YILDIZ TECHNICAL UNIVERSITY'S TECHNOPARK COMPANY OF

PROMECH TEKNOLOJİ VE BİLİŞİM SİSTEMLERİ SANAYİ LTD. ŞTİ.

PROCEEDINGS BOOK OF

1th INTERNATIONAL CONFERENCE ON ADVANCES IN SCIENCE AND ARTS

SUPPORTED BY

JOURNAL OF THERMAL ENGINEERING

INTERNATIONAL JOURNAL OF ADVANCES ON AUTOMOTIVE AND TECHNOLOGY

ISBN 978-605-9546-03-4

ICASA 2017

MARCH 29-31,2017

ISTANBUL, TURKEY

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INTERNATIONAL CONFERENCE ON ADVANCES IN SCIENCE AND ARTS ISTANBUL 2017
29 – 31 MARCH 2017, Istanbul, Turkey

AN INVESTIGATION OF THE USE OF EARTH AIR HEAT EXCHANGER (EAHX) SYSTEMS IN TERMS OF ENERGY EFFICIENCY

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Keywords: Earth-air heat exchanger, energy efficiency, cooling and heating, low carbon technologies
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ABSTRACT

Earth - Air Heat Exchanger (EAHX) systems can be used in many applications in terms of energy efficiency. EAHX are systems that are used for cooling the air in summer and heating in winter by using the soil energy. The basis of the concept of energy efficiency is generating more energy with less use of primary resources and less cost. Experimental studies of heating and cooling applications showed that the EAHX systems have energy saving potential. In addition to this, it was also observed that EAHX systems were used in greenhouse studies, surface cooling of the PV panel, zero energy buildings and other applications. Also in this study, the researches on the literature of different applications of EAHX systems were examined in terms of energy efficiency. As a result, it was seen that EAHX systems reduce energy costs and decrease environmental problems which is one of the most important problems of today.

1. INTRODUCTION

The reserves of fossil fuels, which are currently supply a significant portion of the world's energy needs, are rapidly depleting. In addition to this the growing world energy use has already raised concerns over supply difficulties. The other side from the using of non-renewable energy sources; environmental problems like ozone layer depletion, global warming and climate change arised. Because of this situation, it is very important that all energy sources must be used efficiently. In the world where energy needs are constantly increasing but sources are declining, a variety of programs are being implemented to ensure efficient use of energy.

1.1. What is EAHX?

Earth air heat exchanger is one of the passive cooling and heating system, having benefits of reduced energy costs and CO_2 emissions. In summer conditions ambient air with high temperature pass through the EAHX and it gives heat to soil, resulting in cooler outlet temperature of EAHX as compared to the ambient. In winter contiditons ambient air pass through the EAHX, it takes heat from soil, resulting in higher outlet temperature of EAHX as compared to the ambient. An EAHX consists of a network of pipes buried through the ground which air is transported by a fan. There are the two main types of EAHX (Figure 1). Open-loop EAHX takes air from ambient air. The other one, Closed-loop EAHX, takes air from indoor and transport indoor again [1].

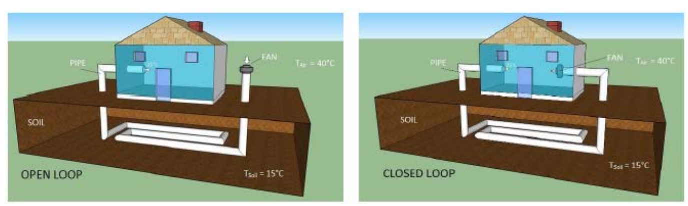

Figure 1. Open and Closed loop EAHX

The soil has a huge energy capacity. It can be used as heat sink during the summer period and as heat source in the winter period. Figure 2 shows the change in ground temperature during the year [2]. At sufficient depth, ground temperature is lower than the outside temperature in the summer and higher in winter.

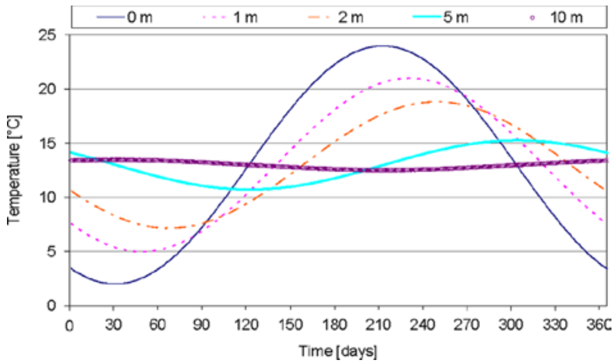

Figure 2. The variation of ground temperature with depth.[2]

Various factors like depth, length and diameter of pipe, air velocity, air flow rate, pipe material, pipe arrangement, loop system, climatic conditions, geographical location and soil properties can affect the design and the performance of an EAHX system according to the theoretical and experimental studies. [3]. Because of these complex and more complicated parameters, each EAHX system must be analyzed separately

1.2. The importance of Energy Efficiency

Energy efficiency covers the whole range of activities in the production, transmission and consumption of energy. It can be examined in two parts. The first is more energy production with less cost and fewer primary sources. The other is doing more work with the same amount of energy or doing the same amount of work with less energy. A wide variety of studies are being carried out in the world, especially in the developed countries, for efficient use of energy [4]. In 2015 in International Energy Agency (IEA) countries, efficiency avoided the amount of energy consumption which has shown in Figure 3. This avoided fossil fuel consumption reduced greenhouse gas emissions by 1.5 Gigatonnes, or 13% of total CO2 emissions from fuel combustion in 2015 [5].

Figure 3.The amount of energy consumption avoided by efficiency(IEA,2015)

In this study, the researches on the literature of different applications of EAHX systems were examined in terms of energy efficiency. The applications which THID systems used are given below:

- cooling and heating of buildings.
- greenhouse studies.
- surface cooling of the PV panel.
- zero energy buildings.
- gas turbine applications.

2. RESULTS AND DISCUSSION

2.1. Cooling and heating of buildings

Growth in population, increasing demand for building services and comfort levels, together with the rise in time spent inside buildings, assure the upward trend in energy demand will continue inthe future. For this reason, energy efficiency in buildings is today a prime objective for energy policy at regional, national and international levels. [6] A substantial amount of energy is consumed by today's buildings which are accountable for about 40% of the global energy consumption. There are on-going researches in order to overcome these and find new techniques through energy efficient measures. Passive air cooling of earth pipe cooling technique is one of those which can save energy in buildings with no greenhouse gas emissions.

Because of the high thermal inertia of the soil the outside air temperature fluctuations are reduced at sufficient ground depth (about 3 m). The soil temperature is higher than the outside air in winter and lower in summer. According to analyses of Congedo et al. investigation, in warm climates, the EAHX has significant benefits in the summer for the cooling, but in winter the system is not efficient. (Figure 4). EAHX systems provides pre-heating or pre-cooling the ventilation air by using the thermal energy stored in the ground, [7]

Figure 4. EAHX integrated with mechanical ventilation or heat pump. [7]

Another EAHX system was installed in the garden of a villa in the town of Beaucouzé, located in the center of France, and the system's performance was observed depending on the climatic conditions (Figure 5). The experiment was realized between January 2011 and December 2012. It is stated that a realistic design can be made according to the climatic conditions and soil characteristics of the different regions from the measurement test and the simulation results [8]

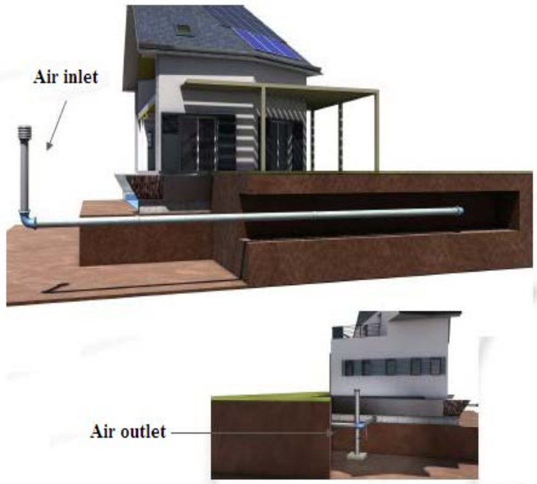

Figure 5. The villa where experiment carried out [8]

In the study by Sonia et al., the EAHX system has supplied to cool the air-conditioner's condenser coil. Test room and schematic diagram of hybrid EAHX system is shown in Figure 6. According to the result of experimental measurements; power consumption is found to be reduced significantly in hybrid system as compared to conventional 1.5 TR window air-conditioner. In addition that economic analysis for the proposed hybrid system gives positive validation [9].

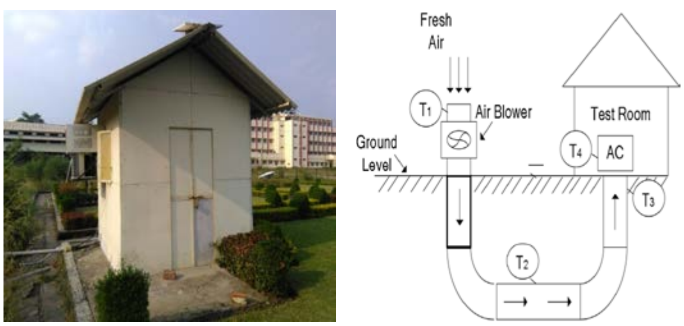

Figure 6. Test room and schematic diagram of hybrid EAHX system. [9]

Jakhar et al. stutied to improve the low heating potential of EAHX by integrating the system with solar air heating duct (SAHD). (Figure 7) The aim of their study is to present a model to estimate the heating potential for EAHX system with and without SAHD. From the experimentation; the depth of 3.7 m is sufficient for pipe burial and the 34 m length of pipe is sufficient is observed to get optimum EAHX outlet temperature.[10]

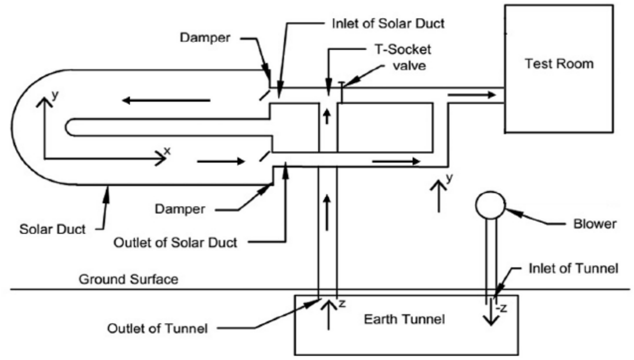

Figure 7. Schematic diagram of the experimental setup. [10]

2.2. Greenhouse studies.

Heating or cooling greenhouses and similar agricultural structures with EAHX in summer and winter is possible. By using EAHX in these structures, the use of conventional sources can be reduced. In addition, it is predicted that the environmental damage and the emission of pollutants such as carbon, methane, nitrogen oxides, etc. can be reduced.[11]

Mongkon et al. [12] evaluated geothermal cooling ability and parameters studied in Thailand by mathematical model. The measurement of the effect on plant cultivation was carried out in two identical greenhouses with 30 m^2 of greenhouse volume (Figure 7). The EAHX supplied cooled air to the model greenhouse (MGH), and the plant growth results were compared to the growth results of a conventional greenhouse (CGH).As a result the qualities of the plants with the EAHX were better than the non-cooled plants.

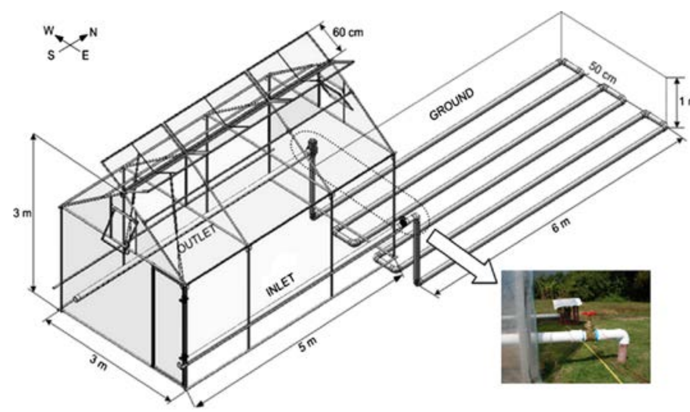

Figure 8. Isometric view of EAHX with greenhouse. [12]

Ghosal et al. investigated the potential of using the stored thermal energy of ground for space heating with the help of two buried pipe systems. In the study; it has been seen that temperatures of greenhouse air which ground air collector were used is 2–3 ºC higher than those with EAHX. Additionally, he temperature fluctuations of greenhouse air were also more when operated with EAHX as compared to ground air collector [13].

Ozgener and Ozgener investigated the performance characteristics of an underground air tunnel (UAT) for greenhouse heating with a 47 m horizontal, 56 cm nominal diameter U-bend buried galvanized ground heat exchanger (Figure 9). The system was installed in the Solar Energy Institute, Ege University, Izmir, Turkey. Based upon the measurements made in the heating mode, the average heat extraction rate to the soil is found to be 3.77 kW, or 80.21 W/m of tunnel length, while the required tunnel length in meters per kW of heating capacity is obtained as 12.46 [14].

Figure 9. A view of greenhouse outside and inside[14]

2.3. Surface cooling of the PV panel.

It is well known that the efficiency of PV panels vary under temperature changes and the high temperature decreases the power output of PV panels. There are some technical solutions to lower the temperature of PV panels. One of them is using the earth-air heat exchangers. The earth-air heat exchangers (EAHX) can supply cool air in order to decline the temperature of PV panels. In another experimental study, the PV panel was cooled with cool air which is obtained from EAHX. The temperatures of Monocrystalline PV panels with EAHX and without EAHX, air velocity and the solar radiation were measured under climatic conditions of Şanlıurfa which is a very hot and arid. The Current-Voltage (I-V) Characteristic Curves are also determined during the experimental study. The measured results of PV panels with EAHX and without EAHX were compared each other. The results show that the high temperature has negative effect on the power produced from PV panels and EAHX can be used for cooling PV panels in order to produce more energy.

Figure 10. Monocrystalline PV panels with EAHX

2.4. Zero energy buildings.

Today, reduce the building energy demand and $CO_{2\text{-equivalent}}$ emissions are crucial. Because of this situation, important of the investigation about Zero Energy Buildings (ZEB) is decreases. Ascione et al. analyses a case study concerning a multipurpose building located in Palermo (Southern Italy), and evaluates the benefits related to the use of an earth-to-air heat exchanger in a Net Zero Energy Buildings (NZEB), in terms of energy saving and reduction of $CO_{2\text{-equivalent}}$ emissions, for a Mediterranean climate. In the study, to pre-heating the ventilation outside air in winter and cooling it in summer the EAHX system has been used. [15]

In the experimental investigation of Pagliano and Zangheri which has been done at Italy, an earth to air heat exchanger (EAHX) and natural night ventilation (in summer) has been used to reach comfort conditions with very low energy consumption. Based on the measurement campaign and analysis performed they developed and tested a steady-stationary analytical model aimed at estimating the behaviour of the system building- EAHX in term of both energy performances and indoor thermal comfort [16].

2.5. Gas turbine application

The application of EAHX as an inlet air cooling system on gas turbine performance has been investigated by Barakat et al. (Figure 11) Transient, one-dimensional model was developed for predicting the thermal performance of EAHX. Gas turbine output power, efficiency and specific fuel consumption are assessed with application of EAHX. The output power and thermal efficiency of gas turbine increases by 9% and 4.8%; respectively. [17].

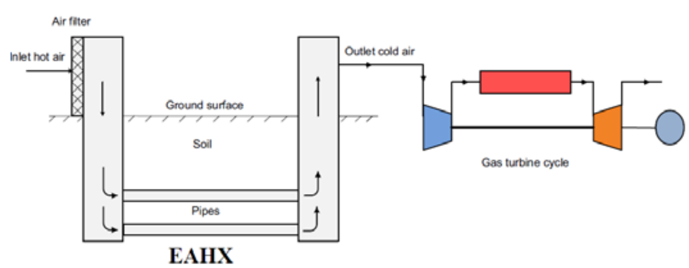

Figure 11. Schematic diagram of EAHX system installed in gas turbine power plant. [17].

CONCLUSION

Experimental studies of heating and cooling applications showed that the EAHX systems have energy saving potential. Additionally; by using EAHX in greenhouses, the use of conventional sources can be reduced. Also it is predicted that the environmental damage and the emission of pollutants such as carbon, methane, nitrogen oxides, etc. can be reduced. The results of another application of EAHX show that the high temperature has negative effect on the power produced from PV panels and EAHX can be used for cooling PV panels in order to produce more energy. In addition that; the energy demand of the zero energy building is reduced by an EAHX that pre-heats the ventilation outside air in winter and cools it in summer. Finally another application of EAHX as an inlet air cooling system on gas turbine performance; output power and thermal efficiency of gas turbine increases by 9% and 4.8%; respectively. According to all these results, it is clearly seen that the EAHX has energy saving potential in the applications mentioned in this study

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