International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-2, Issue-4, April 2014

Cooling Potential Evaluation of Earth-Air Heat Exchanger System for Summer Season

Trilok Singh Bisoniya, Anil Kumar, Prashant Baredar

Abstract -- **Earth-air heat exchanger (EAHE) system can be used effectively to reduce cooling energy demand of buildings in hot and dry climate. A quasi-steady state, 3-dimensional model, based on computational fluid dynamics was developed to evaluate the cooling potential of EAHE system. The simulation model was developed in CFD platform CFX 12.0. The simulation results were validated against experimental observations taken on experimental set-up installed in Bhopal (Central India). A good agreement was observed between simulation results and experimental observations with maximum values of coefficient of correlation and root mean square of percent deviation 0.997 and 8.18% respectively. The drop in air temperature and total hourly cooling energy gain obtained from experimental set-up of EAHE varies from 12.9^0 C to11.3^0 C and 0.85 to 1.87 MJ h respectively for air flow velocities of 2m/s to 5m/s. Diameter of pipe and air flow velocity were found to greatly affect the thermal performance of EAHE system.**

Index Terms-- **CFD modeling, Coefficient of correlation, Cooling potential, Earth-air heat exchanger (EAHE)**

I. INTRODUCTION

In view of ever increasing per capita energy consumption and exponentially rising population, the earth's conventional energy resources are not likely to last for long time. Therefore, a well organised efforts are expected from scientific community to ensure that energy requirement of world at large is assured for long time and at low economic cost. So, it becomes very important to find and explore non-conventional energy sources to meet the energy requirement of the society. The non- conventional energy sources are better option of clean and sustainable energy. This kind of energy is, at principle, inexhaustible and can be found and exploited equally well on the planet [1]. The conventional air-conditioners (AC) used for achieving thermal comfort conditions in offices, buildings, residential and industries are responsible for global warming and ozone layer depletion because of use of chlorofluorocarbons (CFCs) as refrigerants in these machines. To minimize depletion of the ozone layer and global warming and to reduce high grade energy consumption; numerous alternative techniques are being currently explored [2], [3]. One of the promising techniques is earth-air heat exchangers. EAHE is basically a series of plastic, metallic or concrete pipes buried underground at a specified depth and fresh atmospheric air passes through it. It is the property of earth that temperature of ground at a depth of 1.5 to 2m remains fairly constant throughout the year. This constant temperature (earth's undisturbed temperature) remains lower than ambient temperature in summer and vice versa in winter. The fresh ambient air drawn through pipes of EAHE gets cooled in summer and vice versa in winter and if at sufficiently low/high temperature can be supplied directly for cooling/heating of space. Otherwise, the output of EAHE is connected to the conventional AC. In both the cases EAHE system can be used to save significant amount of electrical energy.

Several researchers have reported the EAHEs coupled with buildings as an effective passive energy source for building space conditioning [4]–[6]. Sodha et al. [7] and Bansal et al. [8] performed experimental analysis of large earth-to-air heat exchanger system assuming constant wall temperature, axial symmetric flow, negligible humidity variations etc. to provide thermal comfort inside the whole building complex at one of the hospitals in India. Kumar et al. [9] studied heating and cooling potential of an earth-to-air heat exchanger using artificial neural network. Ajmi et al. [10] calculated the cooling capacity of EAHEs for domestic buildings in a desert climate and found that it can reduce cooling energy demand in a typical house by 30% over the peak summer season. Hamada et al. [11] proposed and evaluated an improved EAHE by using a no-dig method in order to reduce cost of attaining comfort conditions using underground thermal energy. Vaz et al. [12] conducted experimental and numerical analysis of an EAHE which is used to reduce consumption of conventional energy for heating and cooling of built environments through the use of thermal energy contained in the soil. Chel and Tiwari [13] analyzed space heating and cooling with an EAHE integrated stand alone photovoltaic system in New Delhi, India. It was found that the energy payback is less than 2 years on investment in EAHE system and total average COP in the experimental period was 10.09. Woodson et al. [14] examined the performance of EAHE at different burial depth and observed that underground temperature was lowest at the time of the day when the ambient temperature was highest. Sehli et al. [15] proposed a 1-D numerical model to check the performance of EAHEs installed at different depth. Khalajzadeh et al. [16] evaluated thermal performance of ground heat exchanger and evaporative cooler hybrid system in summer conditions of Tehran, Iran. They [16] found that the hybrid system is capable to replace the conventional air-conditioner effectively and its cooling effectiveness is more than unity.

Manuscript received April 20, 2014.

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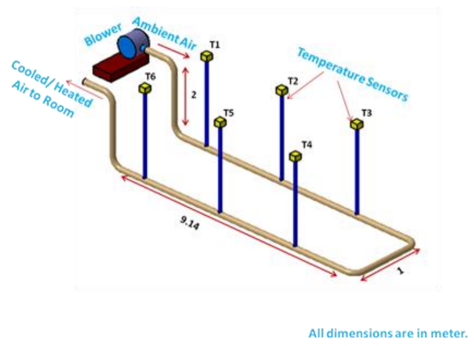
Ozgener et al. [17] determined the optimal design of a closed loop EAHE for greenhouse heating by using exergoeconomics.

The EAHE system examined in this paper presents evaluation of cooling potential for summer season in hot and dry climate of central India with parameters of EAHE system like pipe diameter, depth of burial, pipe length and air flow velocities different than previous researchers had used. The simulation of EAHE system was performed on CFD simulation platform CFX, which was also less covered in earlier research. The experimental set-up was installed in Bhopal (Central India) and the simulation model was validated with experimental results. The effect of air flow velocity on thermal performance of EAHE was studied.

II. DESCRIPTION OF EXPERIMENTAL SET-UP

The experimental study was done to get actual performance behaviour of EAHE system. The experimental set-up of EAHE system as shown in Fig. 1a, b consists of a two cylindrical pipes of 0.1016m inner diameter made up of PVC. The length of each pipe was 9.114m and both pipes were connected in series by elbows and a pipe of 1m length and of same inner diameter. The total burial length of pipe assembly was 19.228m which was buried at a depth of 2m in a flat land with black cotton soil. The open end of pipe assembly was connected through a vertical pipe to a 1hp, single phase, 2700 RPM, 0.075m^3/s centrifugal blower. The centrifugal blower draws fresh ambient air and throws it through the buried pipe assembly. The air flow velocity at inlet of pipe assembly can be varied by changing RPM of blower with the help of an auto transfer with range 0-280 Volt, 3.5A Max, single phase with least count of 1V. Six K-type thermocouples were inserted in pipe assembly at fix intervals to measure temperature (T_1, T_2, T_3, T_4, T_5 and T_6) of air along the length of pipe assembly. The temperature range of K-type thermocouples used was –270 to 1260^{0}C and Special Limits of Error: +/- 1.1^{0}C or 0.4%.

(a) 



(b)

Fig. 1 (a) Actual picture of EAHE installation and (b) Model of experimental set-up of EAHE system

The thermo hygrometer (model: TESTO 625; Humidity range: 0-100%; Temperature range: -10 to 60^{0}C and Accuracy: ±2.5% RH/ ±0.9^{0}F) used to measure ambient temperature and relative humidity. Vane probe type anemometer was used to measure air flow velocities. The velocity range is 0.4 to 25 m/s with least count of 0.1 m/s. The digital temperature indicator (MODEL NO.: SE-221-6K; INPUT: T/C/Cr/AIT; NO. OF INPUTS: 6; RANGE: -50^{0}C TO 1200^{0}C; ACCURACY: ±0.5% FSR ± 1 COUNT) is used to display temperature of thermocouples inserted in EAHE pipes at six different locations. The observations were taken for air flow velocities of 2m/s, 3.5m/s and 5m/s.

III. DESCRIPTION OF CFD MODEL

Modeling is very useful tool in order to predict the effect of the operating parameters like pipe length, radius, depth of burial and air flow rate on the thermal performance and heating/cooling capacity of EAHE systems. A number of computer modeling tools are commercially available. EnergyPlus and TRNSYS have EAHE modules that work well, however these are analysis tools and are not quickly used for design. Presently, Computational Fluid Dynamics (CFD) is very popular among researchers for modeling and performance analysis of EAHE systems. CFD codes were prepared around the numerical algorithms that can tackle fluid flow problems. The partial differential equations governing airflow and heat transfer can be solved numerically in a discretised form with CFD. The effect of operating parameters i.e. pipe length, radius, depth of burial and air flow rate on thermal performance and cooling/heating capacity of EAHE can be analysed. Some of the commercial CFD codes in use are FLUENT, CFX, STAR CD, FIDAP, ADINA, CFD2000, PHOENICS and others [18].

The CFD code CFX 12.0 is used for simulation of EAHE system. The following assumptions were mainly considered in CFD modeling.

- The surface temperature of the ground can be taken equal to the ambient air temperature, which equals the inlet air temperature.
- Earth's undisturbed temperature can be approximated to annual average temperature of the location (Bhopal- India).
- The PVC pipe used in EAHE is of uniform cross section.
- The thickness of pipe used in EAHE is very small hence thermal resistance of pipe material is negligible.
- The temperature on the surface of pipe is uniform in the axial direction.

Thermal model of EAHE system with specified dimensions was developed in Unigraphics NX 7.0. The model was imported in ICEM CFD where mesh of geometry was generated. The CFD simulations were performed considering 3-D steady state, turbulent flow (k-epsilon model) enabling heat transfer and thermal energy. The 3-D models become more popular in recent years because these models are dynamic and technically more advanced. It can provide room for all types of grid geometry to produce detailed thermal analysis of EAHE systems. The total number of nodes and elements generated in meshing of geometry of EAHE were 1066370 and 3814194 respectively. So, approximately 3.8 million elements (control volumes) were used in CFD analysis.

The following governing transport equations in 3-D Cartesian coordinates of fluid flow and heat transfer have been used in the analysis [19].

Continuity equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad (1)$$

x- Momentum equation:

$$\left[u\,\frac{\partial u}{\partial x}+v\,\frac{\partial u}{\partial y}+w\,\frac{\partial u}{\partial z}\right]=-\frac{1}{\rho}\,\frac{\partial P}{\partial x}+\vartheta\,\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right] \quad (2)$$

y -Momentum equation:

$$\left[u\,\frac{\partial v}{\partial x}+v\,\frac{\partial v}{\partial y}+w\,\frac{\partial v}{\partial z}\right]=-\frac{1}{\rho}\,\frac{\partial P}{\partial y}+\vartheta\,\left[\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right] \quad (3)$$

z- Momentum equation:

$$\left[u\,\frac{\partial w}{\partial x}+v\,\frac{\partial w}{\partial y}+w\,\frac{\partial w}{\partial z}\right]=-\frac{1}{\rho}\,\frac{\partial P}{\partial z}+\vartheta\,\left[\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right] \quad (4)$$

Energy equation:

$$\left[u\,\frac{\partial T}{\partial x}+v\,\frac{\partial T}{\partial y}+w\,\frac{\partial T}{\partial z}\right]=\alpha\,\left[\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right] \quad (5)$$

In the above equations, u, v and w are the velocity components in x, y and z directions, p and T is the pressure and temperature of the flowing air and α is soil thermal diffusivity. The main purpose of CFD modeling is to analyse the effect of variation in air flow velocity on thermal performance of EAHE system. The thermo-physical properties of PVC and air used in CFD simulation are shown in Table I.

Table I
Thermo-physical properties of materials used in simulation

Material	Density (kg/m^3)	Specific heat capacity (J/kg K)	Thermal conductivity (W/m-K)	Dynamic viscosity (kg/m-s)
Air at 40.4^{0}C	1.1261	1006.9	0.0271	1.9166E-05
PVC	1380	900	0.16	-
Soil	2058	1843	0.54	-

IV. EXPERIMENTAL VALIDATION AND RESULT ANALYSIS

The earth's undisturbed temperature is an important parameter in simulation of EAHE system. Assuming homogeneous soil of constant thermal diffusivity, the temperature at any depth z and time t can be estimated by the following expression: (Labs et al. [20]

$$T_{z,t}=T_m-A_s\exp\left[-z\left(\frac{\pi}{365\,\alpha_s}\right)^{\frac{1}{2}}\right]\cos\left\{\frac{2\pi}{365}\left[t-t_o-\frac{z}{2}\left(\frac{365}{\pi\,\alpha_s}\right)^{\frac{1}{2}}\right]\right\} \quad (6)$$

where $T_{z,t}$ is ground temperature at time t (s) and depth z (m); T_m , average soil surface temperature (^{0}C) ; A_s , amplitude of soil surface variation (^{0}C); α_s, soil thermal diffusivity (m^2/s; m^2/day); t, time elapsed from beginning of calendar year (day) and t_o, phase constant of soil surface (s; days).

It is very difficult to calculate accurate value of earth's undisturbed temperature because the soil parameters are often unknown. Additionally, it is defined for mean soil properties. Hence, earth's undisturbed temperature is hypothetical value which can be taken equal to annual average soil surface temperature of a particular locality. The soil surface temperature is assumed equal to the ambient air temperature. So, the earth's undisturbed temperature for Bhopal (Central India) is taken 25.2^{0}C which is equal to annual average temperature for the same (source: Indian meteorological department, Pune).

The simulation results obtained from CFD modeling of EAHE were validated by experimental observations taken on actual experimental set-up which was fabricated and installed at Bhopal (Central India) as shown in Fig. 1. The experiments were carried out on May 17, 2013 at Bhopal (India) prevailing hot and dry weather conditions during summer. Both simulation and experimental observations were taken at air flow velocities of 2m/s, 3.5m/s and 5m/s. The total hourly cooling energy gain was evaluated for air flow velocities of 2m/s, 3.5m/s and 5m/s by using following equation:

$$Q_c=3600\dot{m}C_p(T_{in}-T_{out}) \quad (7)$$

Where Q_c is total hourly cooling energy gain (MW h); $\dot{m}=\left(\frac{\pi}{4}\right)d^2\rho v_a$; $\dot{m}$, mass flow rate of air through pipe assembly (kg/s); d, diameter of the pipe (m); ρ, density of air at given inlet temperature (kg/m^3); v_a, air flow velocity through the pipe (m/s); C_p, specific heat capacity of air (J/kg K); T_{in}, air temperature at inlet of EAHE and T_{out}, air temperature at outlet of EAHE.

Table II
Comparison of experimental and simulated temperatures at different locations along the length of PVC pipe

Location	Air flow velocity = 2m/s			Air flow velocity = 3.5m/s			Air flow velocity = 5m/s		
	Sim. Temp.	Exp. Temp.	% diff.	Sim. Temp	Exp. Temp.	% diff.	Sim. Temp.	Exp. Temp.	% diff.
T_{in}	40.4	40.4	0.00	40.4	40.4	0.00	40.4	40.4	0.00
T_1	31.1	33.4	6.82	32.1	34.6	7.22	32.8	35.9	8.63
T_2	25.9	28.1	7.82	27.0	29.1	7.21	27.9	29.8	6.37
T_3	25.6	27.9	8.24	26.6	28.7	7.31	27.4	29.5	7.11
T_4	25.4	27.8	8.63	26.2	28.5	8.07	27.0	29.4	8.16
T_5	25.4	27.6	5.79	26.0	28.3	8.12	26.9	29.4	8.50
T_6	25.3	27.5	8.00	25.8	28.2	8.51	26.7	29.2	8.56
T_{out}	25.2	27.5	8.37	25.7	28.2	8.86	26.6	29.1	8.59

Table II shows comparison of experimental and simulation temperatures at different locations along the length of PVC pipe. In Fig. 2 the locations of six thermocouples (T_1 to T_6) and T_{in} and T_{out} is shown on horizontal axis. The variation of air temperature along the length of pipe from inlet to outlet is shown on vertical axis. Fig. 2 indicates that the drop in air temperature is faster for initial length of pipe and it becomes moderate for the remaining length. The simulation results were obtained at air flow velocities of 2m/s, 3.5m/s and 5m/s. It was seen that the maximum and minimum drop in air temperature of 12.9^{o} C and 11.3^{o} C occurs at air flow velocities 2m/s and 5m/s respectively. This is because of the fact that as the air flow velocity is increased, the time to which air remains in contact with ground is reduced.

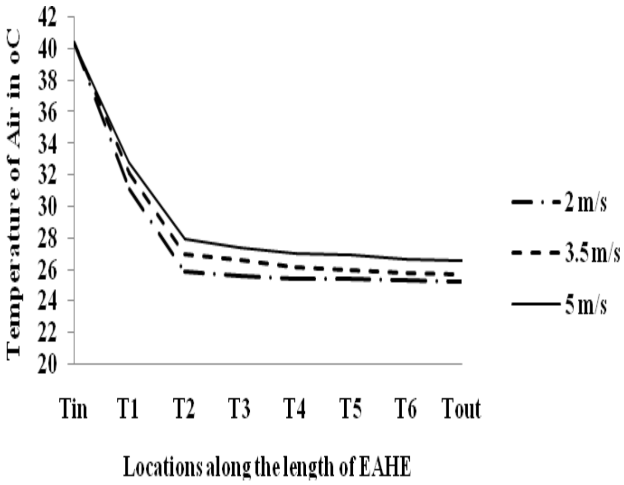


Fig. 2 Simulated temperature along the length of EAHE for various air flow velocities

(a)
(b)
(c)

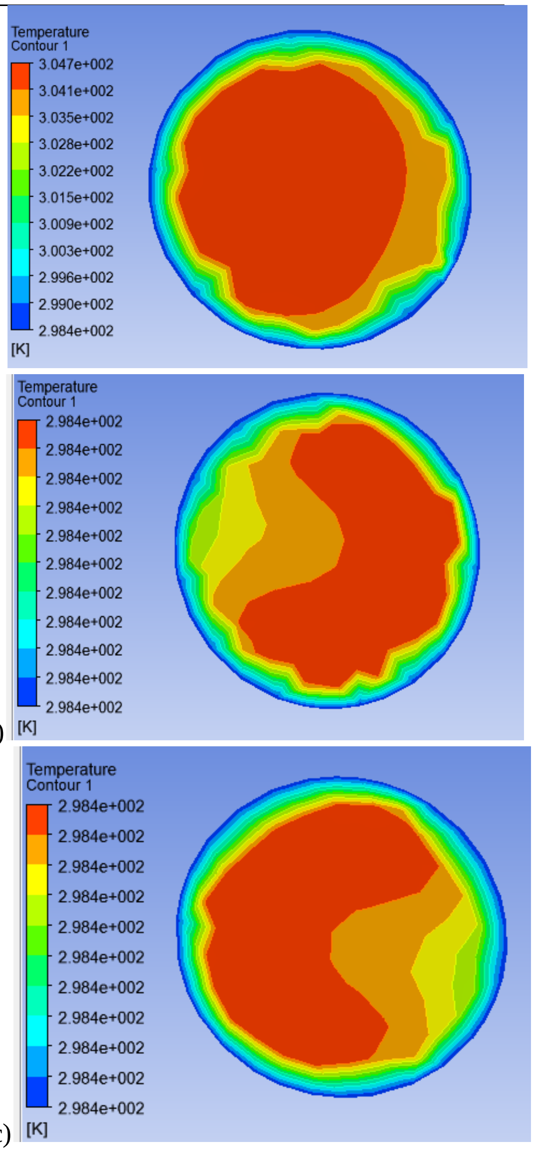


Fig. 3 Temperature contour at (a) 0.557m (b) 4.557m and (c) 18.661m along the EAHE from inlet for air flow velocity 2m/s

Temperature contour at 0.557m, 4.557m and 18.661m from inlet along the length EAHE pipe for air flow velocity 2m/s as obtained from CFD platform, CFX model of EAHE system are shown in Fig. 3. The variation in air temperature from central axis to wall of EAHE pipe in radial direction can be visualised through temperature contours.

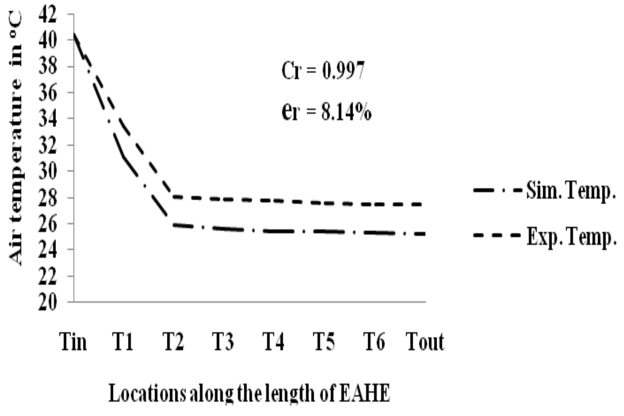


Fig. 4 Temperature distribution along the length of the pipe for air flow velocity 2.0 m/s

The comparison of simulation and experimental results obtained at different locations along the length of EAHE pipe for air flow velocities of 2m/s, 3.5m/s and 5m/s are shown in Figs. 4, 5 and 6 respectively.

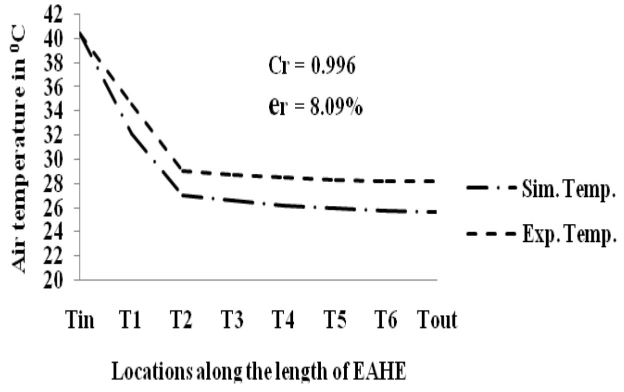


Fig. 5 Temperature distribution along the length of the pipe for air flow velocity 3.5 m/s

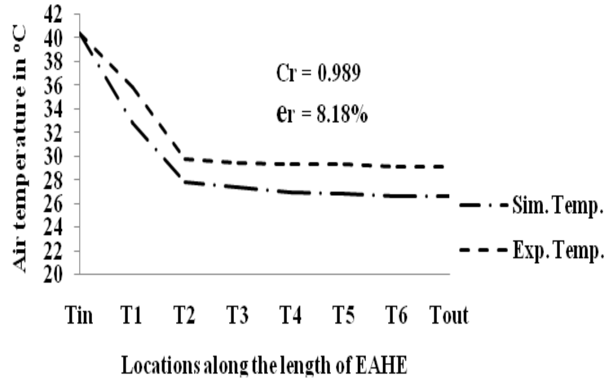


Fig. 6 Temperature distribution along the length of the pipe for air flow velocity 5m/s

The validation of simulation results with experimental results are shown in table 2. It was observed that deviation in simulation and experimental results ranges from 0 to 8.86% of experimental results. This deviation may arise due to assumptions made in CFD simulation, difference in physical properties like coefficient of friction of engineering material used in simulation and experimental set-up, irregularities like pipe joints, flow losses at elbows and inappropriate insulation at the risers of experimental set-up.

A. Statistical Error Analysis for Validation of CFD Model

For validation of simulation results obtained from CFD model with experimental results, statistical analysis presented by Chapra and Canale [21] was carried out to calculate correlation coefficient (r-value) and root mean percentage error (e-value).

Coefficient of correlation (r-value)

In order to validate the simulation results with experimental observations, correlation between simulation (predicted) and experimental values is presented with a coefficient known as coefficient of correlation. The coefficient of correlation can be calculated by the use of following equation:

$$C_r = \frac{n\sum X_i Y_i - (\sum X_i)(\sum Y_i)}{\sqrt{n\sum X_i^2 - (\sum X_i)^2}\sqrt{n\sum Y_i^2 - (\sum Y_i)^2}}$$

(8)

Where C_r represents the coefficient of correlation between experimental(X_i *or* X_{exp_i}) and predicted (Y_i *or* X_{pre_i}) values from CFD model and n is the number of observations. The value of coefficient of correlation varies from -1 to +1. The positive value indicates positive correlation between simulation results and experimental observations whereas the negative value shows negative correlation. If the value of the coefficient of correlation is greater than 0.8 it means there is strong relationship between experimental observation and simulation results and at its maximum value 1 means there is perfect relationship. The zero value of correlation coefficient means that there is no relationship.

Root mean square of percentage deviation (e-value)

How close the simulation results with the experimental data are, can be presented in terms of root mean square of percent deviation. The root mean square of percent deviation (e_r) is given by following equation:

$$e_r = \sqrt{\frac{\sum (e_i)^2}{n}}$$

(9)

Where $e_i = \frac{(X_{pre_i} - X_{exp_i})}{X_{pre_i}} \times 100$ and X_{pre_i} and X_{exp_i} are the predicted and experimental values for n number of observations.

The values of coefficient of correlation (C_r) and root mean square of percent deviation (e_r) are shown in Figs. 4, 5 and 6. It was seen that the values of coefficient of correlation (C_r) and root mean square of percent deviation (e_r) at air flow velocities 2m/s, 3.5m/s and 5m/s through EAHE pipe were 0.997, 8.14%; 0.996, 8.09% and 0.989, 8.18% respectively. This showed that the CFD model of EAHE system presented in this paper was in good agreement with the experimental results for hot and dry climate of Bhopal (India).

The total hourly cooling energy gain or cooling potential obtained from experimental set-up of EAHE discussed in this paper varied from 0.85 to 1.87 MW h for air flow velocities of 2m/s to 5m/s. The maximum hourly cooling potential of EAHE system was obtained at air flow velocity of 5m/s. The hourly cooling potential of EAHE system depends on air flow velocity and air temperatures drop both. It was seen that the increase in air flow velocity is 66.67% and decrease in air temperature drop is 12.4% only with increasing velocity from 2m/s to 5m/s. The first factor is predominant, therefore maximum hourly cooling energy gain or cooling potential was obtained at higher air flow velocities.

B. Experimental Results and Discussion

On the basis of experimental observations taken on May 17, 2013 it was concluded that maximum drop in air temperature occurred at air flow velocity of 2m/s. So, experimental observations were repeated on May 28, 2013 and 1st and 10th day of June, 2013 for air flow velocity of 2m/s at inlet of EAHE system.

Table III

Comparison of experimental temperature at different locations along the length of the pipe during May-June, 2013 for air flow velocity 2m/s

Location	Experimental temperature at air flow velocity 2m/s			
	May 17, 2013	May 28, 2013	June 01, 2013	June 10, 2013
T_{in}	40.4	38.8	39.9	36.3
T_1	33.4	32.9	33.8	30.9
T_2	28.1	29.2	28.9	27.4
T_3	27.9	28.9	28.6	27.2
T_4	27.8	28.7	28.4	27.2
T_5	27.6	28.5	28.3	27.0
T_6	27.5	28.4	28.3	26.9
T_{out}	27.5	28.4	28.1	26.8

In each month, two representative days were chosen which corresponds to the summer season of Bhopal (India). It was seen that maximum drop in air temperature whereas it passes through the pipe of EAHE system occurs when the inlet air temperature is highest. The maximum drop in air temperature of 12.9^{0}C was recorded on May 17, 2013 when the inlet air temperature was 40.4^{0}C and minimum drop in air temperature of 9.5^{0}C was recorded on June 10, 2013 when the inlet air temperature was 36.3^{0}C as shown in table III.

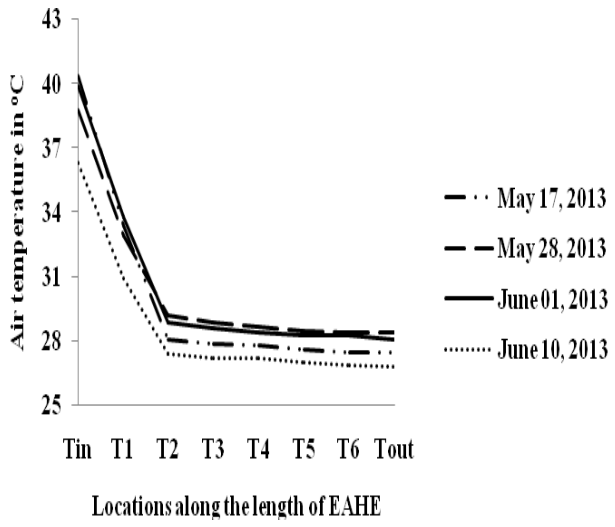


Fig. 7 Temperature distribution along the length of the pipe during May-June, 2013 for air flow velocity 2m/s

The temperature distribution along the length of the pipe during May-June, 2013 for air flow velocity 2m/s is shown in Fig. 7. The drop in air temperature at outlet of EAHE system depends on temperature difference between earth's undisturbed temperature (EUT) and air temperature at inlet and humidity also. The hourly cooling energy gain of 0.85 MW h, 0.69 MW h, 0.78 MW h and 0.637 MW h was observed on 17th, 28th May, 2013 and 1st, 10th June, 2013 respectively.

Several researchers have presented the results of experiments on EAHE systems for evaluating its cooling potential in summer season. Mongkon et al. [22] presented the performance analysis of horizontal earth tube system (HETS) for cooling in an agricultural greenhouse in the tropical climate of Thailand. The experiments were undertaken in 30m^2 of greenhouse volume with the HETS (about 38.5 m of length, 0.08m diameter) buried to a depth of 1 m. The maximum coefficient of performance (COP) of the typical summer day observed was 3.56. Wu et al. [23] evaluated cooling capacity of earth–air–pipe systems installed in Guangzhou, Southern China. They have developed a transient and implicit model in CFD platform, PHOENICS to evaluate the effects of the operating parameters (i.e. the pipe length, radius, depth and air flow rate) on the thermal performance and cooling capacity of earth–air–pipe systems. The pipe with length of 60 m and radius of 0.2 m was buried at the depth of 3.75 m. The daily cooling capacities of the earth–air–pipe systems obtained were 43.2 kW h for the radius of 0.2 m and 74.6 kW h for the radius of 0.3 m, respectively. It was concluded that earth–air–pipe systems can be used to reduce the cooling load of buildings in summer.

The geometrical dimensions, operating parameters and modeling tool used in this paper were different than previous researchers had used. The CFD simulations can be used to evaluate cooling potential of EAHE system for different operating parameters.

V. CONCLUSION

The simulation model of EAHE system was developed in CFD platform CFX. The simulation and experimental results were obtained for air flow velocities of 2m/s, 3.5m/s and 5m/s on May 17, 2013. It was concluded that the maximum and minimum drop in air temperature of 12.9^0C and 11.3^0C occurred at air flow velocities 2m/s and 5m/s respectively. It was observed that the drop in air temperature was faster for initial length of pipe and it became moderate for the remaining length. The total hourly cooling energy gain or cooling potential obtained from experimental set-up of EAHE with PVC pipe of 19.228m length and 0.1016m diameter buried at 2m depth varied from 0.85 to 1.87 MW h for air flow velocities of 2m/s to 5m/s. A good agreement was observed between simulation results and experimental observations for modeling of EAHE system with maximum values of coefficient of correlation and root mean square of percent deviation 0.997 and 8.18% respectively.

The experimental observations were repeated on May 28, 2013 and 1^{st} and 10^{th} day of June, 2013 for air flow velocity of 2m/s at inlet of EAHE system. It was concluded that maximum drop in air temperature whereas it passed through the pipe of EAHE system occurred when the inlet air temperature was highest. The hourly cooling energy gain of 0.85 MW h, 0.69 MW h, 0.78 MW h and 0.637 MW h was observed on 17^{th}, 28^{th} May, 2013 and 1^{st}, 10^{th} June, 2013 respectively.

Finally, it was concluded that EAHE system can be used effectively to reduce cooling load of buildings in hot and dry summer weather conditions. A considerable amount of electrical energy can be saved if EAHE is used in place of conventional AC for summer cooling. The high grade energy consumption can further be reduced by integrating renewable energy source like wind turbine, solar PV panels, biogas etc with EAHE system to meet its energy requirements.

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