig. 3 (b) shows the same temperature evolutions provided by PVC and Zinc EAHE in the same time representation (48 hours) distributed in April, May, June, July and August. During these months, it is observed that the air temperatures at the outlet of the PVC EAHE vary between 21°C and 34°C compared the air temperature variations provided by the Zinc EAHE which vary between 20°C and 27.5°C. At the beginning of the summer season, there was no significant difference between the air temperature provided by the Zinc and PVC EAHE in April 1/2, 2014. The air temperature difference increases during this season until reaching the 7.5°C in July 28/29, 2014. Comparison of outlet air temperature between PVC and Zinc EAHE shows significant difference at the beginning of the heating period, i.e. November and December. This difference became very low in mid-winter season till it disappears in April and it reappears again till the cooling period, i.e. the end of august. In other manner, the nature of the material could affect the performance of the system depending on period.

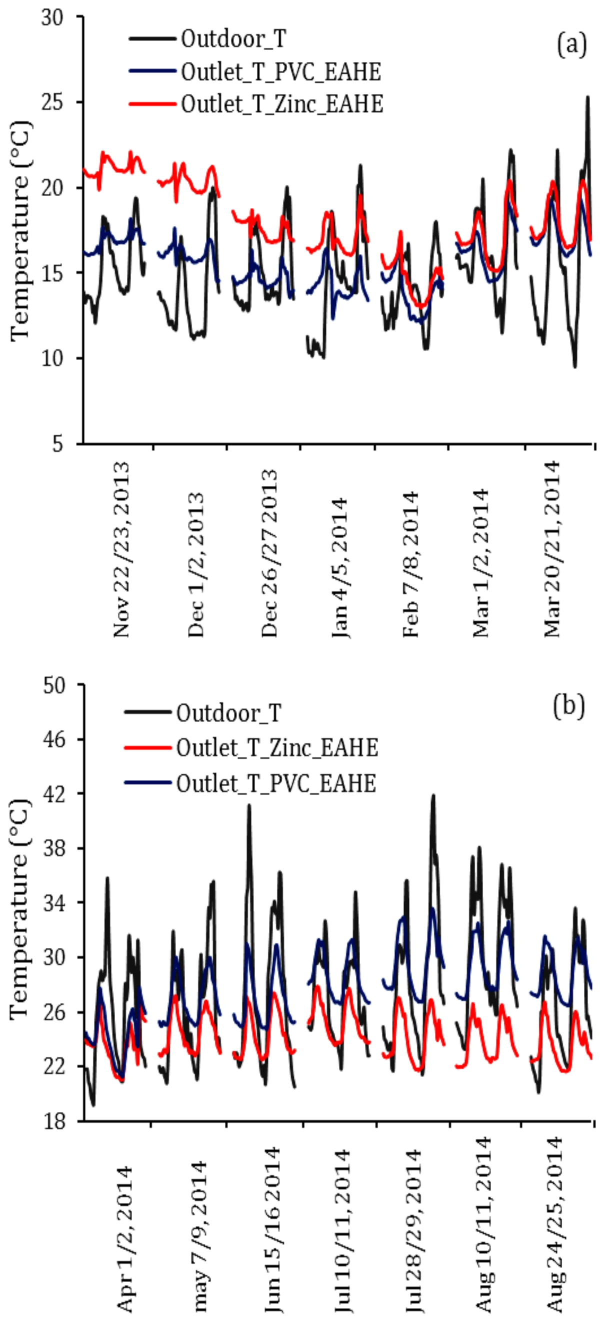

Fig. 2. Comparison between the air temperature supplied by the PVC EAHE and that of Zinc (a) heating period, (b) cooling period.

4 Conclusions

A comparative experimental study between two earth-air heat exchangers (EAHEX) with different pipe materials, PVC and Zinc, was carried out. The comparison aims to study the effect of pipe materials on EAHE performance. The two PVC and Zinc EAHE are installed at the institute of civil engineering and mechanics of Oran, in the North-West of Algeria (southern Mediterranean). The experiment is conducted under the same climatic conditions, geographical, topological, the same dimensions (length, diameter, thickness and depth) and the same dynamic conditions (air velocity and mass flow).

The Zinc EAHE provides a higher air temperature than the PVC EAHE with a difference of up to 7.5°C recorded at the beginning of the winter season.

The temperature differences between the air supplied by the Zinc EAHE and PVC EAHE became very low in mid-winter season until they disappear in March to April. This difference reappears until the cooling period, that is, the end of August.

It can be concluded from this analysis that performance of the EAHE system is affected by the pipe material in the middle of the winter and summer season. On the other hand, the pipe material does not have any effect on the performance of the EAHE in April and March, i.e. when the EAHE passes from the heating mode to the cooling mode.

Finally, the effect of the pipe material on the EAHE performance depends on the climatic period

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