Thermal Effect of Geothermal Energy and its Analysis using Air as a Flow Medium - A Review

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ABSTRACT

The flow medium gets cool in the summer and gets heated in the winter due to the temperature difference between the flow medium and underground surface. Study of model is carried out using ANSYS software. Software simulation is being used for measurement of heat transfer. The software requires parameters, such as the diameter, air flow rate depth, tube length and condensation in the meantime have to be considered., Computational Fluid Dynamics (CFD Fluent) workbench under ANSYS software is used as simulation analysis. The parameters used for computation are the pipe of 45 m length, 0.004 m thickness and 0.08 m diameter. Velocity of air is considered to be 1 m/s and 5 m depth of pipe from the earth ground. The inlet temperature for a days according the climate of Algeria. Copper is considered for analysis. Using Fluent heat variations is being analyzed. It is observed at increasing velocity increases the rate of heat transfer, mid temperature, outlet temperature vary in summer and winter.

KEYWORDS:* *EATHE, Heat Convection, Temperature, Numerical simulation

1. INTRODUCTION

In the past over 30years, researchers have actively considered using soils for thermal energy storage applications e.g., [1–8]. The nearly constant ground temperature at a certain depth has been regarded by several researchers as a passive means for heating and cooling of buildings. Depending mainly on the ambient air temperature, shallow soils could be the unique heat source or sink needed for heating or cooling purposes, for considerable periods of time throughout the year. Hence, soil temperature is an important parameter in solar and geothermal energy applications such as the passive heating and cooling of buildings and agricultural greenhouses [4]. In many engineering applications it is necessary to know the soil temperature at different levels in order to determine the system design parameters.

Although soil temperature is considered to be constant at certain depths, it varies especially near surface levels. It is well known that in system such as EAHEs. The depth at which they are installed has vital importance on dimensions, performance and installation costs of the system. In many cases a detailed investigation of the soil properties and long term soil temperature measurements as a function of time at different depths of the research area are needed in order to deter- mine design parameters and feasibility of a system. However, researchers are in the need of more practical tools as obtaining a detailed site survey is not always possible. Despite its importance in scientific research and operations, relatively few data are available on soil temperature. Even when available, the data are often scattered and incomplete. These problems could be attributed to the substantial investment of money and time, and relatively large network of data acquisition system needed for detailed characterization of soil temperature at different depths and times. This study focused on utilizing easily accessible data such as annual daily average air temperatures to predict daily soil temperatures depending on depth and time. Energy demand is increasing at an alarming rate and more furiously the availability of resources to produce energy is decreasing that led the world to think about alternative approaches for energy generation and conservation. An earth-air heat exchanger came out as one of the promising technique for space conditioning. EAHX uses ground as heat source or heat sink to accept or reject heat for full or partial cooling/heating of buildings, in this system tubes are buried in ground hence it is also called as ground coupled heat exchanger.

A serious issue that has always been debated among the environmentalists over the decades till today is air pollution. While the technology keeps on evolving and emerging it carries along undesirable effects apart from its broad applications. One of the main contributors to this pollution is said to be CFCs and HFCs used in AC systems. Thus, to reduce the ill-effects of these contributors on our environment, an ETHE is used to condition the space.

Geo-thermal energy is a renewable, eco-friendly energy source and is available freely on earth. Its use will ensure the conservation of conventional energy sources and prevent their depletion. It also helps in avoiding the increasing use of refrigerants used in air- conditioning, thus it helps in avoiding the ozone depletion. Also the operational cost of the system is very low compared to that of conventional air-conditioning systems. Thus we can say that, here it is a great need of implementing these systems and improving these kinds of techniques for green future. The average temperature at soil strata at depth of 2-5 m is 25 to 27 °C and is constant throughout the year. Below a certain depth like 2-4m, the temperature is low compare to outside air temperature during summer and comparatively high during winter season.

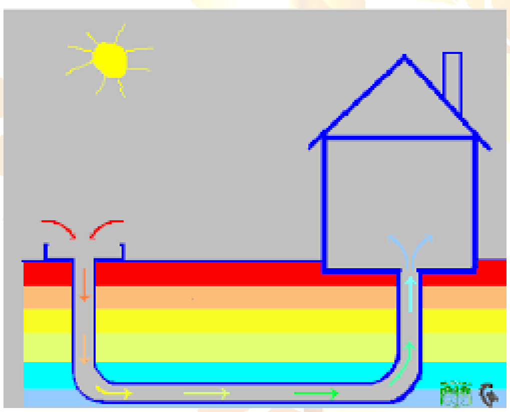

Fig. 1: Working of an *Earth Air Tube Heat Exchanger* (EATHX)[12]

In many European countries people implement this system for private houses and buildings and also in some of the passive houses and greenhouses this system is used for space conditioning. Though the concept of using ground as heat source and sink is not new but the interest for such system dwindled because of the availability of cheap resources to produce energy.

An earth air heat exchanger (EAHE) consists of one or more pipes laid underground to supply air conditioning in buildings for cooling in summer and heating in winter. The ambient air is used for ventilation and also to reduce or partially replace the energy demand so as to maintain thermal comfort in buildings or houses. EAHEs are characterized by their large potential for energy saving and low maintenance.

The physical phenomenon is simple and depends on the temperature difference between the soil and the ambient air. In summer, the soil temperature is lower than that of the ambient air. Soil temperature also remains almost constant throughout the year at a given depth below ground level. However, the soil temperature profile is a function of the depth involved and depends on other factors such as the physical properties of the soil and the climatic conditions.

To understand the thermal performance of EAHEs, several mathematical models, methods and computer tools were developed and used in the open literature. Krarti et al. analyzed the heat transfer process in an EAHE and proposed an analytical model for the EAHE system. A physical model to simulate the EAHE was developed and validated by Mihala-kakou et al. Benkert et al. highlighted the lack of optimization criteria when analyzing EAHEs and developed a specific computer tool based on a physical model which was experimentally validated. Al-Ajmi et al. developed an analytical model of an earth air heat exchanger to predict the air outlet temperature and the potential of these cooling de-vices in a hot arid climate. In their model, the thickness of the disturbed layer of the soil was taken as equal to the radius of buildings in summer and hence the comfort of individuals. This work aims to demonstrate that a simple pipe placed underground and connected to a building can significantly regulate indoor thermal comfort and thus help in energy savings in hot arid climate conditions. The study was con-ducted in the month of July, in which the highest cooling demand is registered over a year, and the climatic conditions were those of the region of Adrar in the Algerian Sahara.

2. LITERATURE REVIEW

Various studies on effect of air on earth tube air heat exchanger were carried out by many researchers in the past. Some of references related to the present study were reviewed in the followings:

Sodha et al. [1993][26] investigated number of configurations of ground coupled air pipe system to observe the effect of air mass flow rate, radius and length of pipe on thermal cooling potential (TCP) of system. For Jodhpur's climate maximum TCP 1920 kWh/m^2 for radius and length of pipe 5 cm and 12.5 m respectively and mass flow rate is 24000 m3/h, for Delhi's climate TCP is 1280 kWh/m2 for radius and length 5 cm and 12.5 m respectively.

Krarti et al. [1996][27] suggested on the basis of their numerical model concluded that on increasing the diameter of pipe there will be lesser temperature drop while on increasing discharge higher capacity fan will be needed, results also infer that on increasing air velocity, due to shorter residence time temperature drop will decrease.

Deglin et al. [1999][28] showed the effect of different factors like pipe dimensions, type of ground and velocity of air on extent of heat exchange between soil and pipe.

Al-Ajmi et al. [2006][41] they have shown a temperature drop of 2.8^0C during peak hours in summer, a decrease of 420 kWh is achieved using this system. A simple accurate model based on numerical transient bi-dimensional approach is developed by **Badescu.**

Badescu [2007][44], paper concerned about heating and cooling potential of ground heat exchanger under real conditions also the effect of different design parameters were analyzed. Although most of the earlier researches have been performed to find out optimized design, thermal and ground parameters for the design of earth air thermal heat exchanger because these factors dominate the performance of the system hence present work is an attempt to reduce the dominance of aforementioned factors by implementing fins so that heat transfer can be amplified.

Bansal et al. [2009, 2010][46] conducted his experiment at Ajmer in India, the experimental setup consists of two horizontal cylindrical pipes each of 150 mm diameter and having a buried length and depth of 23.42 m and 2.7 m. One cylindrical pipe is made up of polyvinyl chloride (PVC) while the other is made up of galvanized steel. The experimental results show that the performance of the system was not affected by the material of the buried pipe for summer and winter. However, the cost of the project was higher by 20- 25% if galvanized steel is used.

Ascion et al. [2011][16] experimented concluded that best energy performance could be obtained for wet soil by introducing pipe of more than 50 m in length and buried at a depth of 3 m.

Misra et al. [2012][15] experimental setup consists of hybrid EATHE system with window AC. The experimental setup consists of 60 m long, 100 mm diameter poly vinyl chloride pipe buried at a depth of 3.7 m in the ground. There were four modes of test shown in Table 3. It was concluded that mode-III could conserve significant amount of energy.

Sehli et.al. [2012][9] Studied and proposed an one-dimensional steady numerical model is proposed to estimate the performance of earth-to-air heat exchangers, installed at different depth, used for building cooling/heating. Two parameters are considered to evaluate the performance of the system (Reynolds number and the form factor).With appropriate simplifications; Numerical simulation treatment is proposed to predict the temperature fields of the fluids in the pipe and the soil in the proximity of the buried pipe, taking into account meteorological data of south Algeria. Moreover, the agreement with some experimental data available in the literature is very satisfactory.

Misra et al. [2013][23] conducted an exhaustive parametric analysis on the performance of earth air thermal heat exchanger (EATHE) also analyzed how in continuous operation performance degrades and devised a term "derating factor" to relate this degradation. Their results show a variation of 0% to 64% in derating factor which is caused by choosing different parameters like air velocity, pipe's dimensions, depth, soil's thermal conductivity. Using a non-steady state 3D model.

Tudor et al. [2013][30] studied influence of certain design parameters on the performance of a registry type system considering the weather of South Eastern Europe. Length, diameter of pipe and depth of burial were the parameters under consideration. Results have shown that increasing the depth lead to 24.31% rise in heat gain and 47.57% more heat loss is observed. For desert climate the cooling capacity of earth air heat exchanger is analyzed by Al-Ajmi et al.

Debbarma. [2013][6] Studied and proposed research activities are ongoing to develop Earth-Air Heat Exchanger (EAHX) with the purpose to achieve a high efficiency and to improve their economical competitiveness. However, there is still a big deficiency in understanding and prediction of soil temperature in various depths on earth. In this paper, tank were proposed in the conventional model and has been investigated using the computational fluid dynamics (CFD) code FLUENT to provide basic knowledge of the Air flow behaviour and to gather the first experience in the application of CFD codes to heat transfer in Earth-Air Heat Exchanger (EAHX). .An Earth-Air Heat Exchanger (EAHX) is a simple subterranean cooling system that utilizes the stable soil temperature that is cooler than ambient temperature in summer. A single pass earth-tube heat exchanger (ETHE) was performed to study its performance in cooling. ETHE is made of 0.5 m long 10 cm diameter ms pipe at inlet and 3.5 m long outlet tank with both wall thickness of 3 mm. A 1 m2 area tank is buried at 3 m deep below surface. Ambient air is supply. Air at 11 m/s. Computational cooling tests was carried out using k-epsilon standard and RNG model. In this paper an earth-to air heat exchanger was considered based on summer cooling system. Numerical model shows ETHE was able to reduce the temperature of hot ambient air by as much as 9.8oC in May. This natural geothermal based system can decrease heating loads and significantly reduce the room air temperature during summer seasons.

Capozza et.al. [2014][1] Studied and proposed the ground source heat pump systems are worldwide used for space heating and cooling of buildings. The

Popovici et.al. [2016][5] examined and studied common types of geothermal heat exchange, the surface and the depth is characterized by demanding uneven ground. Uniformity thermal load of the massive and efficiency may be a solution in the sense of optimizing energy storage capacity and therefore reduced surface / volume of land used. A solution atypical geothermal heat exchanger, shallow, variable spatial geometry using cylindrical or tapered, which compared with geothermal drilling or pilots, presents significant recovery in terms of thermal capacity of the ground. For the spiral pipe conducted with constant diameter is maintained disadvantage loading / unloading uneven ground. The situation is radically altered when using the spiral geometry of tapered or cylindrical modular charge transfer areas to which it is directly proportional to the reduction in temperature of the work and its evolution, leads to a transfer of that charge / discharge uniformly. From a functional perspective and energy, this solution is obvious superior to any surface or deep usual, the heat transfer in the heat exchanger is variable. The novelty of the proposed solution is a favorable argument optimizing surface geothermal exchanger used in making reversible heating / cooling with solar energy.

Manjul1 et.al. [2016][11] studied as a growing interest in heating and cooling systems based on renewable energy. This is the property of earth ground the below about 2.5 to 3 m, the temperature of ground remains nearly constant throughout the year. This constant temperature is called undisturbed temperature of earth. However, a good visualize the undisturbed ground temperature, for a correct interpretation of the geothermal heat exchanger. The undisturbed temperature is very important yourself, which remains higher than the outside temperature in winter and lower than the outside temperature in summer. The EAHEs are considered as an effective passive heating/cooling medium for buildings. It is basically a series of metallic, plastic or concrete pipes buried underground at a particular depth through which the fresh atmospheric air flows and gets heated in winter and supplied to the building if at sufficiently high temperature and vice versa in summer. Until now, many researchers have conducted a series of studies in the development, modeling and testing of systems of the earth. This paper reviews on the experimental, analytical studies and earth air heat exchanger performance in summer cooling for various supply air.

Belatrache et.al. [2016][13] presented the modeling and simulation of an earth air heat exchanger (EAHE), employed as an air-conditioning device for buildings in the climate conditions of the south of Algeria. The earth tubes buried in the ground can offer considerable advantages in terms of energy savings. The appropriate depth of the buried tubes was calculated taking into account the physical properties of the soil in the region under study and using a specific program developed by the authors. A parametric analysis was carried out taking into account the length and the radius of the pipe and the velocity of the air in the pipe. The results of performance and overall energy savings are presented. The maximum daily cooling capacity of the EAHE studied was 1.755 kWh. Results showed that a simple EAHE system can provide 246.815 kWh in a period of one year

3. DESIGN & METHODOLOGY

3.1. Description of system

Advanced technology provides a number of options to the researchers to carry out study of complicated heat transfer, mass transfer and many other problems on software instead of creating the exact real model. Such ANSYS software tools have become popular to carry out complex flow analysis thoroughly. CFD employs discretizing whole system in smaller grids and applying governing equations like mass, momentum and energy on every grid, it provide solution of differential equations for every grid in flow domain.

Present system is designed in Unigraphics NX/ Autocad and meshed in meshing tool of ANSYS Workbench, complex heat transfer and air flow process is examined in Fluent. This study is conducted assuming homogenous soil conditions, incompressible flow and properties of pipe and ground material are independent of temperature.

Table 3.1: Parameters of earth tube heat exchanger used in our simulation (Belatrache et.al 2016)[13]

PARAMETERS	REFERENCE VALUE
Pipe length(L)	45 m
Inside diameter (Di)	80mm
Pipe thickness(e)	4mm
Air Velocity(V)	1m/s
Pipe depth	5m

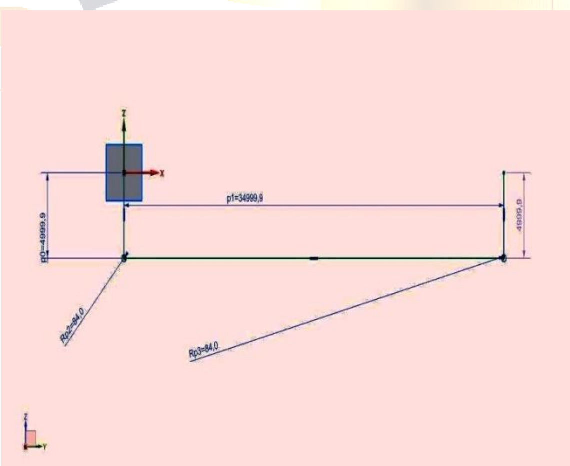

Figure 3.1: Figure drawn on Unigraphics NX for result analysis on ANSYS CFD workbench.

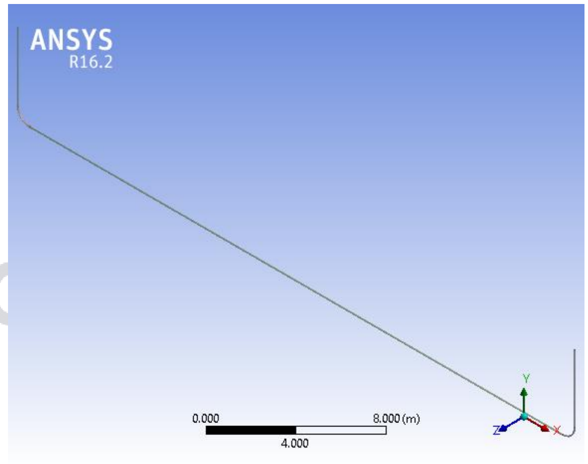

Figure 3.2: Figure on ANSYS CFD workbench (Design Modular)

3.2. Boundary conditions

- **Inlet:** At pipe inlet speed of air is given 1 m/s simultaneously, The inlet temperature for a days in June (2016) to May (2017) according the climate of Algeria.
- **Wall:** Temperature of the wall is taken similar to earth's undisturbed temperature.
- **Inlet and exit faces:** Inlet is taken at the inlet and software boundary conditions are filled, further minimum, maximum value are obtained through the software.
- **Soil-pipe interface:** Coupled condition for heat transfer with 1 m/s velocity is taken.

Measurement can be performed under quasi- steady conditions, and manual control were used to over ride the automatic control. It will be considered as a closed system. The constant basic soil temperature in summer season and winter season is (25.4 - 37)^{o} C throughout the year. The inlet temperature for a days in June (2016) to May (2017) according the climate of Algeria.

CFD Fluent analysis using ANSYS Software on ETHE system a day in every month from JUNE 2016 to May 2017 with velocity of 1 m/s. validated from Djamel Belatrache et.al. "Numerical analysis of earth air heat exchangers at operating conditions in arid climates" 2016.

Solution is completed in Fluent's pressure based velocity solver, applying realizable k-є model. Secondorder upwind scheme is used for spatial discretization of governing equations.

5. CONCLUSION AND DISCUSSION

Performance of EAHX model based on CFD modeling and simulation for summer climatic conditions is evaluated. The various authors carried out the experiment related to the earth air tube heat exchanger. According to the above authors, some conclusions are left by the researchers for the following scope:

- EAHE may prove positive improvement in the system.
- This system can be very much helpful in summer as outside temperature reach up to 40-45 °C, leaving very little room for consumption of thermal energy. The excess waste heat, thus easily dissipated with the help of geothermal principle.
- When velocity of air is 1m/s it gives maximum efficiency. As due to low velocity the travel time increases, so cooling or heating is done more efficiently.
- The temperature difference can be further increased by reducing velocity of air passed through the pipe so as to ensure contact between air and pipe for a longer period providing more time for heat transfer.
- At lower speed greater temperature difference can be obtained.
- Mass flow rate will be approximately similar in inlet and outlet.
- Using CFD it is easy to predetermine the performance of EAHE.
- This work can to be used as a design tool for the design of such systems depending upon the EAHE.
- Observations taken shows that during cooling mode ETHE system can provide the maximum temperature difference of about 15 °C.
- The increasing of pipe length, decreasing pipe diameter and decreasing mass flow rate of flowing air inside the buried pipe and earth below the depth up to 4 m then the performance of EATHE becomes better.
- EATHE can be used as replacement for the conventional air conditioning system. EATHE is the better result of summer.
- The design of earth air tube heat exchanger mainly depends on the heating / cooling load requirement of a building to be conditioned.
- After calculation of heating /cooling load, the design of the earth air tube heat exchanger only depends on the geometrical constraints and cost analysis. The pipe length, diameter of pipe and number of pipes are the main of parameters to be investigated.
- With an increase of pipe length then pressure drop and thermal performance increase.

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