Renewable and Sustainable Energy Reviews 15 (2011) 4483–4490

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review on the experimental and analytical analysis of earth to air heat exchanger (EAHE) systems in Turkey

Leyla Ozgener*

Department of Mechanical Engineering, Faculty of Engineering, Celal Bayar University, TR-45140 Muradiye, Manisa, Turkey

ARTICLE INFO

Article history:
Received 29 March 2011
Accepted 5 July 2011
Available online 15 September 2011

Keywords:
Energy analysis
EAHE
Exergy analysis
Exergoeconomic
Geothermal
Solar
Renewable energy
Turkey

ABSTRACT

During the last three decades, a number of studies have been conducted by various investigators in the design, modeling and testing of earth to air heat exchanger (EAHE) systems. This paper reviews the studies conducted on the experimental and analytical analysis of EAHE systems in Turkey and around the world as of the end February 2011. The studies undertaken on the EAHE systems are categorized into two groups as follows: (i) open loop for space heating/cooling and (ii) closed loop for space heating/cooling systems. This paper investigates the studies on EAHEs, also known underground air tunnel systems.

Contents

1. Introduction

The idea of using earth as a heat sink was known in ancient times. In about 3000 B.C., Iranian architects used wind towers and underground air tunnels for passive cooling [1,2]. Underground air tunnels (UAT) systems, nowadays also known as earth to air heat exchangers (EAHEs), have been in use for years in developed countries due to their higher energy utilization efficiencies compared to the conventional heating and cooling systems. EAHE is a passive climate control technique that has application in residential as well as agricultural building utilizes the underground soil temperature that stays fairly constant at a depth of about 2.5–3 m [2,3].

Abbreviations: COP, coefficient of performance; CFC, chlorofluorocarbons; EXCEM, exergy cost energy and mass; EAHE, earth to air heat exchanger; GSHPs, ground-source heat pumps; GSHPS, ground-source heat pump system; ISAHP, integral-type solar assisted heat pump; PVs, photovoltaics; TRT, thermal response test; UAT, underground air tunnel systems; UEAHESGHPA, utilization of earth air heat exchangers for solar greenhouses pre heating and performance analysis.

* Tel.: +90 236 2412144x240; fax: +90 2323886027.
E-mail address: leyla.ozgener@bayar.edu.tr

1364-0321/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2011.07.103

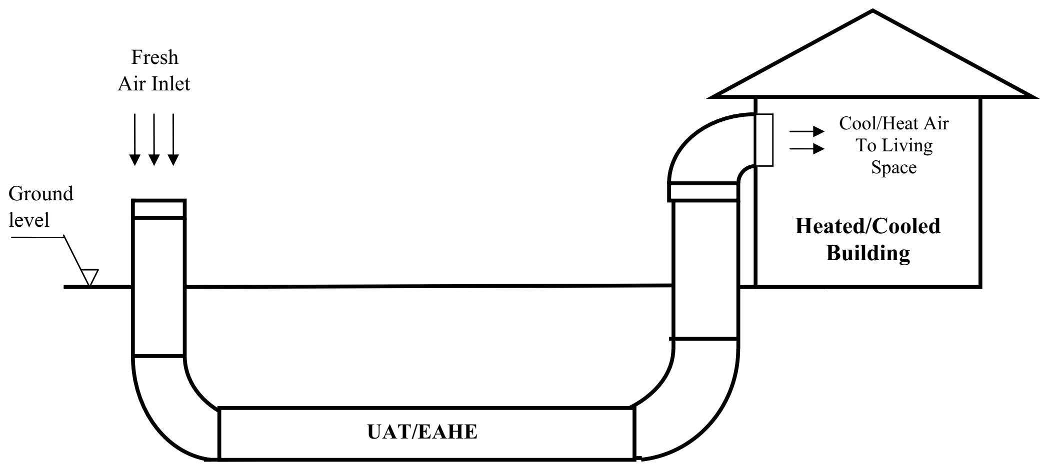

Fig. 1. Schematic of open loop EAHE (underground air tunnel).

The energy performance of an EAHE system can be influenced by three primary factors: the EAHE pipe material, the circulating fan, and the soil characteristics and moisture content [1–43]. Knowledge of soil thermal properties is very important in the design and application of this technique [3–5,12,14–20].

EAHEs have been used for many years for both space pre heating and pre cooling; however, their efficiency is influenced by the variation in outside temperature. When heat is most needed, the outside air is cooler, thus often requiring backup electric resistance heating during the coldest days. Similarly, cooling is needed during the hottest days, requiring the equipment to work at low efficiencies.

Overcome the problem of resource variations, as ground temperatures remain fairly constant throughout the year. Depending upon the soil type and moisture conditions, ground (and groundwater) temperatures experience little if any seasonal variations below about 10 m [2].

The EAHE thus have several advantages over air source heat pumps, integral-type solar assisted heat pump (ISAHP) and GSHPs [44–53]. These are:

- They consume less energy to operate,
- It is expected that air pollution problems will be minimized by using EAHEs for passive cooling and heating purposes,
- In Mediterranean and tropical regions, they do not require supplemental heat during extreme low outside temperature,
- They do not use compressor, CFC, or any refrigerant,
- Air uses as working fluid in EAHE,
- They have a simpler design and consequently less maintenance,
- They do not require the unit to be located where it is exposed to weathering,
- They have lower initial cost than GSHPs and ISAHP.

The main disadvantages of EAHEs,

- EAHEs are the higher initial cost, being about 20–40% more expensive than air source units under Turkey conditions. This is due to the extra expense and effort to bury heat exchangers in the earth or providing a sink for the energy source. However, once installed, the annual cost is less over the life of the system, resulting in a net savings. The savings is due to the coefficient of performance (COP), averaging over 3 for EAHE and GSHP as compared 2 for air-source heat pumps and ISAHP [28–33,54–57].
- Second disadvantage of EAHE is convection of fan noise via pipes to the far away living space.
- Third disadvantage of EAHE is air vapor condensation discharge from EAHE. Useful solution for solving condensed water vapor discharge problem in the underground air tunnel, there is a way to pump out any water in the pipe, that is, a small submersible pump is located at the lowest point. However, this solution will increase total energy consumption of the system. It is expected that sum of the total COP value of the system will decline [29].
- Fourth disadvantage of EAHE is during the operating period working fluid (air) quality decreases and possibility of fatal microorganisms cultivate, so proper filter should be used or air quality should be monitored strictly by operators.

One of the first steps in the consideration of an EAHE system is a characterization of the site in terms of geology availability. Information concerning aquifer (or aquifers) available at the site, their ability to produce water, depth to water, geology, depth to bedrock and the nature of the soil and rock (hydraulic and thermal properties) are key issues. This information guides the designer in the selection of the type of GSHP or EAHE system to be used and in the design of the system [1–43].

Two major types exist: open loop EAHE (Fig. 1) or closed loop EAHE (Fig. 2). The ground coupled uses a buried earth coil with circulating air in a closed loop of horizontal or vertical pipes to thermal energy to and from the earth.

The structure of the paper is as follows. The first section includes the introductory part; Section 2 gives a brief information about historical background of EAHE, Early studies conducted on experimental and analytical analysis of EAHE in the world are investigated in the third section; Section 4 conducted on EAHE systems at the Turkish universities, and the last section concludes.

2. A brief of historical background of EAHE in the world

In tropical climates, air conditioning is widely employed not only for industrial production but also for the comfort of occupants. It can be achieved efficiently by vapor compression machines, but due to depletion of ozone layer by chlorofluorocarbons (CFCs) and the need to reduce high grade energy consumption; numerous alternative techniques are being currently explored. One such proposition is the earth air pipe system. It uses soil as a heat sink and air as the heat transfer medium for space cooling summer. When the warm air flows in the earth air pipes, heat is transferred from air to the earth. As result, the air temperature at the outlet of the earth air pipes is much lower than that of the ambient [41].

As mentioned earlier, the idea of using earth as a heat sink was known in ancient times. In about 3000 BC, Iranian architects used wind towers and underground air tunnels for passive cooling [2,8]. In 19th Century Wilkonson [21] designed a barn for 148 where a