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HEATING CAPACITY AND COEFFICIENT OF PERFORMANCE ANALYSIS OF THE EATHE

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ABSTRACT

Today one of the challenges that human being has to overcome is to reducing environmental emissions. It can only be achieved by a proper management and energetic efficiency of the processes that exist nowadays. Several academic works have done which increases the efficiency of the system, further it not only increases the sustainability but also decreases the environmental impact. One of the processes that require more attention is the heating and cooling of buildings because major part of the electric bill is contributes by this process. In this modernization and on the demand of energy saving a new alternatives earth-air tunnel heat exchanger system has been used by few countries. In which an ambient air is passed through pipes which is buried under 2 to 3 meters below the earth. After passing from pipe air gets cooled during summer and heat up during winter because of temperature difference between ambient air temperature and the ground temperature and this air can be subsequently injected into the buildings in both season. To predict the thermal performance and cooling and heating capacity of earth–air tunnel heat exchanger systems a transient and implicit model based on computational fluid dynamics was developed inside the FLUENT *simulation program and validated against experimental investigations on experimental set up in Ajmer (Rajasthan, India). Good agreement is obtained between experimental data and simulated results. In this paper the heating capacity and* COP *of the* EATHE *system is discussed. This* COP *may depend on the velocity of air through pipe and material of the buried pipes and further increases more when coupled with solar heating duct.*

Keywords –Earth Air Tunnel Heat Exchanger, Solar Air Heating Duct, **FLUENT**

I INTRODUCTION

Climate change is one of the biggest issues in front of the today's society. This climate change not only affects the diversity but also affect the temperature of the earth. Temperature fluctuation is commonly seen by last few decades. This temperature fluctuation made human life uncomfortable. Further to make human comfortable by using machinery and equipment we neglected the impact on environment by using this. As these systems also increases the electrical energy and depleted the fossils fuel which is used to produce this energy. In most of the region of earth cooling and heating are essential. Some countries uses air conditioning in building to reach their desire goal, but because of expensive technology most of them are not used this equipment. Now today, to reach the goal of air conditioning for heating or cooling buildings new alternatives has been used and one of the best is the use of earth-air tunnel heat exchanger system, which uses earth as a sink or source of energy [1, 2]. Earth-air-tunnel heat exchanger (EATHE) system is one of the passive heating and cooling system, which provide both heating during winter season and cooling during summer season. As earth or ground is one of the best heat exchangers, at a sufficient depth, the ground temperature is always lower in summer and higher than that of the outside air in winter or we can say that at a depth of 2 to 3 meters the temperature of earth always remains constant throughout the year and this constant temperature can be used during both the seasons [3].

Vikas Bansal et al. [5] 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. [6] 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. [8] 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. [9] 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. [10] 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. [11] 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.

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II DESCRIPTION OF EATHE

The Earth-Air Tunnel Heat Exchanger (EAHE) is a passive heating and cooling device or simply called as underground heat exchanger, which is made by one or more buried pipes in series or in parallel under the ground at a depth of 2 to 3m from the ground surface [4]. As it is researched by the researchers that at a certain depth the average temperature of earth remains constant throughout the year means during hot summer day and cold winter season the surface temperature of earth goes high and low respectively but at a certain depth it remain constant in both the seasons. Commonly, EATHE are used to provide thermal comfort in building environment by directly reduce the electric energy consumption. As much more electric energy is used by using air conditioning system. The EATHE is very simple and efficient system which works on the principle of transfer heat from ambient air to the soil which surrounds the buried pipes. During winter seasons the cold ambient air is inserted with the help of blower. When it passes from the buried pipe it gets heat up as the temperature of pipe surface is higher than outside temperature and we get hot air at exit. Similarly during the summer season, the hot ambient air is sent from inlet and passes from the buried pipe and gets cooled while passes as it gives its heat to surrounding soil near pipe surface and we get cooled air from exit as shown in Fig.1 . This makes the building area comfort in both the season. This technique is used by many western countries even in north western area of Rajasthan, India.

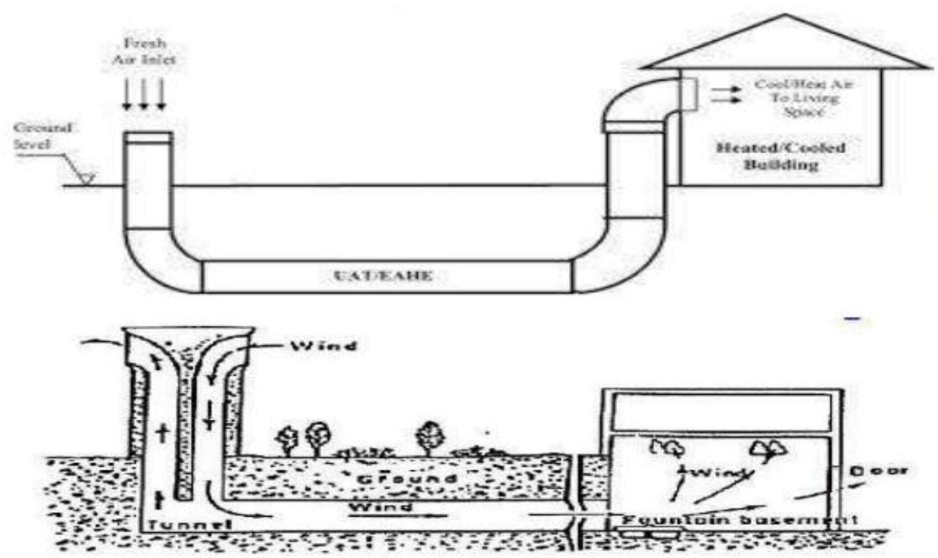

Fig. 1. Earth-Air Tunnel Heat Exchanger

Many researchers work on the design parameters, thermal performance, parametric analysis of EATHE and many more. Change of climate from last few decades affects the thermal performance of EATHE. During the summer season western part of India touches the temperature at 48℃ and sometimes even goes higher. Similarly during winter season same part reaches at a low temperature. Because of tremendous increasing or decreasing this seasonal temperature affect the performance of Earth-Air Tunnel Heat Exchanger. To overcome this problem only some

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researchers works on increasing the thermal performance of Earth-Air Tunnel Heat Exchanger by parametric analysis and some by using coupled system [5, 6, 7, 8]. This paper focused the thermal performance of Earth-Air Tunnel Heat Exchanger during winter season.

IV EATHE COUPLED WITH SOLAR AIR HEATING DUCT SYSTEM

The test facility having EATHE coupled with a solar heating duct system is located in the city of Ajmer, Rajasthan (India) [7, 12]. The climate of this regions are hot semi-arid having mean maximum and absolute maximum ambient air temperatures during summer season (April to June) as 47℃ and 39℃ respectively with average ambient air temperature during summer season from 30 to 32℃. And During winters season (November to February), the climate remains mild and average ambient temperature is in between 15 and 18 ◦C. During winter season, the mean minimum and absolute minimum temperatures of ambient air are close 9℃ to 4℃ respectively. Further, the annual average ambient temperature of this region is 26.7℃. Fig. 2 . Shows up of EATHE which is coupled with a solar heating duct finally connected to test room. This experimental set up consists of 60 m long horizontal PVC pipe having 0.10 m diameter. This PVC pipe is buried in dry soil at a depth of 3.7 m. The inlet of this PVC pipe is attached with vertical pipe having ends connected with single phase, 0.75 kW, variable speed motorizes blower (maximum speed – 2800 rpm and maximum flow rate – 0.0945 m^3/s).

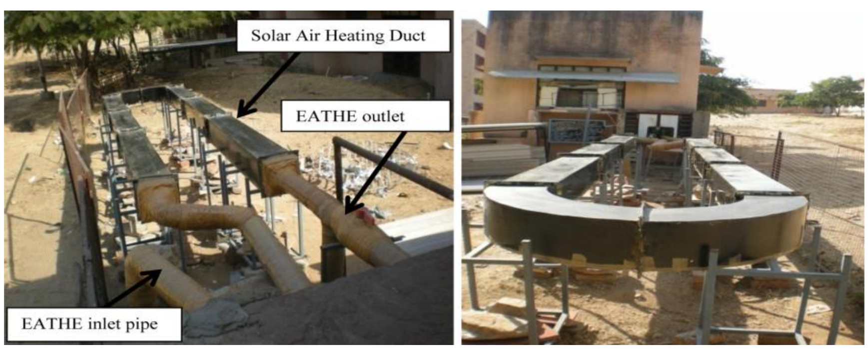

Fig.2. EATHE coupled with solar heating duct

Now, solar heating duct which is in U–shaped made of galvanized iron and having 12.2 m long and 0.0645 m^2 cross-section area. This solar heating duct receives solar energy from its lateral wall have surface area 2.6 m^2 and top area 3 m^2. With the help of T-socket inlet duct is connected to outlet pipe of EATHE. And outlet was connected to some suitable position at the exit of EATHE as shown in Fig. 3. The exterior surface of the duct was painted with black color so that maximum solar radiation is absorbed. To regulate the flow of air a dampers is provided at both the ends of solar heating duct as well as to the exit of EATHE pipe.

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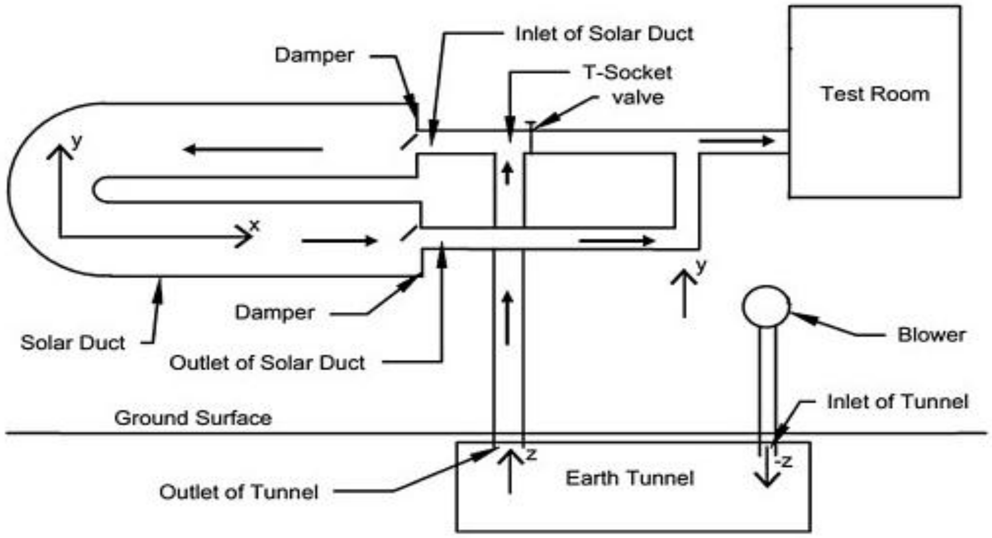

Fig.3. Schematic diagram of the experimental setup

This experimental test use solar heating duct which is coupled with EATHE system. Now EATHE and solar heating duct was investigated experimentally by three different arrangements or modes.

The three modes are described as:

(i) Mode-I –without functioning of EATHE and solar heating duct. Only room temperature was monitored. This mode is a base case and was used as comparison of thermal performance of both other 2 mode.

(ii) Mode-II – solar heating duct was not functioning and exit air is from EATHE was directly supplied to the test room.

(iii) Mode-III –exit air from EATHE is further heated in solar heating duct and then supplied to test room.

V. PERFORMANCE AND RESULT

Solar heating duct coupled with EATHE system and its performance is evaluated on three winter days of 2013 (14-16 January). Results also show that temperature of 27.4℃ was found at a depth of 3.7 m, almost 11℃ higher than ground surface temperature. From experimental analysis it is found that temperature of in the room was in between 17.7-21.1℃, 17.5-22.3℃ and 17.6-24.1℃ respectively during Mode-I, Mode-II and Mode-III. It can be therefore say by using solar heating duct which is coupled with EATHE resulted in 1.1-3.5℃ higher temperature than noted in Mode-I (base Mode).

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Table 1. Thermal performance of different Modes on three consecutive days

Time	Room air Temperature		
	Mode-I (14 January)	Mode-II (15 January)	Mode-III (16 January)
9:00 am	14.6	16	16.2
10:00 am	16.3	17.6	17
11:00 am	19.1	19.5	18.9
12:00 pm	20	21.1	20.3
1:00 pm	21	22.2	21.7
2:00 pm	21.7	22.8	22.2
3:00 pm	22.3	23.4	22.4
4:00 pm	21.7	22.7	22
5:00 pm	20.8	21.5	21.3
Temperature difference	3.4	4.8	6.5

From the table it is clear that EATHE coupling with solar heating duct increases the temperature of air by almost 6.5°C. Therefore Mode-III increases the heating potential of EATHE system significantly. Similar results were obtained on different dates during winter season.

The heating capacity (kWh) of the EATHE and solar air heating duct is also calculated by using equation

$$Q_h = \dot{m}\, Ca\, \Delta T \qquad \text{……………(1)}$$

Where, $\dot{m}$ is the mass flow rate of air (kg/s), Ca is specific heat of air (kJ/kg K) and ΔT is temperature difference between ambient air temperature (inlet of EATHE) and outlet temperature of EATHE (in case of Mode-II), while it is the difference of temperature between duct inlet temperature and outlet temperature in room (in case of Mode-III). The coefficient of performance (COP) can be calculated as the heating capacity of EATHE (Mode II) or overall heating capacity of the system (Mode III) is divided by the blower energy consumption of the system as shown in Table 4.

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Table 2. Heating capacity and COP of EATHE and Solar air heating duct.

Experimental Date	Heating capacity of EATHE (kWh) (a)	Heating capacity of solar air heating duct (kWh) (b)	Total heating capacity of system (kWh) c = (a+b)	COP of system
14 Jan	-	-	-	-
15 Jan	665.529	-	665.529	1.540
16 Jan	758.396	1217.625	1976.02	4.570

From experimental test result this proves that the solar heating duct increased the heating capacity and the COP of the system for equal power consumption.

VI CONCLUSION

A test room prepared where the performance of EATHE evaluated and this system is coupled with solar heating duct to absorb more solar radiations during the winter season of Ajmer, Rajasthan, India. Climate of this region is arid, located in northwestern India. This experimental work was done on three different Modes of operations and their results were observed. Without the operation of EATHE and solar heating duct the Mode of operation is considered as a Mode –I (base Mode). With the use of EATHE alone is considered as Mode-II. And the operation is carried out when the EATHE is coupled with solar heating duct consider as Mode- III. While working with all three different Modes of operation it can be observed that heating capacity improves during working of Mode-III. And heating capacity of EATHE system got increased by 1217.625 to 1280.753 kWh while working on Mode-III. Temperature of the test room is increased by 1.1 to 3.5℃which is higher than the Mode-I (base Mode). Further experimental results confirmed that the coefficient of performance of the EATHE when coupled with solar heating duct during winter increases up to 4.57 for the same power consumption.

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