Analysis of Velocity for Earth Air Heat Exchanger in Hot-Humid Climate

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Abstract

Air cooling by conventional methods is practically everywhere, i.e. homes, hotels and hospitals. The temperature of the environment, increasing day by day due to heavy vapor compression systems used to meet the cooling load of buildings. The huge electricity is required for handling the cooling demands which are further destroying our natural resources. Efforts can be made to look for sustainable cooling system instead of using costly air conditioning systems. In this study effort is made to look for a low cost air cooling system for buildings by use of thermal energy of soil. The geothermal effect of soil can be very helpful for decreasing or increasing the temperature of the air. Using this method of cooling, the high grade energy demand as well as environmental issues can be minimized. The best use of geothermal energy can be made effective with the use of Earth Air Heat Exchanger method. The study of the air velocity may help in finding a maximum temperature drop of the air. With the rise in velocity to appropriate value it gives better results at a velocity of 2.5 m/s the maximum drop in temperature is 7.2 °C, for 3.4 m/s maximum drop is 6.5 °C and at a velocity of 4.8 m/s drop is 4.0 °C. Therefore the velocity of 2.5 m/s is cost effective and result oriented to a given Earth Air Heat Exchanger. The maximum average fall for a velocity of 2.5 m/s is equal to 5.4 °C in the month of July for hot- humid climate.

Key Words: Air cooling,Geothermal energy, Earth Air Heat Exchanger, Climate.

1. INTRODUCTION

The environment friendly technique to be used for cooling, which is suited for providing comfort and pollution free air to the human beings. Earth Air Heat Exchanger (EAHE) plays a very good role in minimizing the severe conditions of environment. This type of heat exchanger is good for making environment comfort for human beings. It uses the unaffected temperature of the earth for cooling/heating the space. The temperature deep in earth remains constant and works as a heat reservoir, where number of air carrying pipes are burried. It is connected with a fan or blower, which passed the air through the buried pipes.

1.1. Different parameters study for Earth Air Heat Exchanger

Generally the material used for the pipe is Poly Vinyl Chloride because it is well installed in the fields in any complex form. The conductivity of PVC is not so good for achieving major temperature drop from inlet to exit. The design parameters that impact the valuation of the system are: pipe depth, pipe length, tube diameter, air velocity, air flow rate, pipe material, pipe arrangement [1].EAHE system is studied for hot-humid climate shows less temperature drop as compared to study in hot-dry climate due to humidity in the air. This trouble can be improved by the utilization of earth coupled heat exchangers in air conditioning system [2]. It suitably meets heating and cooling energy loads of a building. Its performance is based upon the seasonally varying inlet temperature, and outlet temperature, which further depends on the ground temperature.The observational, analytical studies and ground air heat exchanger performance in summer cooling for various supply air conditions of EAHE systems may be done around the earth [3]. Most challenging problems are the “Global Warming” and Ozone Layer Depletion of the planet. This engineering technique is practiced to trim down this problem. The performance analysis of Earth Air Pipe Heat Exchanger (EAPHE) done by altering the various parameters like air velocity, volume flow rate, depth of the pipes and material of the pipes, etc. The results obtained revealed that the temperature within the earth can be increased by 8 °C -10 °C During the winter season and can be decreased by 12 °C -13 °C during summer season compare to the atmospheric air temperature [4].At a depth of approximately 1.5 to 2 m, the temperature of the ground stays on almost constant throughout the year. This constant temperature is called earth’s undisturbed temperature, which remains higher than the surface temperature of the ground in winter season and lowers than the surface temperature in summer season. 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. During the last three or four decades, a routine of surveys have been transmitted by several investigators in designing, modelling and testing of earth air tunnel heat exchange systems[5].

Fuxin et al. [6]has been found a regression model for regulating the cooling capability of an EAHE. It combines both high temperature and mass transport between the breeze and the underground. It was calibrated by comparing against the experimental readings from an available renewable energy testing facility. After the calibration, the air temperature, the air relative humidity, the air velocity at the inlet of the arrangement, the tube surface temperature, and the tube length and diameter on the performance were analyzed using the calibrated model. The soft-to-apply formulas can be used in the invention and application of Earth-Air Heat Exchangers.

Guohui et al. [7]saw the performance of ground–air heat exchangers under varying soil and atmospheric conditions and the interactions between the heat exchanger and environments. A computer program has been prepared for simulation. The program solves equations for coupled heat and moisture transport in soil with boundary conditions for convection, radiation and evaporation/condensation that vary with both the climate at the soil top surface and inside the heat exchanger.

Polypropylene capillary heat exchangers, suspended in the gentle wind and immersed into the primer of the greenhouse, are used to store or restore solar energy excess. In parliamentary law to keep the greenhouse air temperature at 20°C, suitable for a defined agriculture, the solar energy and the cold water are respectively used for heating and cooling the greenhouse inside air [8].

Attar et al. [9]has been presented the thermal analysis of air conditioning system with its different components desiccant wheel, solar collector, heat exchanger, ground heat exchanger and water spray evaporative cooler. Three different air conditioning cycles are assumed in the current subject field for different zones like: hot-dry zone, warm-dry zone, hot-humid zone and the warm-humid zone. The outcomes indicate that the desiccant air conditioning system successfully provides a better thermal comfort condition in different modes. This hybrid system significantly decreases the supplied air temperature from 12.7 to 21.7 °C at different climate zones. The highest COP value of the desiccant air conditioning system is approximately 1.03 while the lowest value is approximately 0.15.

1.2. Studies in different parts of India and World

The natural resources of the world are being exploited beyond its sustainable capacity. The construction industry uses up about 40 % of the global energy demand. A major part of this energy is used in meeting air-conditioning requirements. The present scenario demands increased energy efficiency, i.e., indoor thermal comfort with minimal energy consumption in buildings. The applicability of EAHE in Chandīgarh (India) based upon literature review, particularly in the Indian context and keeping in mind the nature of the land and climatic conditions of the city [10]. In Bhopal (India) EAHE used effectively to achieve the cooling energy requirement of buildings in hot and dry climate. The entire drop in air temperature and total hourly cooling energy gain obtained from experimental set-up varies from 12.9 °C to 11.3 °C and 0.85 to 1.87 MJ-h, respectively for air flow velocity was 2 m/s to 5 m/s on May 17, 2013. From this experiment it was set up that the diameters of pipe and air flow velocity were greatly affected the thermal performance of this system [11].

Giacomo et al. [12]presented the results of a 12-month-long monitoring campaign of an earth-to-air horizontal heat exchanger system in a school complex in Imola, Italy. With more than 2 km of buried pipes, it presents one of the biggest Italian applications of this technology. Considerable differences between inlet and vent air temperature have been observed both in winter and in summer season. Air temperature and relative humidity have been presented over a psychometric chart while the energy performance of the system was analyzed based on data of sensible heat exchange.

The thermal potential of Earth-Air Heat Exchangers (EAHE) determined experimentally in Viamao, a city located in the south of Brazil. Three independent ducts are buried in the soil, ducts A and B are installed at a depth of 1.60 m and 0.60 m apart, while duct C is installed at a depth of 0.50 m. Results showed that the months of May and February were the best for heating and chilling. Moreover, it was developed a complete database about the transient temperatures of the soil, external air and inside the building.

2. AIMS AND OBJECTIVES OF THE STUDY

1. To study the variation of the inlet and outlet temperatures from morning to evening.
2. Determine the effect of different air velocities of particular length and depth of earth air heat exchanger in hot-humid climate.

3. EXPERIMENTAL SET-UP AND INSTRUMENTATIONS

The EAHE is installed in the village Bazidpur of Ferozepur City, Punjab, India. It consists of concrete pipe of diameter 0.224 m and is buried in the soil at a depth of 1.54 m.The dimensions of the test room are 3.414 m x 3.353 m x 2.286 m. The one end of buried pipe is open to the fields and other end is open in the room. A blower with Variac is connected to the open end of pipes in the fields which delivers air to the room for study. The RTDs (0.5°C accuracy and least count 0.1°C), range 0-100 °C are placed at locations. Two RTDs placed at after the blower and two are placed in the room at the outlet of the pipe. One RTDs is to check Dry Bulb Temperature (DBT) and the other is to check Wet Bulb Temperature (WBT). The velocity is measured by a portable, digital vane type anemometer (Thermo-Anemometer, PROVA Instruments). The velocity range 0.3 to 45 m/s. The anemometer has range of 0.3 to 45 m/s and means velocity is obtained at required locations measuring at different points. The arrangement of different instruments used for the investigation of the complete system shown in figure 1.

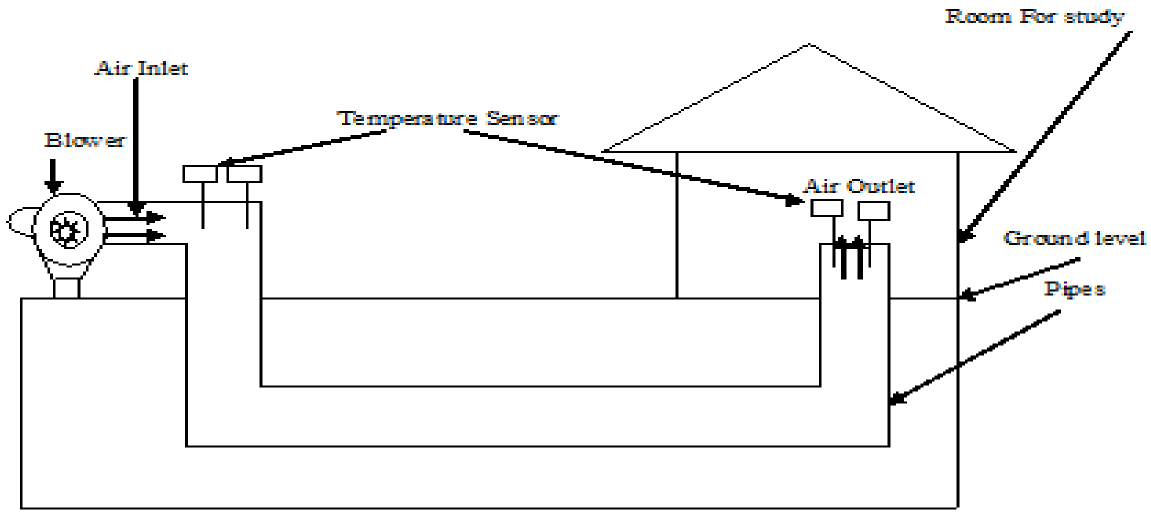

Fig -1 The EAHE system setup

4. METHODOLOGY

The EAHE system run time 8.00 am to 4.00 pm on four days. The effect of three different velocities i.e. 2.5 m/s, 3.4 m/s and 4.8 m/s have been done in the study. The velocity of air is maintained 4.8 m/s on 14 July 2017, 3.4 m/s on 16 July 2017 and 2.5 m/s on 18 July 2017 for a length of 15 m and depth of 1.5 m. The temperature is noted for every half hour. The dry bulb temperature and wet bulb temperature are noted at required locations as inlet temperature (T_{in}) and temperature of tested room or outlet temperature (T_{out}). The RTDs mounted for measure ment of DBT and WBT at inlet and outlet of the buried pipe are shown in fig 2.

Fig -2 The inlet of the buried pipes where the blower is connected and outlet of the pipe in the tested room with temperature sensors connected to the pipe.

5. RESULTS & DISCUSSIONS

5.1. Daily Results of Temperature Drop Variation

The results of the day wise observation are recorded from the morning to the evening system for inlet and outlet temperatures and corresponding relative humidity can be calculated by dry bulb and wet bulb temperature. Various parameters of the EAHE system during working from 8 am to 4 pm on 14/07/2017, 16/07/2017 and 18/07/2017 are as shown in figure 3 - 8. It has been found that initially in the beginning of the day, the temperature drop of the air is small i.e. approximately 0.5 ^{o}C at 8 am on 14/07/2017 corresponding to velocity 4.8 m/s, length 15 m and depth 1.5 m with the air inlet temperature 28.2 ^{o}C. The results obtained reveals that in the morning, due to result in heat transfer rate is increases but the effect of increase in residential time of air for the heat transfer dominates. The temperature drop is small i.e. 0.5 ^{o}C and relative humidity is very large i.e. 85 % at 8 am on 14/07/2017 corresponding to the velocity 4.8 m/s, length 15 m and depth 1.5 m with the air inlet temperature 32.9 ^{o}C. As soon as the difference between the temperature of the air and soil temperature increases, which enhance the rate of heat transfer, for the air flowing through the pipe so that air gets cool and supplied to the room. The maximum temperature drop of 4.0 ^{o}C and corresponding relative humidity is 53 % has been observed with the air inlet temperature 43.4 ^{o}C at 1.30 pm, because the inlet temperature reaches to maximum and thereafter the temperature drops of the air at EAHE is decreased due fall in the outdoor temperature.

5.2. Effect of velocity

As noted from the results with increase in air velocity the drop of temperature decreases considerably as shown figures 3, 5 and 7. The air velocity influence calculated by day based observations for a length of 15 m and depth of 1.5 m. Also the heat transfer between the air and the soil increases with decrease in velocity of the air. May be the heat transfer from air to soil is multiple of heat transfer rate and duration heat transfer, therefore temperature drop of the air in EAHE is found higher at lower velocities. The trends of variation of the temperature drop for day wise run of the EAHE at different velocities are found and plotted

The figure 3 & figure 4 gives the variations of temperature for a velocity of 4.8 m/s and Time vs Relative Humidity (RH). The minimum temperature drop of 0.5 ^{o}C (T_{in} = 32.9 ^{o}C) is observed at 8.00 am and corresponding RH is 85 %. The maximum temperature drop of 4.0 ^{o}C (T_{in} = 43.4 ^{o}C) is observed at 1.30 pm and corresponding RH is 53 %. The temperature difference is increases with increase in difference of inlet temperature and outlet temperature.

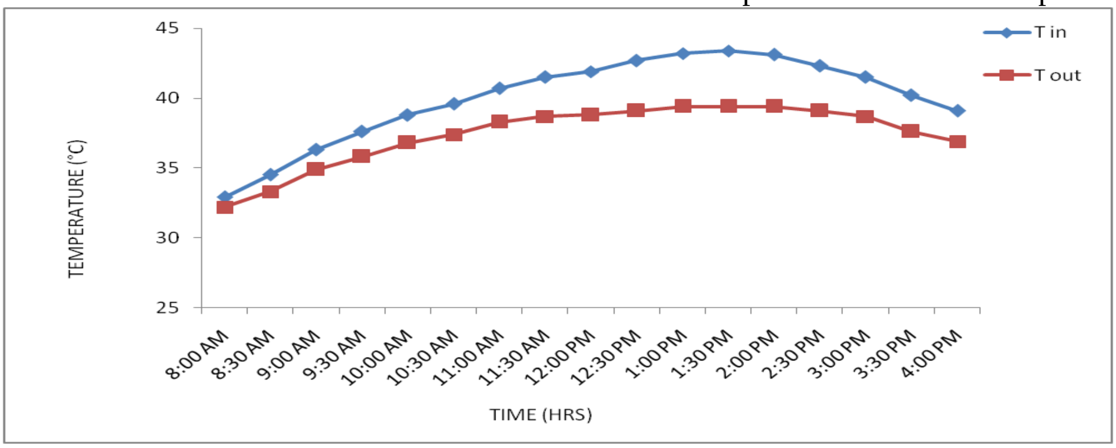

Fig -3 Time vs. temperature plots for an air velocity = 4.8 m/s, pipe length = 15 m, depth = 1.5 m of 14 July 2017

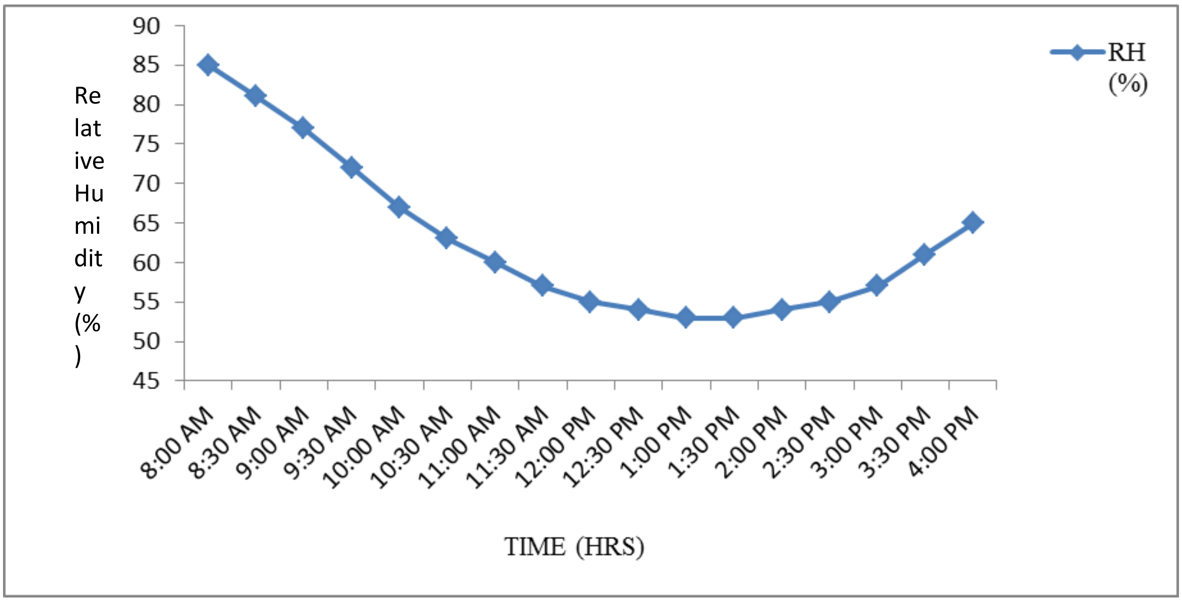

Fig -4: Time vs. Humidity plots for an air velocity = 4.8 m/s, pipe length = 15 m, depth = 1.5 m of 14 July 2017

The reading of two temperatures shows considerable change in the inlet and outlet values of temperature. The environments conditions are also affect the EAHE system considerably. Figure 5 & 6 shows the inlet and outlet DBT temperatures variations and Relative Humidity for an air velocity of 3.4 m/s on date 16 July 2017. The plots for dry bulb temperature shows that with decrease in air velocity from 4.8 m/s to 3.4 m/s maximum fall in outlet temperature to the room temperature increases by 2.1 °C. The major drop of temperature 6.5 °C (T_{in} = 44.2 ^{o}C) and RH is 53 % which is due to decrease in air velocity of 3.4 m/s at that day.

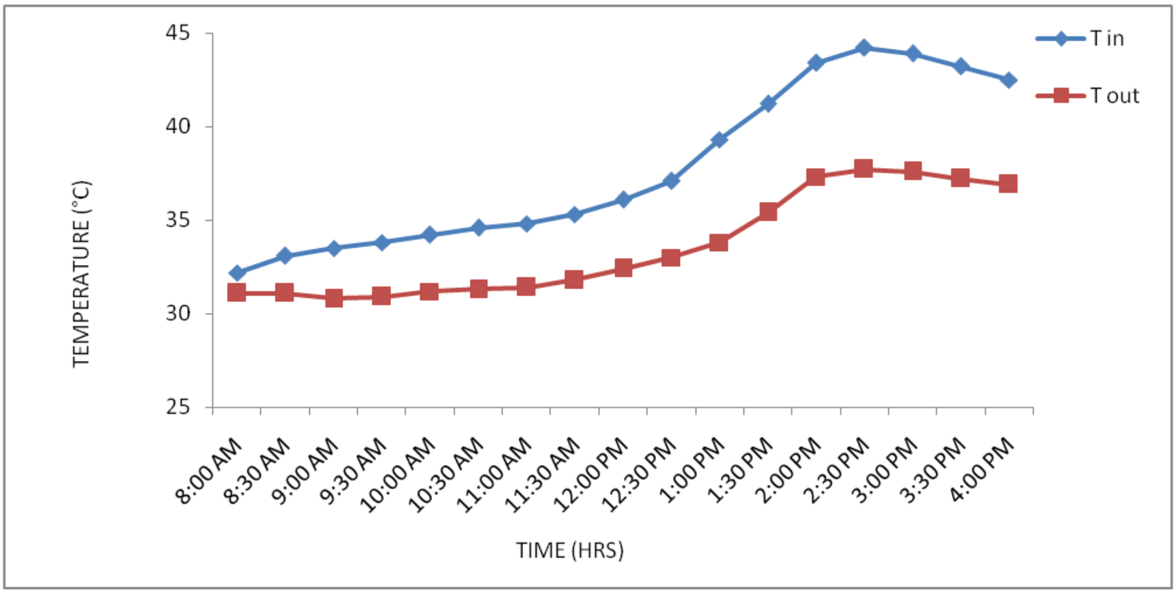

Fig -5: Time vs. temperature plots for air velocity = 3.4 m/s, pipe length = 15 m, depth = 1.5 m of 16 July 2017.

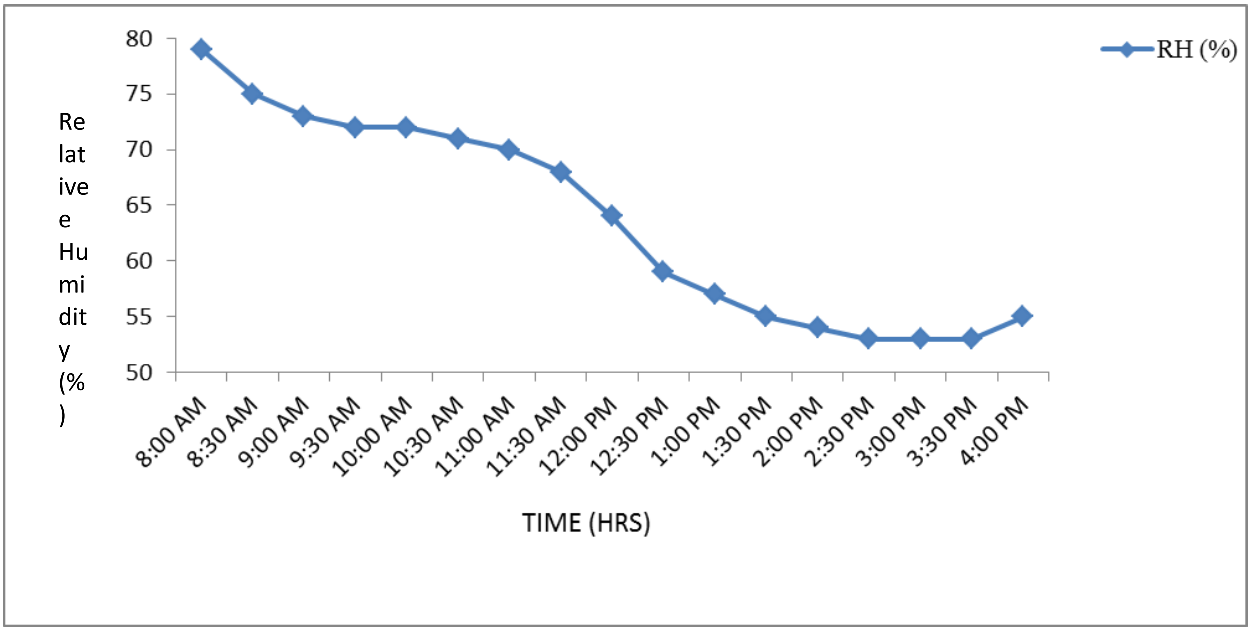

Fig -6 Time vs. Humidity plots for air velocity = 3.4 m/s, pipe length = 15 m, depth = 1.5 m of 16 July 2017

The time vs. temperature plots for dry bulb temperature and Relative Humidity for the air with velocity of 2.5 m/s on 18 July 2017 is shown in figure 7 & 8. The temperature drop remains approximate equal to 8.5 °C from 3.00 pm to 4.00 pm. It means for a concrete pipe of diameter 0.254 m, length 15 m and depth 1.5 m temperature fall remains constant over 5 to 5.5 hour starting of the blower.

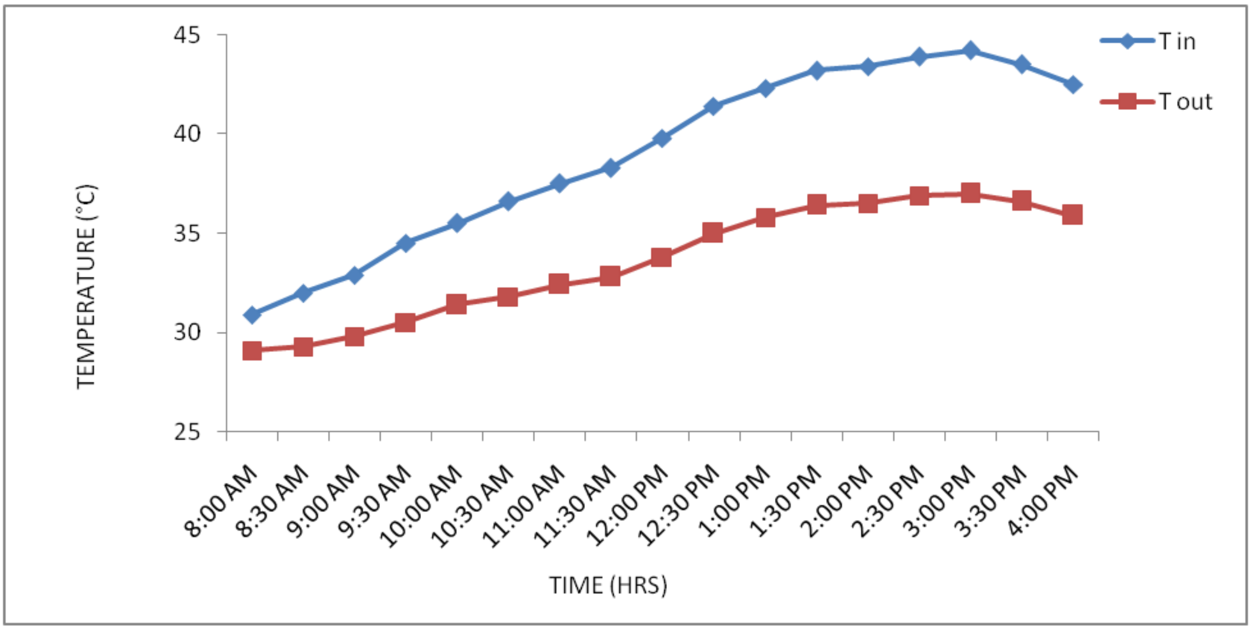

Fig -7: Time vs. temperature plots for an air velocity = 2.5 m/s, pipe length = 15 m, depth = 1.5 m of 18 July 2017.

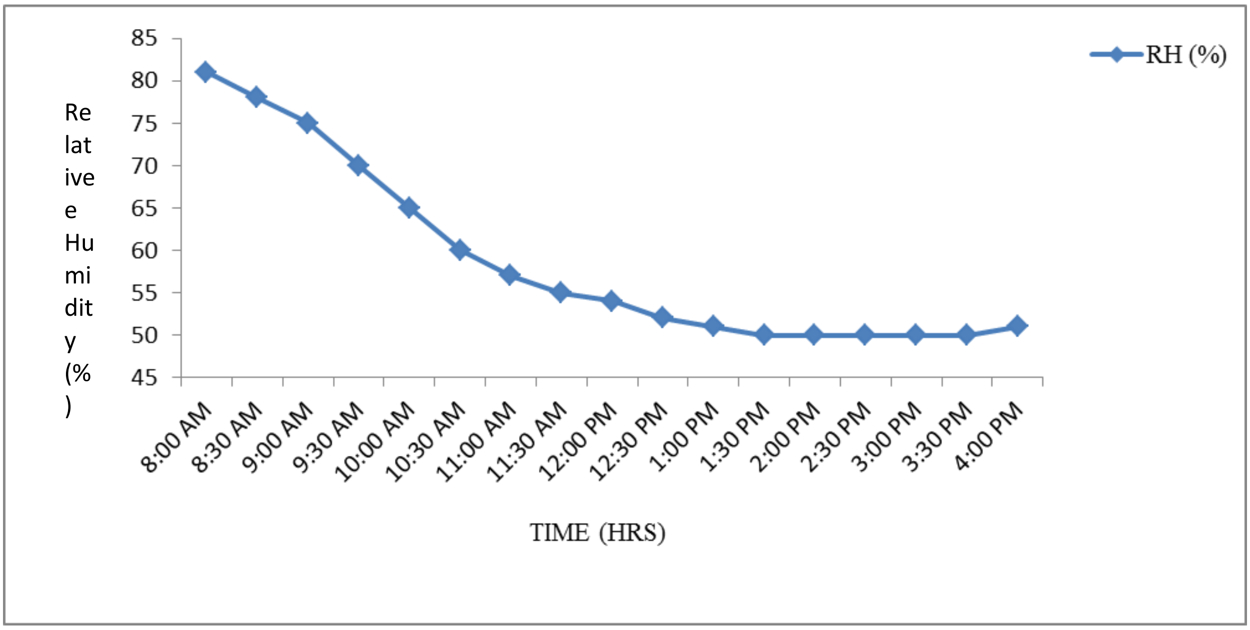

Fig -8 Time vs. Humidity plots for an air velocity = 2.5 m/s, pipe length = 15 m, depth = 1.5 m of 18 July 2017.

Figure 9 shows the average temperature fall vs. velocity for three days from 14 July, 16 July and 18 July 2017 for a pipe length of 15 m, air velocity 2.5 m/s, depth 1.5 m. The average fall for a velocity of 4.8 m/s is equal to 2.6 °C. The average fall for a velocity of 3.4 m/s is equal to 4.2 °C. The average fall for a velocity of 2.5 m/s is equal to 5.4 °C. As long as the air remains in the soil the geothermal effect of soil cools the air greatly.

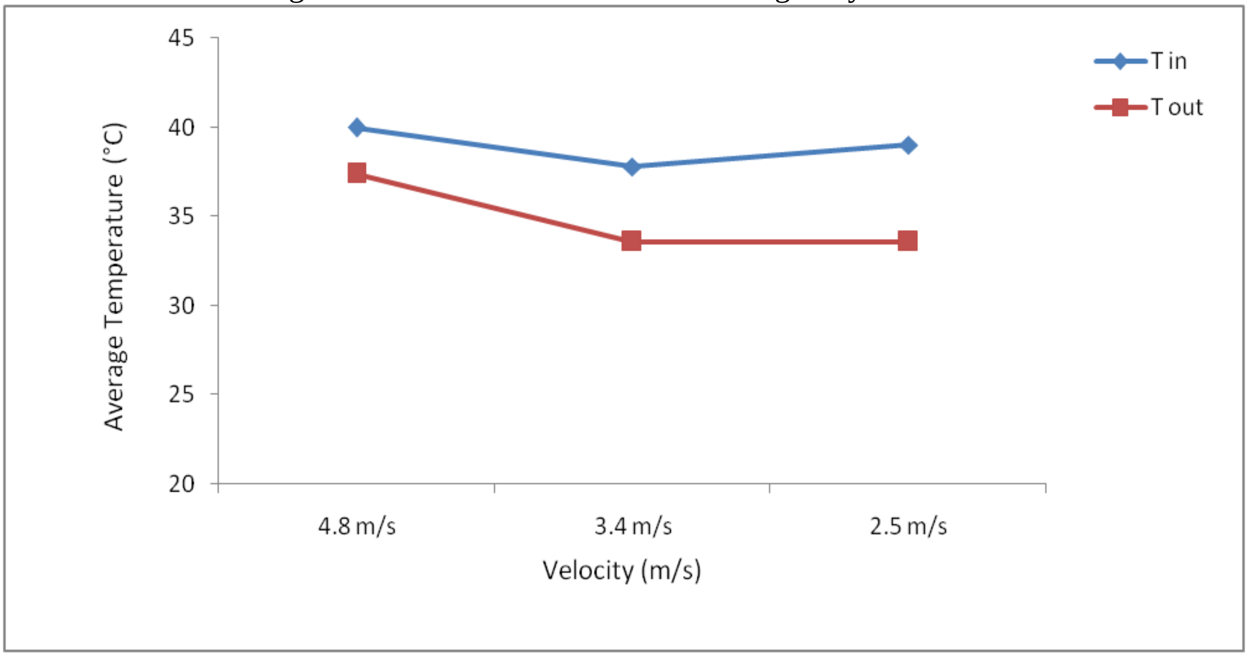

Fig -9: Average Temperature vs. Velocity for 14 July, 16 July and 18 July2017

6. CONCLUSIONS

The conclusions of the study reveal that Earth Air Heat Exchanger is a very effective system of for comfort environment. It becomes popular by increasing day by day improvement in their studies by different researchers. The observational study of this system makes it famous by varying length of pipe, by varying velocity of air and by varying the depth of the pipe used for EAHE system construction. EAHE system brings us that technology of varying temperature with the soil temperature found many benefits like energy saving, money is saved and environment saving. These benefits may help us lot in future in the study of renewable energy resources which is peak demand of the society. The loss of energy can be minimized with the help such type of systems. The use of EAHE is very limited in the state of Punjab and therefore the Punjab can become an energy crisis state in a few years; if renewable energy resources not implemented at the state level. With the rise in velocity to appropriate value it gives better results at a velocity of 2.5 m/s the maximum drop in temperature is 7.2 °C, for 3.4 m/s maximum drop is 6.5 °C and at a velocity of 4.8 m/s drop is 4.0 °C. Therefore the length of 30.6 m is cost effective and result oriented to the study of Earth air heat exchanger. The maximum average fall for a velocity of 2.5 m/s is equal to 5.4°C.

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