Analysis of Earth Air Heat Exchanger (A Review)

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Abstract:
The earth–air heat exchanger (EAHE) is a favourable method which can efficiently use to reduce the heating/cooling load of a building by heat up the air before entering in to the cooling space in winter and vice versa in summer. In the last two periods, a lot of study has been done to develop analytical and mathematical models for the analysis of EAHE systems. In this review paper study the CFD analysis of EAHE systems in India.

Keywords: CFD, Earth air heat exchanger and Renewable energy.

I. Introduction:

The idea of using earth as a heat sink was identified in prehistoric epochs. In about 3000 B.C., Iranian designers used wind towers and underground air channels for inert cooling. Underground air tunnels (UAT) systems, currently also identified as earth to air heat exchangers (EAHEs), have been in use for years in advanced countries due to their higher energy utilization effectiveness related to the conventional heating and cooling systems. EAHE is an inert climate governing method that has use in housing as well as farming building operates the underground soil temperature that stays fairly constant at a depth of nearby 2.5–3 meter. [1]

The utilization of geothermal energy to decrease heating and cooling requirements in buildings has received growing attention for the duration of the last several years. An Earth Air Tunnel Heat Exchanger (EATHE) contains of a long underground metal or plastic pipe through which air is drained. As air move through the pipe, it gives up or takes some of its heat to/from the surrounding soil and enters into the room as conditioned air during the cooling and heating period. [2]

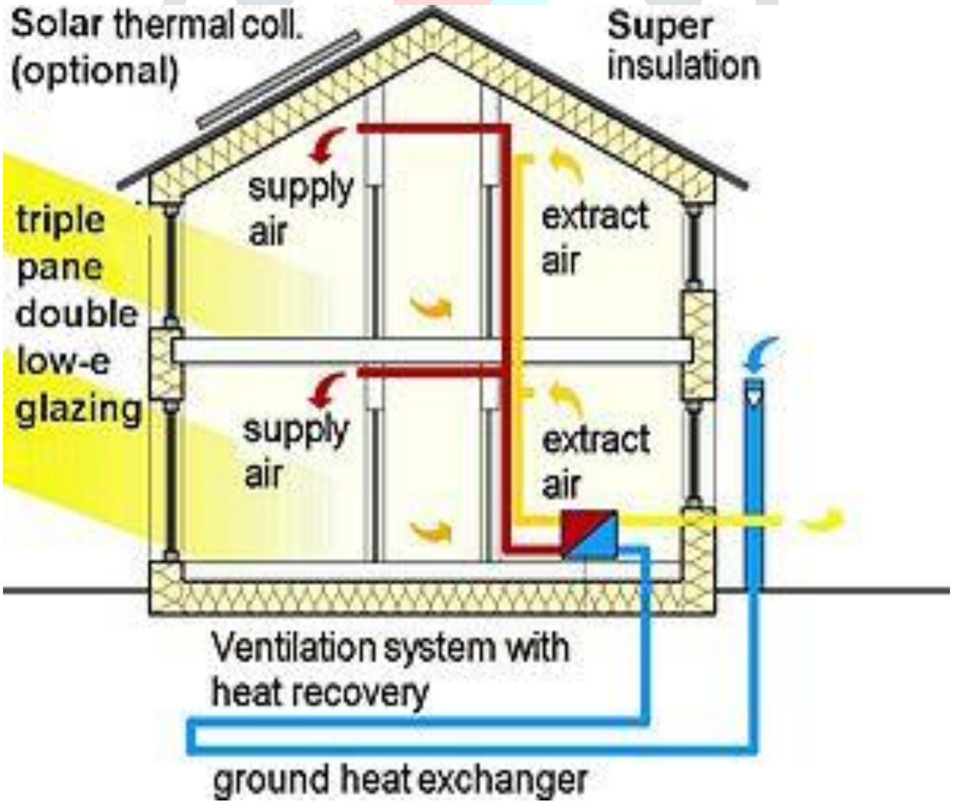

Figure (1) Schematic view of Earth Air Heat Exchanger

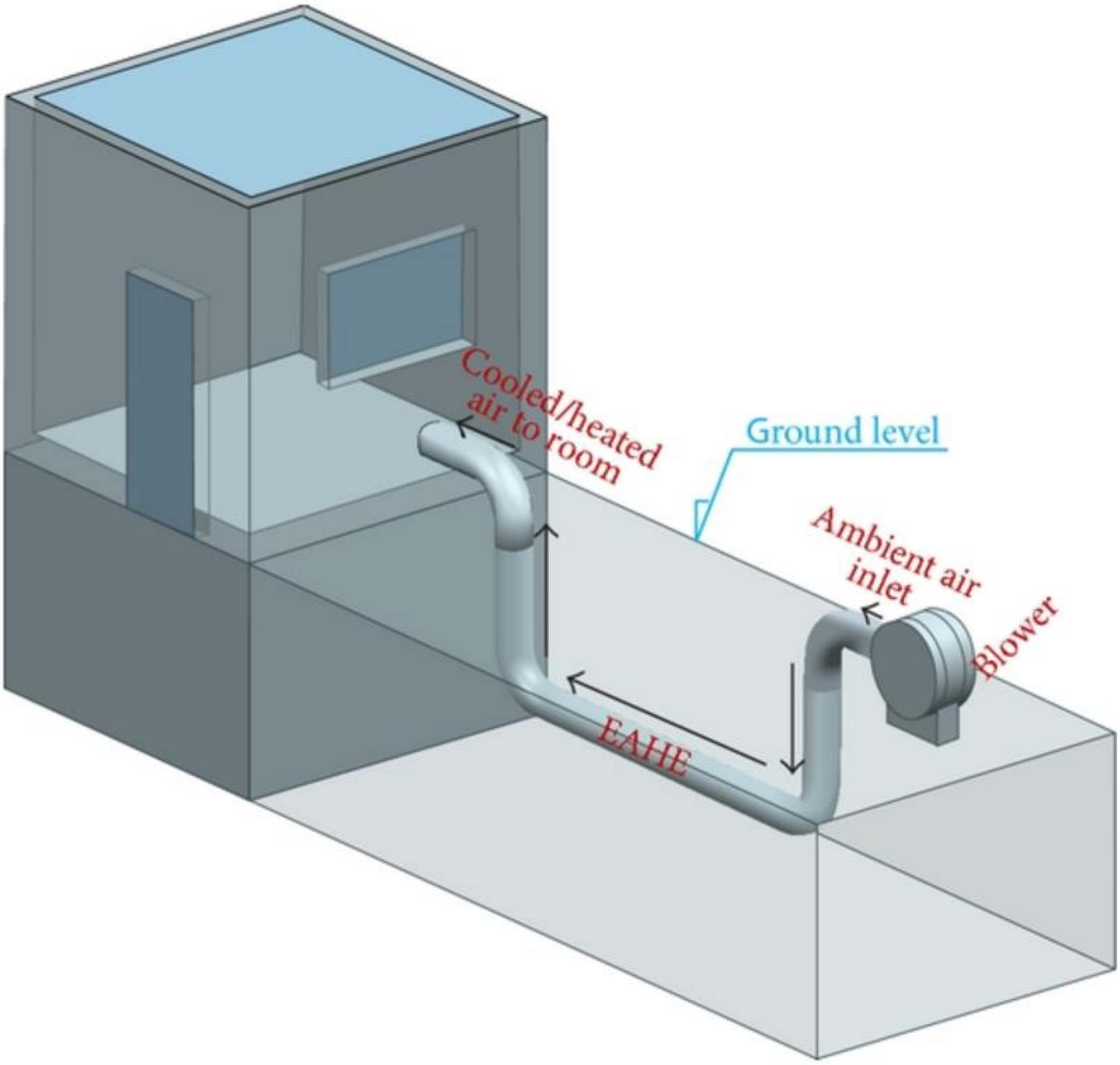

Figure (2) Schematic diagram of earth air heat exchanger

A **ground-coupled heat exchanger** is underground heat exchangers that can absorb heat from and/or release heat to the ground. They use the Earth's near constant underground temperature to hot or cool air or other fluids for housing, agricultural or industrial purpose. If building air is driven by the heat exchanger for heat recovery ventilation, they are called **earth tubes** (also known as earth cooling tubes or earth warming tubes).

Earth tubes are often a possible and economical substitute or supplement to conventional central heating or air conditioning systems since there are no compressors, chemicals or burners and only blowers are required to move the air. Earth tubes are used for either partial or full cooling or heating facility of ventilation air. Their uses that can help buildings meet Passive House standards or LEED certification.

Earth-air heat exchangers have been used in agricultural services (animal buildings) and gardening facilities (greenhouses) in the United States over the previous several years and have been used in conjunction with solar chimneys in hot dry areas for thousands of years, probably beginning in the Persian Empire. Execution of these structures in Austria, Denmark, Germany, and India has become fairly common since the mid-1990s, and is slowly being adopted in North America.

Earth Air heat exchanger may also use water or antifreeze as a heat transfer fluid, often in combination with an Earth air heat pump. [3]

(A) Design of Earth air heat exchanger:

Most systems are generally made from 100 to 600 mm (3.9 to 23.6 in) diameter, smooth-walled (so they do not easily trap condensation moisture and mold), rigid or semi-rigid plastic, plastic-coated metallic pipes or plastic pipes glazed with inner antimicrobial layers, suppressed 1.5 to 3 m (4.9 to 9.8 feet) underground where the ambient ground temperature is typically 10 to 23 °C (50 to 73 °F) all year round in the temperate latitudes where most humans live. Ground temperature becomes steadier with depth. Smaller diameter tubes require more energy to move the air and have less ground contact surface area. Larger tubes permit a slower airflow, which also yields more efficient energy transfer and permits much higher volumes to be transmitted, permitting more air exchanges in a smaller time period, when, for example, you want to clear the building of offensive odours or smoke but suffer from lesser heat transfer from the pipe wall to the air due to increased distances.

Some consider that it is more effective to draw up air through a long tube than to push it with a fan. A solar chimney can use for natural convection (warm air rising) to generate a vacuum to make clean passive cooling tube air through the largest diameter cooling tubes. Natural convection process may be slower than using a solar-powered fan. Sharp 90-degree angles should be avoided in the creation of the tube – two 45-degree bends produce less-turbulent, more effective air flow. While smooth-wall tubes are more effective in moving the air, they are less efficient in transferring energy. [4]

(B) Description of CFD model:

Computational fluid dynamics (CFD) is a computer-based simulation method for analysing fluid flow, heat transfer, and related phenomena such as chemical reactions. This project uses CFD for analysis of flow and heat transfer. Some examples of application areas are: aerodynamic lift and drag (i.e. airplanes or windmill wings), power plant combustion, chemical processes, heating/ventilation, and even biomedical engineering (simulating blood flow through arteries and veins). CFD analyses carried out in the various industries are used in R&D and manufacture of aircraft, combustion engines, as well as many other industrial products.

Computational fluid dynamic (CFD) is well known as a powerful method to study heat and mass transfer for many years. CFD codes are structured around the numerical algorithms that can tackle fluid flow problems. It provides numerical solutions of partial differential equations governing airflow and heat transfer in a discretised form. To examine the complicated airflow and heat transfer processes in an earth–pipe–air heat exchanger system, CFD software, FLUENT 6.3, was used in this study. In order to provide easy access to the solving power of CFD codes, FLUENT 6.3 packages include sophisticated user interfaces to input problem parameters and to examine the results. CFD codes in FLUENT contain three main elements: (i) a pre-processor, (ii) a solver and (iii) a post-processor.

Pre-processing consists of the input of a flow problem to a CFD program by means of definition of the geometry of the region of interest: the computational domain, Grid generation – the subdivision of the domain into a number of smaller, non-overlapping sub-domains: a grid (or mesh) of cells (or control volumes or elements), selection of the physical and chemical phenomena that need to be modeled, definition of fluid properties, specification of appropriate boundary conditions at cells which coincide with or touch the domain boundary. Solver uses the finite control volume method for solving the governing equations of fluid flow and heat transfer. Post-processor shows the results of the simulations using vector plots, contour plots, graphs, animations etc.

The CFD simulations were performed using FLUENT and considering 3-D transient turbulent flow (standard k–e model) with heat transfer enabled. In this transient analysis time step is taken as 100 s with 20 iterations in each step. Total numbers of the control volume used for the CFD analysis were about 3.8 million.

CFD analysis is carried out for two different pipe material viz. mild steel and PVC.

The main objective of the CFD study was to investigate the effect of buried pipe material on the performance of the EPAHE system (for this two materials, mild steel and PVC were considered) and also to study the effect of air velocity on the performance of the EPAHE system.

In the study it was assumed that air is incompressible and subsoil temperature remains constant since the penetration of the heat from the surface of the soil is very slow. It was also assumed that engineering materials used are isotropic and homogeneous. [5]

I. Literature Review:

Literature review is one of the scope studies. It works as guide to run this analysis. It will give part in order to get the information about Earth Air Heat Exchanger analysis using CFD. From the early stage of the project, various literature studies have been done. Research journals, books, printed or online conference article were the main source in the project guides.

Aashish sharma, Shashank Srivastava, Sanjeev Kumar, et al (2017) Performance of EAHE model based on CFD modeling and simulation for different medium of source/sink is estimated. It was observed that the cooling potential of the earth tube heat exchanger increases significantly. The reason for this is the higher thermal properties of the materials chosen as medium. Different mediums show different temperature drop across the section. It is definite that if we work in this direction, a much better performance can be achieved for existing Earth Air Heat Exchanger.

Shashank Srivastava, Ashish Sherma, Ketan Ajay et al (2016) Performance of earth tube heat exchanger model based on CFD modeling and simulation for different geometries of the pipe/duct is evaluated. It was observed that the cooling potential of the earth tube heat exchanger increased, this was due to increased internal surface area and eddy formations caused by the corrugation geometry. It is definite that if we work in this direction, a much better performance can be achieved for existing Earth Air Exchanger.

Trilok Singh Bisoniya et al (2015) In this paper the earth–air heat exchanger (EAHE) is a promising technique which can effectively be used to reduce the heating/cooling load of a building by preheating the air in winter and vice versa in summer. In this paper, the author has developed a one-dimensional model of the EAHE systems using a set of simplified design equations. The method to calculate the earth's undisturbed temperature (EUT) and more recently developed correlations for friction factor and Nusselt number are used to ensure higher accuracy in the calculation of heat transfer. The developed equations enable designers to calculate heat transfer, convective heat transfer coefficient, pressure drop, and length of pipe of the EAHE system. A longer pipe of smaller diameter buried at a greater depth and having lower air flow velocity results in increase in performance of the EAHE system.

Vikas Bansal, Rohit Misra, Ghanshyam Das Agrawal, Jyotirmay Mathur et al (2009) In this paper to develop a transient and implicit model based on computational fluid dynamics is developed to predict the thermal performance and heating capacity of earth–air–pipe heat exchanger systems. The model is developed inside the FLUENT simulation program. The model developed is validated against experimental investigations on an experimental set-up in Ajmer (Western India). From this study they conclude following. There is a fair agreement between the experimental and simulation results for modeling of EPAHE system with maximum deviation of 2.07%. Rise in air temperature is found to decrease with increase in flow velocity. It can be concluded from this analysis that performance of the EPAHE system is not affected by the material of the buried pipe, therefore a cheaper material pipe can be used for making the pipe.

II. Conclusion

Following conclusion can be determined from the previous research;
On the behalf of research paper I concluded that in earth air heat exchanger there is significant temperature rise with decrease in air velocity, so the air velocity is as low as possible for efficient heat transfer. The smaller pipe is buried at a greater depth for lower air flow in the pipe which result higher performance rate.

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