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An intense review on the latest advancements of Earth Air Heat Exchangers

Namrata Bordoloi[a], Aashish Sharma[a,*], Himanshu Nautiyal[b], Varun Goel[c]

[a] School of Mechanical Engineering, Lovely Professional University, Punjab 144411, India
[b] Department of Mechanical Engineering, THDC IHET, Tehri, Uttarakhand 249124, India
[c] Department of Mechanical Engineering, National Institute of Technology, Hamirpur 177005, India

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ABSTRACT

Energy saving is a vital element in today's scenario. Earth Air Heat Exchangers (EAHE) is a technique that promotes energy savings. EAHE is a non-conventional technique that uses the earth's underground heat for space cooling/heating. In this article, review of different combinations of EAHEs is presented. The review presents an apprehensible summary of the previous works on EAHE. The review addresses an elaborated description of the analytical and experimental studies on the different combination of EAHE and analyses the results from the thermal performance. It also consider the environmental aspect in the field of energy saving. It is concluded from the summary that the design parameters directly or inversely affect the outlet temperature. The result also shows that the pipe materials does not have much influence on the outlet temperature. In the case of energy saving, EAHE technology saves more energy that can replace the conventional air conditioning systems. Thus, this technology can effectively reduce the greenhouse gases and improve the environment.

1. Introduction

Energy is one of the major input in the economic growth of a country but energy saving is one of the major challenges in today's world. Our concern is to deprecate the use of high-grade energy and to endorse the use of renewable energy. Out of the world's total energy demand, RES supply up to 14% [1,2]. Renewable energy includes biomass, geothermal energy, hydropower etc. [1] In the developing countries, energy sector is considered as a crucial sector, as the demand for consumption is increasing than its production. India consumes more energy in residential, commercial and agricultural sectors than China, Japan and Russia etc. [3].

The consumption of energy in buildings has significantly increased in the last decade. In order to improve the energy conservation in building, it has been recommended to use energy audit in buildings during construction. The government of developing countries have initiated campaigns and amended strict laws against the consumption of energy. European countries have pledged to reduce the annual consumption of primary energy by 20% by 2020 [4]. The Japanese Ministry of Environment (MOE) launched a campaign that encourages the people to wear lighter clothes and for companies to set their air conditioner at 28 °C [5]. In India, the government in 1977 had created a body named Petroleum Conservation Research Association; the motto of the body was to reduce the country's dependency on oil and gas products and to promote the conservation of Petroleum products [6]. According to the research conducted by United States Department of energy, RES can be a good alternative to the non-renewable sources. Sources like geothermal energy, ocean energy, solar energy and wind energy can be envisaged in the years. These sources have enormous potential to replace the prevailing sources if used in a correct way.

The energy usage depends on temperature, humidity as its changes affect the demand for space heating or cooling. In summers, generally in commercial buildings, air conditioning systems are used. These systems improve the efficiency by using a heat sink and are cooler than the standard air. Heating/cooling of air with Earth Air Heat Exchanger (EAHE) is a passive way to reduce the heat losses due to ventilation and thermal comfort in buildings. This system uses geothermal energy by burying a network of pipes of different combination installed in open spaces or beneath the building at a certain depth [7].

1.1. Earth Air Heat Exchanger (EAHE)

Depending on the current scenario, energy saving has become one of the important element for the economic growth countries like US, Russia, India etc. have been taking initiatives to save energy. EAHE is a new passive technology efficient to save energy which has been used by many countries for achieving thermal comfort in buildings. EAHE is a non-conventional technique that has found applications in residential buildings with air conditioning system, greenhouses, commercial buildings etc. which utilizes the underground soil temperature of the

* Corresponding author.
E-mail address: aashish20212@gmail.com (A. Sharma).

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Nomenclature

ATEHE	Air-to-Earth Heat Exchanger
CFC	Chloro-fluoro carbon
CFD	Computational Fluid Dynamics
COP	Coefficient of Performance
EAHE	Earth Air Heat Exchanger
EER	Energy Efficiency Ratio
EPBT	Energy Payback time
FFT	Fast Fourier Transform
FVM	Finite Volume Method
HDPE	High Density Polyethylene
HETS/HEAHE	Horizontal Earth Air Heat Exchanger System
HVAC	Heating, Ventilation and Air conditioning
MOE	Ministry of Environment
MS	Mild Steel
PID	Proportional Integral Derivative
PV	Photovoltaic
PVC	Polyvinyl Chloride
RES	Renewable Energy Sources
SAHD	Solar Air Heating Duct

Units

m	meter
˚C	Celsius
m/s	velocity

Subscripts

l	length
d	diameter
r	radius
i	inlet
o	outlet

earth.

In ancient times, underground air tunnels were used for cooling and heating buildings by the Iranian architects in 3000 BCE [8]. During the industrial revolution, these natural techniques were faded with time. As the energy reservoir of the world is depleting fast, government of different countries are taking initiatives to promote green energy techniques and EAHE is one such technique.

EAHE system depends on the ambient temperature of any location [9] which can be used for both cooling and heating during summer and winter seasons. During winters, the underground soil temperature is higher than the ambient temperature and vice versa during summers [10]. Researchers found that the underground soil temperature also known as earth's undisturbed temperature remains constant at a depth of 2.5–3 m [8]. EAHE uses a network of pipes buried in the ground at depth of 2.5–3 m with one end acting as an inlet for the ambient air and other as an outlet. Earth is used as heat sink or source. Air enters from the inlet and continuously flows through the buried pipes. This then passes through the stable soil temperature. The temperature is either increased or decreased by conduction with underground soil. This is then delivered to the outlet maintaining a temperature difference with the ambient temperature.

In summers, the ambient temperature is around approximately 39–45 ˚C [11] depending on the location. The hot air flows through the buried pipes; the stable temperature of the soil cools down the temperature of the air and delivers it to the outlet. The air flowing in the building is cool air thus maintaining a lower temperature inside the building than the outside temperature as shown in Fig. 1.

In winters, the ambient temperature is approximately 4–9 ˚C [11] depending on the location, the same process helps in heating the air thus maintaining a higher temperature inside the building keeping the inside environment warmer than the outside. The heat dissipated/generated by the soil is transferred to the pipes by conduction which causes the temperature to increases/decrease inside the buried pipes [7]. For the continuous flow of air through the inlet certain mechanical devices such as fans, blowers etc. or passive systems are installed to create adequate pressure difference.

The performance of EAHE depends on the diameter of the pipe, length of pipe, pipe material, moisture content, soil characteristics, the temperature difference between earth and ambient air etc. [7,8,12]. The material of the pipe should have high thermal conductivity like mild steel, PVC pipes, cemented pipes etc. depending on the soil characteristics [13]. The underground soil temperature is mainly affected by the climatic condition and soil characteristics of a certain location [14].

In order to determine the undisturbed temperature of the earth the soil characteristics have to be determined of any location. The effectiveness of EAHE depends on depth of the pipe installed, thermal diffusivity of the soil, length and diameter of the pipe, Ambient Temperature of a certain location, thermal conductivity of the pipe and air flow velocity [9,13,15–17]. It is generally seen that the effectiveness of these systems is quite high as compared to conventional HVAC system [18]. Nowadays researchers have been using EAHE of configurations to study the performance and to save energy. Results showed that EAHE is an energy efficient system that can be used in lieu of our prevailing conventional system used for thermal comfort. Some researchers that proved this systems compatibility with conventional systems are discussed here.

Sodha et al. [19] has considered the effect of length, radius and mass flow rate to determine the cooling potential of the underground air pipe system. The analysis was done for a hot dry composite climate of Jodhpur and Delhi. Mihalakakou et al. [20] has predicted the soil and air temperature below the surface considering the heat and moisture gradient in the soil. Results proposed that difference between the inlet and outlet temperature as the energy potential of the EAHE system. Ascione et al. [21] has showed that in wet and humid soil having a pipe length of 50 m buried to a depth of 3 m, the best performance of an EAHE system can be achieved. Lee et al. [22] has used Energy Plus software and created a mathematical model form EAHE. A detailed algorithm was used to calculate the variation in the soil temperature variation for each pipe for every time step of the simulation. Thiers et al. [23] laid several pipes in parallel at the same depth. Finite volume method with a limited number of meshes was used. Two

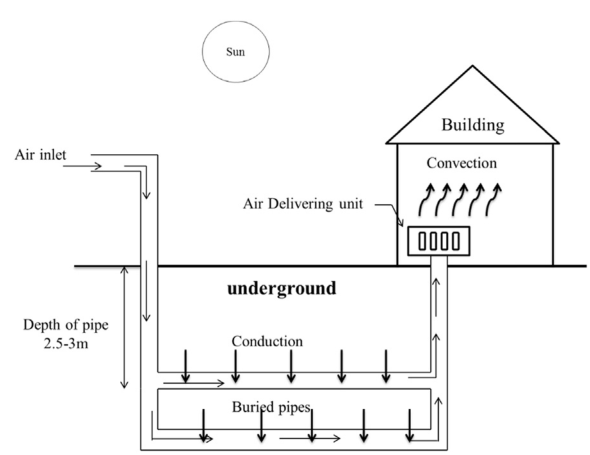

Fig. 1. Working principle of EAHE.