A Review on the Experimental and Analytical Analysis of Earth Air Tunnel Heat Exchanger System

Jagjeet Kaur[1], Prem Singh[2], Harminder Kaur[3]

[1]*Production Department, Guru Nanak Dev Engineering College, Ludhiana, Punjab, INDIA*
[2]*Mechanical Department, Guru Nanak Dev Engineering College, Ludhiana, Punjab, INDIA*
[3]*ECE Department, Guru Nanak Dev Engineering College, Ludhiana, Punjab, INDIA*

ABSTRACT

This is the property of earth that at a depth of about 1.5 to 2 m, the temperature of ground remains almost constant throughout the year. This constant temperature is called earth's undisturbed temperature which remains higher than surface temperature of earth in winter season and lower than surface temperature in summer. For effective utilization of heat capacity of earth, the earth–air tunnel heat exchanger (EATHE) has to be designed. The EATHEs are considered as one of the most passive system due to its ability to provide both the effects; heating in cold months and cooling during warm months. They use the earth's near constant subterranean temperature to warm or cool air for residential, agricultural or industrial used. During the last three or four decades, a number of studies have been conducted by various investigators in the design, modeling and testing of earth air tunnel heat exchanger (EATHE) systems. This paper reviews on the experimental and analytical studies of EATHE systems around the world but the studies are mainly focused on EATHE systems at the Indian universities.

Abbreviations: EATHE, earth air tunnel heat exchanger; COP, coefficient of performance; PVC, Polyvinyl chloride;

Keyword: Earth air tunnel heat exchanger; Earth's undisturbed temperature; Space conditioning

1. INTRODUCTION

Saving energy is one of the most important global challenges in our days. The energy crisis of the mid 1970s dealt a harsh blow to developed countries. The most beneficial outcome of the crisis is that it stimulated interest in the diversification of energy sources and renewable energy.Meanwhile, environmental concerns push this trend much further. In order to reduce greenhouse gas (GHG), which are considered to be culprit of global warming and sources of pollution, the Kyoto protocol set specific targets for reduction of co_2 emissions. Earth as a heat source and heat sink is well studied topic. Using the earth as a component of the energy system can be accomplished through three primary methods: direct, indirect and isolated. In direct system, the building envelope is in contact with the earth and conduction through the building elements regulates the interior temperature. In the indirect system, the building interior is conditioned by air brought through the earth, such as earth air tunnel heat exchanger. The isolated system uses earth temperatures to increase the efficiency of a heat pump by moderating temperatures at the condensing coil.

One such indirect method is the earth air tunnel heat exchanger system. In which hot air during summer and cool air during winter is sent into the pipes that are buried in the ground. When air flows in the EATHE, heat is transferred from air to the earth. As a result, the air temperature at the outlet of EATHE is much lower in summer and much higher in winter than that of ambient. Several researcher have studied the use of the ground as het source and sink such as Santamouris et al.[1] investigated the impact of different ground surface boundary conditions on the efficiency of a single and multiple parallel earth to air heat exchanger system Bansal et al.[6]. They evaluated a large earth air pipe system meant to provide thermal comfort inside the whole building complex at one of the hospitals in India. Mihalakakou et al.[8] presented a parametrical model in which varying parameters were pipe length, pipe radius, velocity of the air inside the tube and depth of the buried pipe below earth surface.. Ghosal et al.[4] developed a thermal model to investigate the performance of earth air heat exchanger integrated with green house. In the present study review on experimental and analytical analysis of EATHE has been done.

2. DESCRIPTION OF EARTH AIR TUNNEL HEAT EXCHANGER

Earth air tunnel heat exchanger(EATHE) is one of the most passive system due to its ability to provide both the effects; heating in cold months and cooling during warm months. It is underground heat exchangers that can capture heat from or dissipate heat to the ground. An earth air heat exchanger consist of one or more tubes lied under the ground in order to cool in summer or pre-heat in winter, the air to be supplied in a building.

The physical phenomenon of earth air heat exchanger is simple: the ground temperature commonly higher than the outdoor air temperature in winter and lower in summer, so it makes the use of the earth convenient as warm or cold sink respectively. Both of the above uses of earth air heat exchanger can contribute to reduction in energy consumption. Several researchers have described the EATHE coupled with buildings as an effective passive energy source for building space conditioning. An earth- to-air heat exchanger system suitably meets heating and cooling energy loads of a building. Its performance is based upon the seasonally varying inlet temperature, and the tunnel-wall temperature which further depends on the ground temperature. The performance of an EATHE system depends upon the temperature and moisture distribution in the ground, as well as on the surface conditions

3. EXPERIMENTAL AND ANALYTICAL ANALYSIS

The heat transfer to and from Earth tube heat exchanger system has been the subject of many theoretical and experimental investigations. Deglin et al. (1999) conducted a theoretical model, with a particular application to livestock buildings; validation using an experimental setup in detail. Corrugated, non-perforated plastic pipes were used. Validation was done with one year of data for a system including 18 m long, corrugated PVC pipes with 3 different diameters (250, 315 and 400 mm), buried at three different depths (1.50, 2.25 and 3.00 m). Conclusions were ;soils saturated in water are better from a thermal point of view, greater depths are preferable since they provide higher temperatures in winter and lower temperatures in summer, smaller pipes are more thermally efficient, i.e. they result in a higher heat exchange per unit volume of air; however they cause greater pressure losses and require larger installations, lower fan speeds lead to higher efficiencies, and 70% of the heat transfer occurs within the first 10 m of the pipe.

Ghosal et al. (2000) developed a simplified analytical model to study year around effectiveness of an EATHE coupled greenhouse located in New Delhi, India. At the end the temperature of greenhouse air on average found to be 6–7 °C more in winter and 3–4 °C less in summer than the same greenhouse when operating without EATHE. Paepe and Janssens A (2002) presented a one-dimensional analytical method to analyse the influence of design parameters of the heat-exchangers on the thermo-hydraulic performance. A relation was derived for specific pressure drop, linking thermal effectiveness with pressure drop of the sir inside the tube. The relation is used to formulate the design method which can be used to determine the characteristics dimensions of the earth-air heat exchanger in such a way that optimal thermal effectiveness is reached with acceptable pressure loss. Thermal performance and pressure drop grows both with the length of tube. Smaller tube diameters gave better thermal performance and also larger pressure drop. More tubes in parallel both lower pressure drop and rise thermal performance. The choice of the characteristics dimensions becomes thus independent of the soil and climatological conditions that give way to the designers to choose the earth-air heat exchanger configuration with the best performance. Bansal et al. (2004) investigated the performance analysis of EAHE for summer cooling in Jaipur, India. They discussed 23.42 m long EATHE at cooling mode in the range of 8.0–12.7 ◦C and 2–5 m/s flow rate for steel and PVC pipes. They showed performance of system is not significantly affected by the material of buried pipe instead it is greatly affected by the velocity of air fluid. They observed COP variation 1.9–2.9 for increasing the velocity 2–5 m/s. Kwang et al. (2006) focused on the effects of pipe radius, length, and air flow rate and pipe depth. It also included a model for soil temperature calculation. A parametric study concluded that, in agreement with common sense, a deeply placed and longer earth tube with a lower air velocity and smaller radius should result in better performance. It should be noted, however, that the model does not include possible latent heat exchange (condensation) with the air blown through the pipes. They predicted that a building air conditioned only with earth tubes experiences only a modest temperature decrease Tiwari et al. (2006) presented an experimental validation of a simple earth tube model using experimental data for a greenhouse located in New Delhi, India. Temperature increases of 4 °C in the winter and decreases up to 8 °C in the summer are observed. The earth tube system is more efficient in the summer than in the winter. Despite its simplicity, the model seems to be in good agreement with experimental data.

Kwang et al. (2006) focused on the effects of pipe radius, length, and air flow rate and pipe depth. It also included a model for soil temperature calculation. A parametric study concluded that, in agreement with common sense, a deeply placed and longer earth tube with a lower air velocity and smaller radius should result in better performance. It should be noted, however, that the model does not include possible latent heat exchange (condensation) with the air blown through the pipes. They predicted that a building air conditioned only with earth tubes experiences only a modest temperature decrease.

4. CONCLUSION

EATHE are a good technology to improve the quality of life in developing countries and to reduce the electricity demand in those countries. Most systems usually constructed from 4–24inch diameter, smooth walled, rigid or semi rigid plastic, plastic coated metal pipes or plastic pipes, buried 1.5 to 3m underground where the ambient earth temperature is typically 10 to 23^0C. Ground temperature becomes more stable with depth. Smaller diameter tubes require more energy to move the air and have less contact surface area. Larger tubes permit a slower air flow, which yields more efficient energy transfer and permits much higher volumes to be transferred, permitting more air exchanges in a short every time period. Sharp 90^0 angles should be avoided in the construction of the tube. Two 45^0 bends produce less turbulent, more efficient air flow.

REFERENCES

[1] Santamouris M. Agas G., Matsaggos T., and Agririou A. (1993) "Use *of environmental heat sinks for heat dissipation"*, Energy and buildings. Vol.17, pp. 321-329.

[2] Ahmed A., Kenneth I., Miller A., and Gidadok, (2009) "*Thermal performance of EATHE for reducing cooling energy demand of office building in the united Kingdom*", International conference of simulation association. pp. 228-35.

[3] Al- Ajmi F., Loveday D.L., Handy V.I., (2006), *"The cooling potential of earth air tunnel for domestic buildings in a desert climate",* Renewable Energy, Vol. (30), pp. 125-129.

[4] Ghosal G., Argiriou A., Lykoudis S., Balaras C., Asimakopoulos D., (2004*), " Experimental study of a earth to air heat exchanger coupled with a photovoltaic system",* Journal of solar energy engineering, pp. 189-195.

[5] Breesch H., Bossaer B., Janssens A., (2005*), "Passive cooling in a low energy office building",* Energy Build, Vol. (45), pp. 215-222.

[6] Bansal V., Misra R., Agrawal G.D., Mathur J., (2010) *"Performance analysis of earth pipe air heat exchanger for summer cooling"*. Energy builds. Vol.42, pp. 645-8.

[7] Badescu V., (2007), "*Simple and accurate model for the ground heat exchanger of a passive house",* Renew energy, Vol. 32, pp.845-55.

[8] Mihalakakou G., Lewis J. O., Santamouris M., (1996), *"On the heating potential of buried pipes techniques –application in Ireland",* Energy Buildings, pp.103-117.