A COMPREHENSIVE REVIEW ON EATHE

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ABSTRACT

Ground temperature below a certain depth of about 1.5 to 2 m remains relatively constant throughout the year. Therefore at a certain depth, the underground temperature is always higher than that of the outside air in winter season and is always lower in summer season. This temperature difference can be utilized as a preheating in winter season and pre-cooling in summer by operating an Earth Air Tunnel Heat Exchanger. In this paper, a thorough review of the available literature on Earth Air Tunnel Heat Exchanger (EATHE) system is presented. The review performed in a thematic way in order to allow a discussion and evaluation of the major findings obtained by researchers, especially on parameters affecting the performance of EATHE and types of studies used in the evaluation of thermal performance of EATHE system. The review covers a historic overview of EATHE technology, detailed description of performance of EATHE, application of EATHE system, CFD simulation of EATHE system. Moreover, thermodynamic assessment of EATHE systems and qualitative evaluation of thermal output offered by EATHE are analyzed in detail.

Keywords - *Computation fluid dynamics, Earth Air Tunnel Heat Exchanger, Passive cooling.*

I. INTRODUCTION

For the existence of our society, energy is important as we know, it is important and urgent to find alternative sources to replace non renewable or conventional fuel or reduce its widespread consumption and adverse impact on the environment. An efficient option does not indicate the alternative energy source, but is synonymous of clean energy. In present times, air conditioning is mostly employed for industrial productions and also for the comfort of occupants. It can be achieved by vapor compression machines, but due to ozone layer depletion and global warming by chlorofluorocarbons (CFCs) there is a need to reduce high grade energy consumption; many alternative techniques are currently explored [1, 2]. One such method is the earth–air tunnel heat exchanger systems. It uses underground soil as a heat source and providing space heating in winter season. Cold ambient outdoor air is sent into the earth-air tunnel heat exchangers. When air flows in the pipes of heat exchanger, heat is transferred from the earth to the air. As a result, temperature at the outlet air from the pipes is much higher than that of the ambient air. The outlet air from the earth–air–pipes can directly used for space heating. Alternatively, the outlet air can be heated further by integrated air conditioning machines. Similarly through the same process cooling can be achieved during summer season. Both of the above uses of earth–air–tunnel can helps to reduction in energy consumption.

The energy demand is increasing in cooling and space heating because of the growing real estate and high variation between peak seasonal temperatures. To meet such energy demand the passive heating and cooling system play an important role. Earth–air tunnel heat exchanger (EATHE) is one of the passive systems, which utilizes the earth temperature at a certain depth to and cool heat the buildings. The mathematical modeling, optimization, parametric/sensitivity analysis, integrated/coupled with, software used and economic viability are the methodology used in various researches.

This paper divides into several sections as follow. The first section includes the introduction part; Section 2 describe the history background of EAHE system, section 3 gives Performance analysis of EATHE system, Section 4 gives application of using EATHE in the world, section fifth describe the methodology conducted in the world, section sixth gives CFD simulation of EATHE, and the last section concludes.

II. HISTORY BACKGROUND OF EATHE

In EATHE, heat is exchange from undisturbed earth to the air flowing through a pipe. There are two general types of earth air heat exchangers: open and closed system. A simple open and closed-loop configuration of EATHE is shown in Figure 1, 2. The EATHE can be made of PVC pipe; mild steel pipe, Cement pipe and any other material of 0·15-m diameter minimum to avoid the friction losses. Length would be taken according to the designed or requirement for a particular building. When air flows through the pipe with the help of low-speed blower, heat will be exchanged between air and ground. The COP of such a system is greater than the conventional air conditioning system**.**

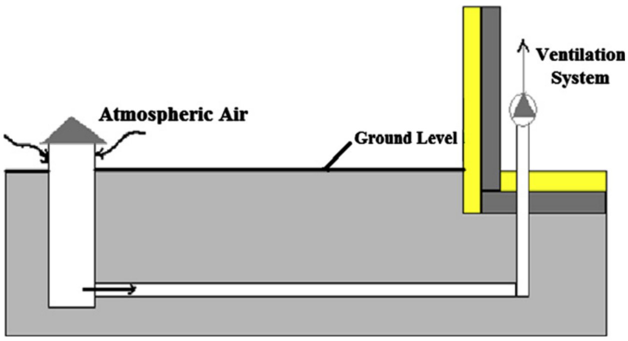


Fig. 1. Earth–air heat exchanger (open loop mode).

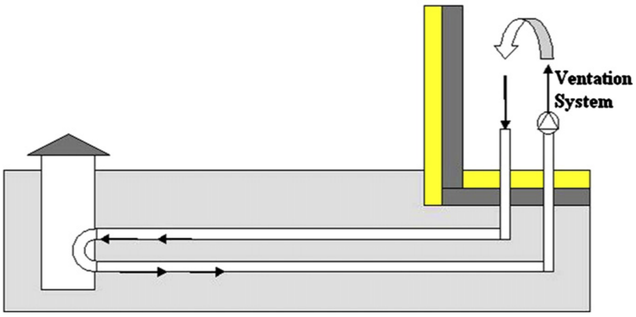


Fig. 2. Earth–air heat exchanger (closed loop mode).

An earth-air tunnel or ground-coupled heat exchanger is an underground heat exchanger that can capture heat from and/or dissipate heat to the ground. They use the earth's constant temperature at certain depth to warm or cool air for agricultural, residential or industrial uses. If air is blown from buildings through the heat exchanger for heat recovery ventilation, they are called earth–air heat exchangers (EAHE or EAHX) in North America or earth tubes (also known as earth warming tubes or earth cooling tubes) in Europe. Earth tubes are often an economical alternative, viable and conventional central heating or air conditioning systems since in EATHE system there are no chemicals or burners, compressors and only blowers are required to move the air. These are used for either partial or full cooling and/or heating of facility ventilation.

III. PERFORMANCE ANALYSIS OF EATHE

The achievement of indoor thermal comfort whilst minimizing energy consumption in buildings is a key aim in most countries and is a particular challenge in desert and cooler climates. The desert climate can be classified as hot and arid and such conditions exist in a number of areas throughout the world. One such area is Kuwait, Thar Desert in Asia, with an average ambient temperature of around 45℃ to 52℃ during summer months. In general, most people feel comfortable indoors when the temperature is between 22℃ and 27℃ and relative humidity is within the range of 40–60%. Such conditions are often achieved through the use of air-conditioning in desert climates; hence there is a significant use of energy in the domestic air conditioning sector. Methods of reducing this energy demand would thus have clear economic and environmental benefits. In Kuwait, domestic air-conditioning operates from the beginning of April to the end of October and buildings in this sector consume about 75–80% of the total electric power, mainly due to the impact of air-conditioning. Despite the fact that the Kuwait population decreases during the summer season, the average electricity peak load for the months May–September is 33% higher than the yearly average electricity peak load.

Similarly in winter season the temperature may fall below 5℃ in most of the north part of India and the rest part of Asia. For these reasons it would be beneficial to investigate earth–air heat exchangers as auxiliary cooling devices to get her with air-conditioning during summer season and auxiliary heating during winter season. Cooling/ heating the outdoor air through buried pipes by means of an earth–air heat exchanger (EAHE) has been known for many years to have potential for increasing a building's comfort whilst decreasing its energy demand.

There are many reported experimental and analytical studies on EAHE; the use of EAHE systems for buildings has been investigated in the case of desert climates like that of Kuwait, northwestern India. The EAHE (or earth cooling pipe) functions by transferring heat from the sub-soil environment to air flowing in a buried pipe. In summer this provides pre-cooling of the outdoor ventilation air, which serves to reduce the cooling load of the building. Several experimental and analytical studies on EAHE have been conducted.

Kuwait, northwestern part of India is typical of a dry desert climate with the highest air temperature being recorded in between April to June with an afternoon average maximum of 50 ℃. Summer starts at the beginning of April and Continues until the end of July, with a mean air temperature of 37 ℃. In addition, the air is generally dry with an average relative humidity ranging from 14–42% in the summer and 42–80% in the winter. In winter, the weather is comfortably cool, generally mild, with a monthly mean temperature of 10℃, and a minimum temperature recorded being occasionally below 5℃. Precipitation is low and dust storms are common.

3.1 Studies perform during both summer season and winter season –

Many researchers install EAHE and study the performance of EAHE in summer and winter and even both the season of Asia. Here some of the researchers who studied experimentally the performance of EAHE in both the season i.e. in summer and winter season of Asia. N. K. Bansal and M. S. Sodha et al.[3, 4] reports the results of experimental investigations on an existing large earth-air tunnel system in a hospital near Mathura, India. The experimentally measured quantities include the dry-bulb and wet-bulb air temperatures and surface temperature of the tunnel along its length in the direction of the air flow. The measured were carried out continuously for the entire summer and winter seasons of 1983. N. M. Thanu et al. [5] studied the performance of an earth-air-pipe system installed at Gurugram, India at a depth of 4 m and having a length of 76.5 m has been experimentally monitored during summer, winter and monsoon seasons. The coefficient of performance and the cooling and heating potential of the earth-air-pipe system have also been evaluated. Rakesh Kumar et al. [6] validated the proposed model with a wide range of experimental data taken from similar tunnel in Mathura, India. It consisting of transient axisymmetric EAT system is capable of predicting the humidity and ground temperature variation accurately. M. K. Ghosal et al. [7] investigate the heating and cooling potential of earth air heat exchanger buried under bare soil for real climatic conditions at IIT, Delhi. Calculations were done for typical winter and summer day in year 2002. Rakesh Kumar et al. [8] use the concept of artificial neural network and goal oriented design to propose a computer design tool that can help the designer to evaluate any aspect of earth-to-air heat exchanger and behavior of the final configuration, the system situated at Mathura, India. M. K. Ghosal et al. [9] investigate the heating and cooling potential of an earth air heat exchanger buried under the bare surface (outside the greenhouse) for the real climatic conditions at IIT, Delhi, India. Moreover, a parametric analysis has been performed to illustrate the overall system performance with an aim to study the improvement in the effectiveness of the earth air heat exchanger in the real site of application. A simplified analytical model has also been developed to simulate the system performance and has been validated with the measured data to determine its accuracy. Rakesh Kumar et al. [10] investigate the effects of various modifications to the basic genetic algorithm for the task of the EAHE optimization. The proposed algorithm is demonstrated by successfully generating sensitivity parameters for an actual heating and cooling potential of an EAHE at Mathura, India. Trilok Singh Bisoniya et al. [11] evaluate the annual thermal performance of EAHE system for hot and dry climatic conditions of Bhopal (Central India). A quasi-steady state, 3-D model based on computational fluid dynamics (CFD) was developed to evaluate the heating/cooling potential of EAHE system. The simulation results were validated against experimental observations taken on experimental set-up installed in Bhopal (Central India). The energy metrics namely energy payback time (EPBT) and seasonal energy efficiency ratio (SEER) for EAHE system were evaluated on the basis of energy analysis of simulation results. Dong Yang et al. [12] predict both the air temperature in the earth-air tube and the indoor air temperature of a building combined with an earth-air tube system. The model has been tested experimentally and the results are in close agreement. The climate parameters are similar to those of Chongqing, China (a city of hot summers and cold winters).

3.2 Studies perform during summer season only –

S. P. Singh et al. [13] developed a mathematical model to evaluate the performance of the earth-air tunnel used for space cooling at Indore, India. The two parameters which are sufficient to determine the cooling capacity of the system have been defined. F. Al-Ajmi et al. [14] developed a theoretical model of an earth air heat exchanger for predicting the outlet air temperature and cooling potential of these devices in a hot, arid climate of Kuwait. Huijun Wu et al. [15] developed a transient and implicit model based on numerical heat transfer and computational fluid dynamics to predict the thermal performance and cooling capacity of earth–air–pipe systems, the model developed is validated against experimental results obtained on an experimental set-up installed in Guangzhou, Southern China. Vikas Bansal et al. [2] developed a transient and implicit model based on computational fluid dynamics to predict the thermal performance and cooling 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). Vikas Bansal et al. [16] enhanced the performance of simple earth–air-tunnel heat exchanger (EATHE) by integrating an evaporative cooler at the outlet. Year round hourly analysis of the integrated system has been carried out for predominantly hot and dry climatic conditions using multiphase computational fluid dynamics (CFD) modeling with FLUENT software (version 6.3). The analysis has been carried out individually for all 8760 h of the year for the city of Ajmer (India), considering the temperature and humidity of ambient air as condition of inlet air. Results show that a simple EATHE system provides 4500 MJ of cooling effect during summer months, whereas 3109 MJ of additional cooling effect can be achieved by integrating evaporative cooler with the EATHE. Rohit Misra et al. [17] investigates the thermal performance of hybrid EATHE system in four different modes by integrating active and passive cooling systems, i.e. combination of window air conditioner and EATHE. An attempt has been made to explore the validity and effectiveness of the employed hybrid EATHE system, enabling its use for project developments about earth-air heat exchangers in the area with very hot weather temperature in summer like Ajmer (India).

3.3 Studies perform during winter season only –

Yuehong Bi et al. [18] in China present a theoretical model, and find a numerical solution of the underground temperature field of the vertical double spiral coil (VDSC) ground heat exchanger (GHX), and then verify the temperature distribution with experimental results. M. K. Ghosal et al. [19] developed a complete numerical model to predict and compare their thermal performance for choosing a suitable heating method in the composite climate of Delhi, India. Experiments were conducted extensively during winter period from November 2002 to March 2003, but the model was validated against the clear and sunny days. Vikas Bansal et al. [1] developed a transient and implicit model based on computational fluid dynamics 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). Sanjeev Jakhar et al. [20] carried out an experimental analysis to evaluate thermal performance of EATHE coupled with solar air heating duct meant for heating the air during winter season for an arid climate of Ajmer city, located in northwestern India. The performance of three different arrangements was compared. Experimental results showed that the heating capacity of the standalone EATHE system (Mode-II) improves when it is assisted by solar air heating duct (Mode-III, in which complete air from the EATHE is further heated by solar air heating duct and then supplied in the room).

IV. APPLICATION OF USING EATHE

EAHEs have been used for many years for both space pre heating and pre cooling; however, their efficiency is influenced by the variation in outside temperature. When heat is most needed, the outside air is cooler, thus often requiring backup electric resistance heating during the coldest days. Similarly, cooling is needed during the hottest days, requiring the equipment to work at low efficiencies. Overcome the problem of resource variations, as ground temperatures remain fairly constant throughout the year. Depending upon the soil type and moisture conditions, ground (and groundwater) temperatures experience little if any seasonal variations below about 10 m**.** The EAHE thus have several advantages such as they consume less energy to operate, it is expected that air pollution problems will be minimized by using EAHEs for passive cooling and heating purposes, in Mediterranean and tropical regions, they do not require supplemental heat during extreme low outside temperature, they do not use compressor, CFC, or any refrigerant, air uses as working fluid in EAHE, they have a simpler design and consequently less maintenance, they do not require the unit to be located where it is exposed to weathering and similarly EAHE has several application such as space heating/ cooling of resident building, provide thermal comfort and can be used in greenhouse or in agriculture purposes.

4.1 Space heating/ cooling –

Earth can be use as heat source and sink by the several researchers such as M. S. Sodha et al. [3]. They evaluated an earth air tunnel system for cooling/ heating of a hospital complex in India. N. K. Bansal et al. [4] developed an EAT system to help meet summer cooling requirements of the entire hospital complex, including the residential area. A.TROMBE present first experimental results of a study performed on buried pipes for individual house air cooling in summer. S. P. Singh et al. [13] developed a mathematical model to evaluate the performance of an earth air tunnel used for space cooling. D. Y. Goswami et al. [21] use the underground air tunnels for heating and cooling agriculture and residential buildings. F.Al-Ajmi et al. [14] developed a theoretical model of an earth-air heat exchanger for predicting the outlet air temperature and cooling potential of these devices in a hot, arid climate. Rakesh Kumar et al. [8] investigate the energy potential of the heating and cooling of EAHX system, firstly by using a numerical deterministic model and then by using a neural network model with inputs of various climatic parameters for the city of Mathura. Viorel Badescu et al. [22] investigate the heating and cooling potential of the system under real climate conditions. Huijun Wu et al. [15] developed a transient and implicit model based on numerical heat transfer and computational fluid dynamics to predict the thermal performance and cooling capacity of earth–air–pipe systems. Vikas Bansal et al. [1, 2] developed a transient and implicit model based on computational fluid dynamics to predict the thermal performance and heating/ cooling 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). Trilok Singh Bisonia et al. [23] developed an EAHE system which 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. A. A. Serageldin et al. [24] investigated the thermal performance of an Earth-Air Heat Exchanger (EAHE) used for heating and cooling purposes is under Egyptian weather conditions. The soil temperature profile and the temperature distribution of flowing air through horizontal Earth-Air Heat Exchanger (EAHE) is experimentally studied. Also, a mathematical model based on unsteady, one-dimensional and quasi-state is developed for energy conservation equation.

4.2 Thermal comfort -

EAHE integrated with building is economical as well as environment friendly option for achieving thermal comfort throughout the year. Sodha et al. [3] built a cooling system that included a large earth–air tunnel system to provide thermal comfort inside a building complex in two different regions in India. The two earth–air tunnel systems were shown to be an effective way to precondition ambient air during the summer. There are many factors that could be varied so as to increase the performance of the EAHE and improve the thermal comfort in the building. Some of these include the length of pipe, the number of pipes used, the diameter of the pipe, velocity of air in the pipe, ground moisture content and ground reflectivity. Al-Ajmi et al. [14] Whilst the indoor temperature cannot be maintained in the thermal comfort range by the use of the EAHE system alone, such a system could usefully enhance the cooling capacity of an air conditioning system, and thereby reduce energy consumption. The EAHE system alone cannot maintain indoor thermal comfort within the acceptable range (22–27℃), but it could be used to reduce energy demand in domestic buildings in Kuwait if used in conjunction with an air conditioning system.

An additional demand on EAHXs in office buildings is that an EAHX should meet the complete cooling energy demand for sufficient thermal comfort. SANTAMOURIS et al. [25] presented an integrated method to calculate the energy contribution of EAHXs to the cooling load of thermostatically controlled buildings. Bojic et al. [26] introduces an energy ratio to calculate, whether an EAHX provides more or less heat or cooling energy than it needs to reach a given comfort temperature inside the building. Besides the heat gain, the electricity demand should be taken into account. In providing thermal comfort, EATHE can be coupled or integrated with the some system called together as a hybrid system.

4.2.1 Hybrid system –

Vikas Bansal et al. [16] carried out an year round hourly performance analysis of integrated EATHE evaporative cooling system using multiphase CFD modeling for investigating performance enhancement over simple EATHE system. Rohit Misra et al. [17] made an attempt in his research to enhance the performance of active cooling system by coupling it with EATHE in four different hybrid modes and thermal performance of the developed hybrid cooling system has been investigated experimentally. Yuebin Yu et al. [27] presented an experimental study of a coupled geothermal cooling system. In this system, an earth-to-air tube is coupled with a solar collector enhanced solar chimney to achieve free space cooling in summer. Haorong Li et al. [28] investigates an innovative passive air conditioning system coupling earth-to-air heat exchangers (EAHEs) with solar collector enhanced solar chimneys. By simultaneously utilizing geothermal and solar energy, the system can achieve great energy savings within the building sector and reduce the peak electrical demand in the summer. R.Vidhi et al. [29] studied the supercritical Rankine cycle coupled with an earth-air-heat-exchanger for power generation from low temperature heat sources. Sanjeev Jakhar et al. [20] in his research present a thermal performance of earth air tunnel heat exchanger (EATHE) coupled with a solar air heating duct, which has been experimentally evaluated for arid climate of Ajmer city of northwestern India, during winter season. Maneesh Kaushal et al. [30] investigated the performance of a hybrid earth to air tunnel heat exchanger under five independent parameters viz., inlet air temperature (Ti), inlet air velocity (v), thermal conductivity of the soil (k), solar radiation intensity (I) and depth of solar air heater channel (d) and two output responses, viz., outlet to inlet air temperatures difference (To-Ti) for hybrid and earth to air tunnel heat exchanger. The thermal performance improvement in the earth to air tunnel heat exchanger can be achieved when operated with a conventional solar air heater. The conventional solar air heaters are easy to operate as well as cheaper in cost, hence more productive when operated with earth to air heat exchanger and they concluded that the hybrid earth to air tunnel heat exchanger can also be used in various thermal applications such as drying of agricultural products, space heating/cooling and industrial purposes.

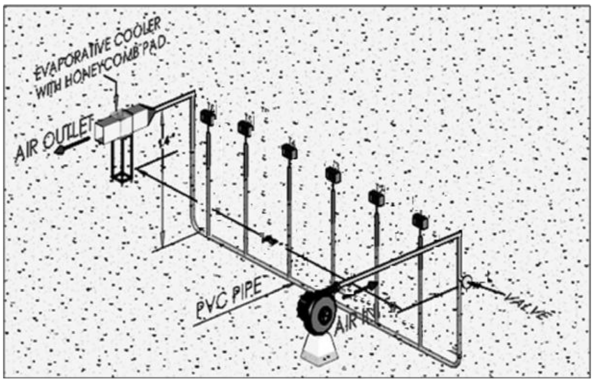


Fig. 1. Experimental set-up of integrated EATHE-evaporative cooling system.

4.2.2 Passive cooling –

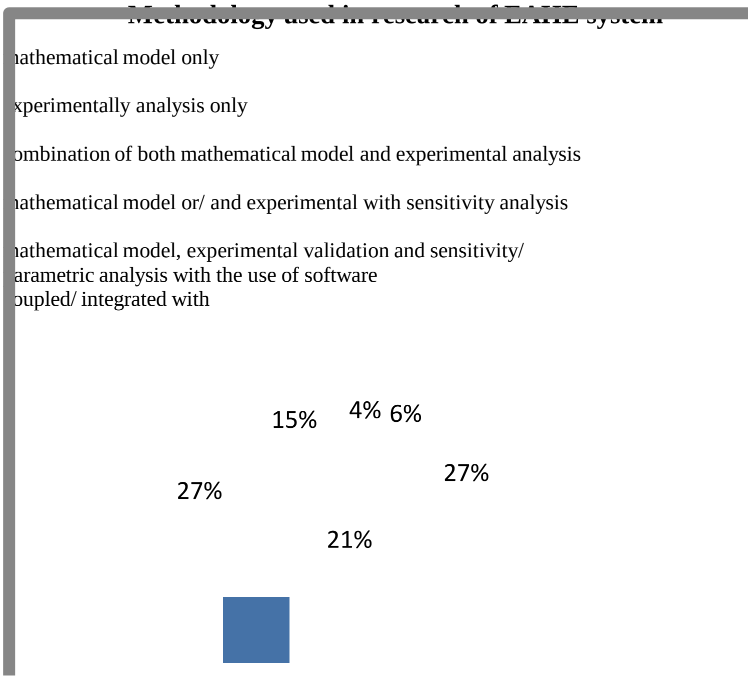
Rakesh Kumar et al. [6] developed a numerical model to predict energy conservation potential of earth-air heat exchanger system and passive thermal performance of building. M. Benhammou et al. [31] design a new passive cooling system which consists in an Earth-to-Air Heat Exchanger (EAHE) assisted by a wind tower. This system is intended for the summer cooling in hot and arid regions of Algeria.

4.3 Green house effect –

M. K. Ghosal et al. [7, 15, 19] developed a simplified analytical model to study the year round effectiveness of a recirculation type earth air heat exchanger coupled with a greenhouse located in IIT Delhi, India, the potential of using the stored thermal energy of ground for space heating and cooling has been investigated. Ashish Shukla et al. [32] developed a thermal model for heating of greenhouse by using different combinations of inner thermal curtain, an earth–air heat exchanger, and geothermal heating.

V. TYPES OF METHODOLOGY CONDUCTED IN THE WORLD –

Analysis of performance of EAHE and its studies were conducted on various way and its results were recorded for future work. In the last two decades, researchers work on the mathematical model, experimental studies, parametric/ sensitivity analysis. During last ten years most of the analysis were performed on computer software using TRNSYS, MATLAB, CFD, and ANSYS and also focused on economically analysis. In the resent five years research also conducted on coupled or integrated with EAHE to improve the performance of EAHE. In this section pie diagram shows the methodology conducted by researches. The below data were obtained by studied of 67 research papers.



5.1 Mathematical model only –

Singh et al [13] developed a mathematical model to evaluate the performance of an earth – air tunnel used for space cooling. The two parameters which are sufficient to determine the cooling capacity of the system have been defined. Numerical calculations have been made to obtain the optimum value of these paramerters for different environmental and thermal load conditions. M.Santamouris et al [25] developed a new integrated method to calculate the contribution of the earth to air heat exchangers to reduce the cooling load of the buildings. The method is based on the principle of balance point temperature. M. bojic et al [26] obtain the mathematical model of the air-to-earth heat exchanger (ATEHE), by divided the soil and pipes into elementary volumes, used steady-state energy equations, and applied a time-marching method and determined how the season, soil thermal conductivity and pipe spacing influence energy transfer from the soil to the ATEHE and also the steel-pipe contribution to this energy transfer.

5.2 Experimental analysis only –

A.Trombe et al [33] analysis first experimental results of a study performed on buried pipes for individual house air cooling in summer. N.M.Thanu et al [21] evaluated the performance of an earth-air pipe system installed at gurugram, India at a depth of 4m and having a length of 76.5m has been experimentally monitored during summer,winter and monsoon seasons. Giacomo Chiesa et al [34] shows the results of a 12-month-long monitoring of an earth-to-air exchanger systems made up of three fields of horizontal pipes located in central Italy (Imola's EAHX system). Data analyses on sensible heat exchange were carried out in order to evaluate the energy performance of the system and its efficiency. Aliyah Nur Zafirah Sanusi et al. [35] investigates the potential of applying the Earth Air Heat Exchanger (EAHE) cooling technology in buildings in Malaysia by measuring its soil temperature underground.

VI. CFD MODELING AND SIMULATION OF EATHE –

Computational Fluid Dynamics (CFD) technique solves mass, momentum, and energy conservation equations on every grid of a discretized simulation domain. The solution includes detailed information of the flow variables at the each grid. With the recent development in computer technologies, CFD is becoming a more convenient way to study convective heat transfer than traditional experimental methods for indoor airflow due to its flexibility of setting up boundary conditions and extracting results [36].

6.1 Steady/ Transient –

Transient performance of EATHE system in continuous operation Simulation was carried out initially to determine the temperature of air along the pipe of EATHE under steady state conditions i.e. keeping the soil surrounding the pipe of the EATHE at constant temperature of 300.2 K. Vikas Bansal et al. [37] devised a new term 'Derating Factor' for evaluating deterioration in thermal performance of Earth Air Tunnel Heat Exchanger (EATHE) under transient operating conditions in predominantly hot and dry climate of Ajmer (India) using experimental and computational fluid dynamics modeling with FLUENT software. Physical significance of derating factor is that it gives a broad comparison between thermal performance of EATHE operating under steady state and transient conditions. Thermal performance of EATHE operating under steady state and transient operating conditions have been compared in terms of derating factor. Vikas Bansal et al. [38] study the performance of EATHE is greatly affected in transient operating condition. Moreover a transient analysis has been carried out to investigate the effect of thermal conductivity of soil, duration of continuous operation, pipe diameter and flow velocity on the thermal performance of EATHE. operating under steady state condition is taken as reference case for comparing the thermal performance of EATHE in transient mode.

6.2 Types of model used –

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. EnergPlus 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 are 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 discretized 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 analyzed. Some of the commercial CFD codes in use are FLUENT, CFX, STAR CD, FIDAP, ADINA, CFD2000, PHOENICS and others.

VII. CONCLUSION –

The EATHE is a promising option from energy conservation point of view, and it extensively used for modern green building for space heating and cooling. The COP of such a system found higher than the conventional AC. The performance of EATHE highly depends on the depth of buried pipe, and it must be optimized. The length, diameter and air velocity are other parameters, which affect the performance of a system. At a depth of about 1.5 to 2 m the temperature of ground remains almost constant. This constant temperature is called earth's undisturbed temperature. The earth's undisturbed temperature remains always higher than that of ambient air temperature in winter and vice versa in summer. To utilize efficiently the heat capacity of earth EAHE system is to be designed. The outlet of EAHEs can be connected to conventional air-conditioning unit, if cooling or heating achieved is not sufficient. The use of green and clean energy in order to minimize CFC emissions and to minimize conventional energy consumption is in prime focus everywhere. The EAHE systems can play a vital role in minimizing energy consumption by preheating air for heating of different types of buildings in winter and vice versa in summer.

Now as we already discussed as most of the work was carried out to evaluate the performance of the EATHE in steady state condition. And some of the researchers discussed the deterioration under transient condition in thermal performance of EATHE, but no researcher drawn attention toward the effect of moisture content present in the soil which helps in the better heat transfer. As the performance of EATHE deteriorate due to the continuous operation of the system. The moisture content in the soil is decreased as the hot air exchanges its heat with earth temperature when it comes in contact with underground buried pipes. Analysis of this moisture content in soil helps us to identify better performance of EATHE. Some of the researchers also studies about role of soil thermal conductivity in the evaluation of performance of EATHE. The higher soil thermal conductivity results into better thermal performance of EATHE system even longer period of operation. A lot of work is required to do in the direction of continuous operation of EATHE under transient condition and how it can be maintain good heat transfer under longer use of earth air heat exchanger.

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