Cooling Potential Evaluation of Single & Integrated Underground Heat Exchanger at Hot & Dry Climate of Bikaner Rajasthan India : An Experimental Approach

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Abstract

The use of earth as a heat source or as a heat sink with the buried pipes can serve as a direct heat exchanger that is called earth air tunnel heat exchanger or geo-thermal heat exchanger or underground heat exchanger. In this research paper, cooling potential of single and integrated underground heat exchanger has been experimentally evaluated for hot and dry climate of Bikaner city of northwestern India, during summer season. Experimental analysis has been done at three different inlet air velocities (10 m/s, 12 m/s & 14 m/s) for obtaining optimum results to enhance the cooling capacity of single EATHE system by coupling it with water cooled heat exchanger at the outlet end. Utilization of waste water of water cooler was carried out in the water cooled heat exchanger. Results shows that the air which comes out from integrated underground heat exchanger is relatively cold than the air supplied by the single underground heat exchanger system. It was found that the average outlet air temperature got increased from 31.63 ˚C to 36.50 ˚C with respect to inlet air velocity 10 m/s to 14 m/s respectively for single underground heat exchanger whereas the average outlet air temperature got increased from 27.09 ˚C to 32.67 ˚C with respect to inlet air velocity 10 m/s to 14 m/s respectively for integrated underground heat exchanger. Therefore, the cooling capacity of EATHE can significantly increased by coupling it with water cooled heat exchanger.

Keywords *: Earth air tunnel heat exchanger, Water cooled heat exchanger, Cooling capacity, Inlet air velocity, Outlet air temperature, Experimental analysis, Summer season.*

I. INTRODUCTION

During the decades, the global energy consumption for winter heating and summer cooling of buildings has significantly increased. So the energy saving is much important factor for the entire world. Costly and power consumable air-conditioning system are used for maintaining surrounding air temperature comfortable to human body which works on VCRC in which harmful CFCs are used as refrigerant. Since CFCs have bad impact on environment of earth i.e. causes global warming and ozone layer depletion. Therefore there are two important factors: power consumption & environment pollution. These two factors can be eliminated by using other passive techniques such as EATHE. Most of people feels comfort zone when the surroundings air temperature is kept in the range of 22˚C to 28˚C and the relative humidity of ambient air is kept in the range of 45 to 55%. This is achieved by using EATHE also. Since the earth ground temperature remains almost constant throughout the year beyond 3 m depth [1]. Therefore earth uses as a heat source in winter season and as a heat sink in summer season with the buried pipes. This concept uses in the mechanism of earth air tunnel heat exchanger in which ambient air forced through the buried pipes with the help of air blower and due to temperature difference between earth soil and ambient air, heat transfer takes place in between earth soil and ambient air. Thus EATHE is provided better cooling and heating in summer season and winter season respectively for buildings.

II. LITERATURE REVIEW

Various research were carried out on the earth air tunnel heat exchanger experimentally as well as numerically for example:

Mathur et al. (2017) performed a comparatively study of straight and spiral earth air tunnel heat exchanger in cooling and heating modes at MNIT Jaipur. The total length of buried tubes was taken as 60 m. Inner diameter and thickness of pipe were taken as 0.10 m and 0.003 m respectively. The material of pipe was taken as HDPE i.e. High Density Poly Ethylene. They concluded that the spiral system of EATHE covers less space as compare to straight system of EATHE. Also the spiral EATHE system is more effective as compare to straight EATHE system [2]. Sanjeev Jakhar et al. (2014) investigated thermal performance of earth air tunnel heat exchanger coupled with solar air heating duct experimentally for arid climate of Ajmer city. They concludes that the EATHE coupled with solar air heating duct is much effective as compare to single unit of EATHE. The pipe material was taken as PVC i.e. Poly Vinyl Chloride. Length of tubes was taken as 60 m. Inner diameter and thickness of earth tube were taken as 0.010 m and 0.003 m respectively [3]. Mihalakakou et al. (1995) developed a parametric model in which varying parameters were pipe length, pipe radius, velocity of the air inside the tube and depth of the buried pipe below earth surface [4]. Santamouris et al. (1997) investigated the impact of different ground surface boundary conditions on the efficiency of a single and a multiple parallel earth-to-air heat exchanger system [5]. Kumar et al. (2003) evaluated the conservation potential of an earth-air-pipe system coupled with a building without air-conditioning [6]. Bansal et al. (2009) investigated numerically the thermal performance of PVC buried EATHE for winter heating purpose and coupled to a room with 100% fresh air. They found that the pipe material has no significant impact on air temperature at outlet [7]. Rohit Misra et al. (2012) did CFD analysis based parametric study for evaluating new concept 'derating factor' for the thermal performance of earth air tunnel heat exchanger [8]. S. Barkat et al. (2016) developed gas turbine power output using earth air tunnel heat exchanger cooling system at Esypt [9]. Bansal et al. (2012) studied transient effect of soil thermal conductivity and duration of operation on performance of earth air tunnel heat exchanger at Govt. Engineering College Ajmer [10]. Rahul Khatr et al. (2016) developed a CFD model for identification of ideal temperature distribution using different location for air conditioning in a room integrated with earth air tunnel heat exchanger [11]. O.P. Jakhar and Rajendra Kukana (2014) did transient thermal analysis of earth air tunnel heat exchanger using CFD approach for summer season. They concluded that the cooling effect is more for sandy soil as compare to sandy loamy soil [12].

In this research work, to enhance the cooling capacity of standalone EATHE system: a water cooled heat exchanger is coupled with the single unit of earth air tunnel heat exchanger at outlet end. Waste water of water cooler was utilized for the cooling purpose inside the water cooled heat exchanger. An experimental analysis was carried out at three different inlet air velocities (10 m/s, 12 m/s & 14 m/s). Operation was done for 9 h daily in the summer season at hot and dry climate of Bikaner city.

III. EXPERIMENTAL METHODOLOGY

A. Description of Experimental Setup

Single and integrated earth air tunnel heat exchanger systems have been installed at the Mechanical Engineering Department , Government Engineering College Bikaner (28.0229˚N, 73.3119˚E) Rajasthan India (334004). Since earth ground temperature beyond 3 m depth remains constant throughout the year [1]. Therefore the experimental setup of earth air tunnel heat exchanger was installed at a depth of 3 m. The total length of earth air tunnel heat exchanger was taken as 13.92 m whereas the length of water cooled heat exchanger was taken as 1.83 m. The inner diameter and thickness of earth air tunnel heat exchanger were taken as 0.04 m and 0.003 m respectively. The inner diameter and thickness of water cooled heat exchanger were taken as 0.108 m and 0.0025 m respectively. Pipe material for the both heat exchanger was taken as MS i.e. Mild Steel due to lower cost and good strength.

TABLE 3.1 SUMMARY OF EXPERIMENTAL SETUP

Parameter	EATHE	WCHE
Length (L)	13.92 m	1.83 m
Inner Diameter (D_i)	40 mm	108 mm
Outer Diameter (D_o)	46 mm	113 mm
Thickness (t)	3 mm	2.5 mm
Material	Mild Steel	Mild Steel

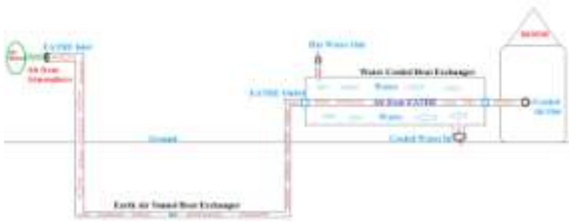

Fig. 3.1 Block Diagram of Integrated EATHE

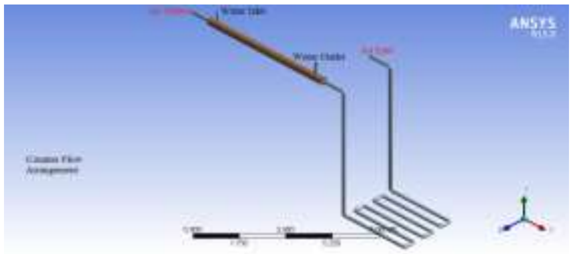

Fig. 3.2 3-D View of Integrated EATHE

Fig. 3.3 Existing System of Integrated EATHE

B. Instruments used for Experimental Analysis

Instrument Name	Function
Digital K-Type Thermocouples & Thermometer	Air Inlet & Outlet Temperature Measurement
Digital Vane Type Anemometer	Air Velocity Measurement
Cheston Variable Speed Air Blower	Air Circulation

C. Experimental Methodology

For Cooling Potential Evaluation, Experimental Analysis was carried in the month of July and August from 9 A.M. to 1 P.M. i.e. I-Session and from 3 P.M. to 6 P.M. i.e. II-Session. Readings were taken every after one hour interval of time. Thus the readings were taken at time 9 A.M., 10 A.M., 11 A.M., 12 P.M. & 1 P.M. and 3 P.M., 4 P.M., 5 P.M. & 6 P.M. The system was kept shutdown from 6 P.M. to 9 A.M. (15 Hours) for soil regeneration.

D. Calculation of Experimental Results

Using experimental results, the Air Temperature Difference (ΔT) for the both systems was calculated. Also the Average Air Temperature Difference ($\Delta T_{avg.}$) for the both systems was to be computed.

Air Temperature Difference (ΔT) is given by following equation:

$$\Delta T = T_1 - T_2 \qquad (1)$$

Where T_1 and T_2 are the Inlet Air Temperature and Outlet Air Temperature respectively.

Average Air Temperature Difference ($\Delta T_{avg.}$) is computed by the following equation:

$$\Delta T_{avg.} = \frac{\sum_1^{72} \Delta T}{72} \qquad (2)$$

Average Inlet Air Temperature and Average Outlet Air Temperature are also computed by using following equations:

$$T_{1avg.} = \frac{\sum_1^{72} T_1}{72} \qquad (3)$$

$$T_{2avg.} = \frac{\sum_1^{72} T_2}{72} \qquad (4)$$

IV. RESULTS

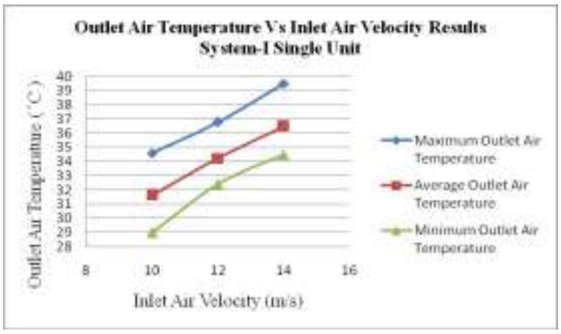

Fig. 4.1 Outlet Air Temperature Vs Inlet Air Velocity System-I

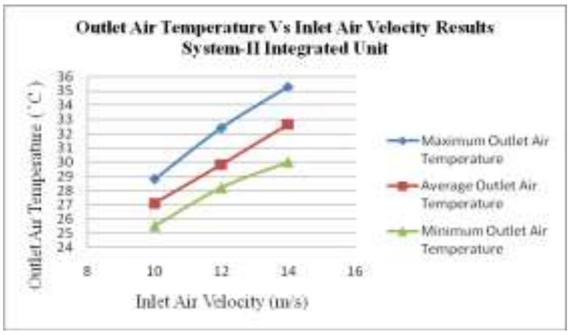

Fig. 4.2 Outlet Air Temperature Vs Inlet Air Velocity System-II

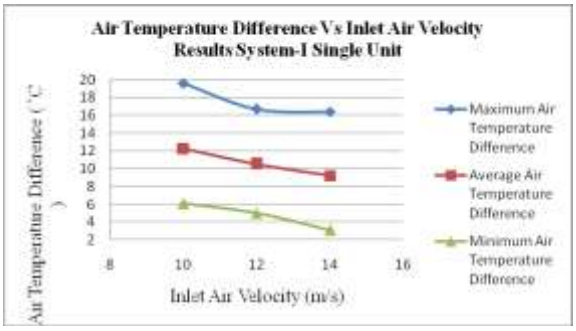

Fig. 4.3 Air Temperature Difference Vs Inlet Air Velocity System-I

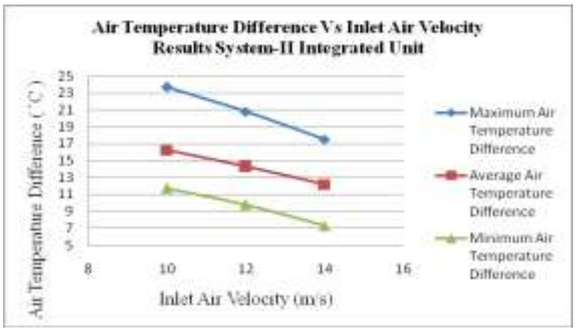

Fig. 4.4 Air Temperature Difference Vs Inlet Air Velocity System-II

V. CONCLUSIONS

Based upon experimental results it is found that the integrated unit is more effective than the single unit of earth air tunnel heat exchanger. The best optimum results were found at inlet air velocity of 10 m/s as compare to 12 m/s and 14 m/s. We found that the as inlet velocity of air increases than outlet temperature of air is also increased because of air takes less time for heat transfer at higher velocity. We use the design of earth air tunnel heat exchanger in series connection that covers less space in the ground as compare to simple design of earth air tunnel heat exchanger. Thus the space limitation problem associated with earth air tunnel heat exchanger were also analyzed carefully in this paper.

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