ISBN 978-93-5156-328-0
International Conference of Advance Research and Innovation (ICARI-2015)

Experimental Performance Analysis of Earth-Air Heat Exchanger for Energy Efficient and Eco-Friendly HVAC Systems

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Article Info

Article history:
Received 3 January 2015
Received in revised form
10 January 2015
Accepted 20 January 2015
Available online 31 January 2015

Keywords

Earth Pipe Air Heat Exchanger Energy Efficiency,
Heating Ventilation Air Conditioning

Abstract

Ground earth air heat exchangers are the emerging technique which reduce the cooling and heating load of buildings in summer and winter season and thus reduce the overall energy consumption in a building. The earth air pipe heat exchanger (EAPHE) control the ventilation air temperature using the geothermal heat energy of the earth. In this paper experimental set up of earth air pipe heat exchanger (EAPHE) installed to find the performance analysis of ventilated air at different operating conditions. The performance analysis of earth air pipe heat exchanger(EAPHE) done by varying the various parameters like air velocity, mass flow rate, depth of the pipe and material of the pipe etc. The results obtained revealed that the temperature inside the earth can be increased by 8-10 0C during winter season and can be decreased by 12-13 0C during summer seasons compare to air atmospheric temperature. In this work the main work is to implement the water jacket around the pipe at the exit section of air flow and then comparative experimental results obtained with and without implementation of water jacket around the exit section of pipe . Maximum Temperature difference attained by EAPHX system without implementing the water jacket is 14.0℃. Maximum Temperature difference attained by EAPHX system with the implementation of the water jacket is 21.3℃.

1. Introduction

In recent years, there is a global consensus for exploration and utilization of different renewable energy sources to meet the energy demand of a rapidly growing world population, driven primarily by increasing prices and limited energy resources of conventional or fossil fuels. The new options should be eco-friendly as well as abundant in nature. The various options may be nuclear, wind, bio mass, solar and geo-thermal energy etc. Geo- thermal energy is a renewable eco friendly and freely available energy resource on earth. Its use will ensure the conservation of conventional energy sources. It also helps in avoiding the increasing use of refrigerants used in air- conditioning, thus it helps in avoiding the Ozone depletion .Also the cost of the system is as low as that of conventional air-conditioning systems. Thus we can say that, here it is a great need of implementing and improving these kinds of techniques for better future.

Earth Air pipe Heat Exchanger (EAPHE). As we know that the average temperature at stratum is 27˚ to 28˚C the soil provides a good inertia to climate change during summer and winter seasons as the depth increases. So below a certain depth like 3-5m, the temperature is low compare to outside air temperature during summer and comparatively high during winter season. In the present work, utilization of geo thermal energy incorporate with earth air pipe heat exchanger for the prior heating or cooling of ventilation air for HVAC purpose. Outdoor air is sent into the pipes which are buried under the ground. When air flows in the earth–air– pipes, heat is transferred from the air to the earth. As a result, the air temperature at the outlet of the earth–air–pipes achieves the same temperature of the earth. The outlet air from the earth–air–pipes can be directly used for space cooling if its temperature is low enough. Alternatively, the outlet air may be cooled further by associated air conditioning machines. In the winter season also when the cold ambient air, can be passed from the same EAPHE during which the heat would flow from soil to pipe by conduction and from pipe to air by convection and thus the air gets heated which can be used for air heating purpose. Both of the above uses of earth–air–pipes can contribute to the reduction in energy consumption. Use of underground air tunnels with a suitable technology in the modern greenhouses will play a leading role in Turkey in the foreseeable future [1]. The study performed by [2] is noteworthy since it is closely associated with the present study. They performed theoretical and experimental studies on an “underground air tunnel” with a horizontal ground heat-exchanger and concluded that using this system is feasible. An engineer designing a system is expected to aim for the highest possible technical efficiency at a minimum cost under the prevailing technical, economic and legal conditions. An experimental study [3] on the thermal performance of earth- air heat exchanger in single pass mode constructed at Gulmohar farm house, Gurgaon, India has been studied. The coefficient of performance of the installed system during summer, monsoon, and winter was found to be 7.9, 1.9 and 2.1, respectively. It is concluded that good thermal comfort conditions can be created reasonably in the building with such a system. A simplified analytical model [4] is developed to study the year round effectiveness of a recirculation type earth air heat exchanger coupled with a greenhouse located in IIT Delhi, India. The performance of the system was evaluated in terms of thermal load leveling and coefficient of performance.

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Calculations were done for typical winter and summer day in year 2002. Temperatures of greenhouse air were found to be on an average 6–7 0C more in winter and 3–4 0C less in summer than the same greenhouse when operating without earth air heat exchanger. A thermal model [5] for heating of greenhouse by using different combinations of inner thermal curtain, an earth–air heat exchanger, and geothermal heating has been developed. The calculations have been made for a typical production greenhouse in southern part of Argentina; available climatic data has been used. It is seen that an earth–air heat exchanger might prove an alternative source for heating of greenhouse. A transient and implicit model [6] based on computational fluid dynamics is developed to predict the thermal performance and heating capacity of earth–air–pipe heat exchanger systems. Investigations on steel and PVC pipes have shown that performance of the EPAHE system is not significantly affected by the material of the buried pipe. Velocity of air through the pipe is found to greatly affect the performance of EPAHE system. The COP of the EPAHE system discussed in this paper varies from 1.9 to 2.9 for increase in velocity from 2.0 to 5.0 m/s.

1.1 Motivation

The greenhouse technology is being used in several regions of the world but the problem associated with is to maintain the favorable environment all the time and use of several electrical devices require power to operate. The electricity demand increasing day by day. HVAC systems consume maximum portion of the electricity .Hence it has been felt to work in this area which is very much related to the existing research on energy efficient green house technology.

In recent years, there is a global consensus for exploration and utilization of different renewable energy sources to meet the energy demand of a rapidly growing world population, driven primarily by increasing prices and limited energy resources of conventional or fossil fuels. The new options should be eco-friendly as well as abundant in nature. The various options may be nuclear, wind, bio mass, solar and geo-thermal energy etc. geo- thermal energy is a renewable eco friendly and freely available energy resource on earth. Its use will ensure the conservation of conventional energy sources. It also helps in avoiding the increasing use of refrigerants used in air- conditioning, thus it helps in avoiding the Ozone depletion. The cost of the system is as low as that of conventional air- conditioning systems. Thus we can say that, here it is a great need of implementing and improving these kinds of techniques for better future.

2. Materials and methods

2.1 Materials with specification

Dimension of set-up and components

Area of digged section	12 x 3 ft^2
Depth of section	9 ft
Polyethylene Pipe	
Diameter of pipe	0.016m
Length of pipe	100m
Blower unit	Voltage-165-250 Volt
Freq- 50 Hz	
Power 500W	
16,000 rpm	
Cooling jacket	
Radius of jacket cylindrical	2.5 inches
Depth of the jacket	5 feet
Small cooling tower	
Anemometer	
Temperature sensors	
No. of thermocouple	2 pieces of least count .1℃
Water pump	Voltage-165-250 volts
Maximum height- 8.5 feet	
Output= 2000lt/hr	

2.2 Experimental set-up and location

Location of the experimental site;

It is located in Gurgaon, 15km milestone from ITM University.

Venue:

South city-2
Near Gurgaon Gramin Bank

2.3 Experimental Set up of Earth Air Pipe Heat Exchanger System with and without Water Jacket

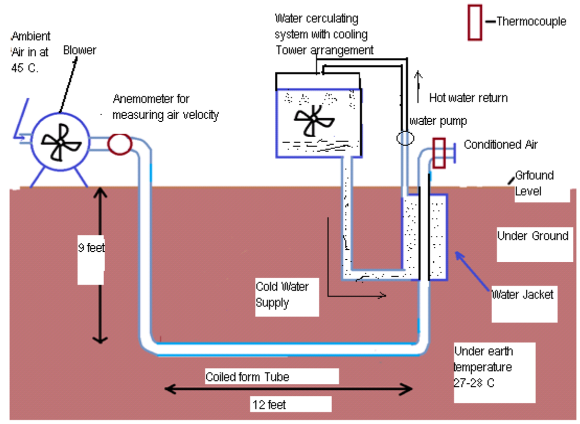


Fig: 1. Experimental set up of EAPHE

Method:

Description: The EAPHE as shown in fig .1 comprise of air blower through which outside air suply at 45^{0}C passes through a PVC tube in coiled form. Subsequently air passes through the anemometer to measure the velocity of air. Air flowing in the coiled pipe along the horizontal length of 12 ft. As we know that the average temperature at stratum is 27˚ to 28˚ C. The soil provides a good inertia to climate change during summer and winter seasons as the depth increases. When the supply air passes through tube then heat transfer takes place between air and cold soil temperature under ground level. Due to which air get cooled, after words the air passes through the indirect type heat exchanger. In which air flowing through pipe and the cold water circulating from induced type cooling tower, due to which heat transfer between air and cold water takes place and the air get re cooled by virtue of coldness of water. Cold water gets heated by heat exchanging to the warm air and recirculated back to the cooling tower with the help water circulating pump. In such a way the temperature of supplied air will be decreases up to 10-15 ^{0}C.The conditioned air supply to various air handling units.

Fig: 2. Coiled form of the Pipe used in the Setup

Fig: 2.3. Showing the Cooling Water Jacket

3. Observations and calculations

3.1 Observation

Table: 1. Physical and Thermal Parameters used in System

Material	Density (kg/m^3)	Specific heat capacity (J/kgK)	Thermal conductivity (W/mK)
Air	1.225	1006	.0242
Soil	2050	1840	.52
PVC	1380	1200	.16
PE	950	2000	.43

Table: 2. Comparison of Temperatures without Water Jacket at Different Velocities of Air

Section	Air velocity =1.7m/s	Air velocity =1.5m/s	Air velocity =1.2m/s	Air velocity =0.7m/s
$T_{(INLET)}$ (in °C)	44.7	44.8	45.0	45.3
$T_{(OUTLET)}$ (in °C)	31.3	31.7	32.5	33.3

Table: 3. Comparison of Temperatures of air with Water Jacket at different Velocities of air

Section	Air velocity =1.7m/s	Air velocity =1.5m/s	Air velocity =1.2m/s	Air velocity =0.7m/s
$T_{(INLET)}$ (in °C)	46.0	46.3	46.6	46.7
$T_{(OUTLET)}$ (in °C)	25.4	26.1	26.2	26.9

3.4 Calculations:-

Sample calculation:-

Change in Temperature without jacket:-

Inlet temperature of Pipe = 44.5 °C

Outlet temperature of pipe = 31.3 °C

Change in temperature (Δt) = 13.2 °C

Change in Temperature with jacket:-

Inlet temperature of Pipe = 46.0 °C

Outlet temperature of pipe = 25.4 °C

Change in temperature (Δt) = 20.6 °C

3.5 Running Cost Analysis:-

Flow rate for the output at maximum speed = 0.02 m^3/ min.

No. of power operated components

Blower unit - 500 W

Water pump - 100 W

Consider that it is operated for 8 hr. a day then

Total power consumption for a day = (.8+4) units

Power consumed in a month = 4.8x30 units

Cost of 1 unit is considered as = 4 Rs.

Total bill on running of equipment = 576 Rs.

3.6 Cofficient of Performance (C.O.P)

We know that,

$$COP = \frac{Referigeration\ effect}{work\ done}$$

$$COP = \frac{mC\Delta t}{work\ done}$$

$$COP = \frac{0.02 * 2000 * 20.6}{600}$$

= **COP= 1.4**

4. Results and Conclusions

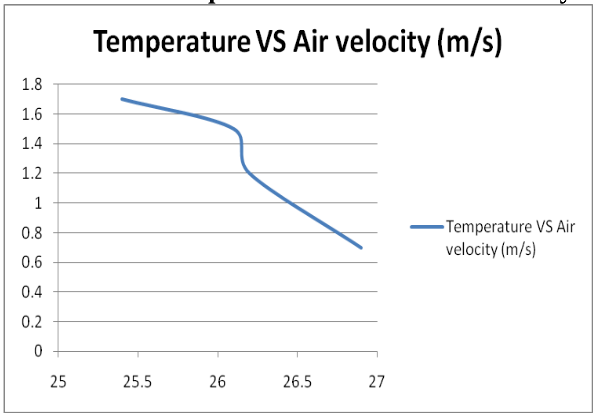
4.1 Results

Maximum Temperature difference attained by EAPHX system without implementing the water jacket is **14.0℃.** Maximum Temperature difference attained by EAPHX system with the implementation of the water jacket is **21.3℃.**

Table: 4. Comparison of results without water jacket and water jacket at different velocities of air

Section	Air velocity =1.2m/s		Air velocity =1.5m/s		Air velocity =1.7m/s	
	Without Water Jacket Temperature	With Water Jacket Temperature	Without Water Jacket Temperature	With Water Jacket Temperature	Without Water-Jacket Temperature	With Water Jacket Temperature
$T_{(INLET)}$ (in °C)	45.0	46.6	44.8	46.3	44.7	46.0
$T_{(OUTLET)}$ (in °C)	32.5	26.2	31.7	26.1	31.3	25.4

4.2 Graphical representation of the dependence of the outlet temperature on the air flow velocity



X axis represent ----- outlet temperature
Y axis represent ----- air flow velocity

5. Conclusions

Effectiveness of the implementation of the cooling jacket:-
At the same velocity,
Effectiveness =

$$\frac{change\ in\ temp. with\ jacket - change\ in\ temp. without\ jacket}{change\ in\ temp. without\ jacket}$$

$$effectiveness = \frac{20.6 - 13.2}{13.2}$$

$$effectiveness = 56.06\ \%$$

Thus we have concluded that with the implementation of the cooling jacket we have increased the effectiveness of the system by **52.14 %.**

6. Future Work

we have complete the work on EAPHE by implementing a water jacket over some portion of the pipe carrying air when it just getting out of the earth, and for cooling the water we have used the pot for cooling the water and thus we get a good temperature difference but we want to add here that this system efficiently can be used in a big building where the cooling tower can be used for cooling the water which is being used for cooling jacket. Also we can also use the fountain water in case of building having a good fountain system as the fountain water also get cooled as like the cooling tower. Further here we have used the EAHE here but these kinds of systems can be used where we make the close loop of the pipe carrying air in coiled form in the pond water. Also we can use the open loop in which we extract the cool water from earth crust and then use it for cooling purpose and then release the same in the open pond and lake for refilling the water table and we can also use this water for other purposes like for irrigation purposes. But this use is limited to places where a huge quantity of water is available. Some of the images which give the idea of open loop and pond water coiled are shown on the next page.

Fig: 6.1. Closed Loop Water Pond System

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