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Design Parameters of Earth Air Heat Exchanger for Effective Performance

Kommineni Venkateshwara Rao[1], Vishvendra Nath Bartaria[2], Prashant Bhave[3]
1. Research scholar, LNCT University, Bhopal,M.P.,India
2. Professor, LNCT University, Bhopal,M.P.,India
3. Associate Professor, Civil & Environmental Engg, VJTI, Mumbai

Abstract
Modern buildings require great amount of energy for making the indoor environment suitable for the comfort requirements of the occupants. An artificial or human made environment is created by bringing the indoor air with desired quality with heating and cooling of air. This requires the refrigeration, air-filtration and means of air distribution in the room and a large amount of conventional energy to be spent. One of the efficient techniques to reduce the heating and cooling energy requirements is usage of Earth air heat exchanger (EAHE) system. The earth can be used to pre heat or cool the air before supplying to the building. Since few years, this method is gaining importance as the conventional methods are of major energy requirements for their operation and are not very much environmental friendly. In this paper, the authors have presented the design parameters of the EAHE and their application in the passive ventilation in room. The performance of EAHE system is mainly influenced by the design parameters such as, tube material, size of the tube, air velocity, buried tube depth, air temperature, type of soil and soil temperatures. The design of an efficient EAHE system needs estimation of the design parameters carefully and accurately. In the last two decades, intensively research work has been done on the design parameters affecting the performance of the EAHE system. Mathematical and numerical studies suggest that earth air heat exchangers are effective in heating and cooling. Still the sufficient information is not available which may be used for the effective design of passive ventilation system with the use of EAHE due to lack of full scale experimental studies and relevant design data.

Keywords: Natural ventilation, Earth air heat exchanger, thermal environment, numerical analysis.

1. Introduction

Modern buildings require great amount of energy for making the indoor environment to fulfill comfort conditions of the occupants. With the growth of the industry and commerce, the societies

are also growing in the world with modern requirements of comfort conditions. Building occupants are being utilizing a great amount of energy in making the indoor environment suitable to fulfill their comfort requirements. An artificial or human made environment is created by bringing the indoor air with desired quality. Indoor air quality requires the refrigeration, air-filtration and means of air distribution.

The energy requirements in buildings for comfort conditions are basically fulfilled by the electricity. As per the current status about 15% of the world population is still in need of electricity for their use. Need of electricity in India is still not being fulfilled to about 23% population because of the either not availability or poor or unreliable access to their remote places. Many non accessibility areas of electricity fall in rural locations which are not being connected or electrified. With the great enhancement of electricity generation, still many are far away from its usage due to practical or feasible reasons of being connected with the electrification. In absence of the availability of cabled electricity, diesel generating sets are used for the residential and commercial purposes. The diesel being used for this purpose imposes great environmental impacts by generating Green house gases (GHG) and global warming effects. It is needed to reduce the usage of energy from non-renewable resources for the sustainable society (Perez-Lombard, Ortiz) [1],(Yu et al. 2010) [2].

The energy consumptions in the urban regions are more and increasing rapidly as the environmental temperatures are also high there as compared to the rural areas. [3], [4]. The rising causes of global warming, climate change and changing weather conditions are concerning for the sustainability of the humans and the ecosystem [5]. Increasing economic activities and the artificially creating indoor environment makes more use of energy and thus causing the climate change [6].

Room air needs to be cleaned and its temperature is needed to be controlled for the human comfort conditions. Renewable energy sources such as solar, wind etc. are great source of energy[7] and are being used for the ventilations of the buildings from the ancient times [8]. Research on the utilization of renewable sources of energy in heating, cooling and ventilation has many aspects such as system design, system optimization and finding other methods and techniques where the conventional energy usage can be reduced. Earth at a certain depth has almost constant temperature which remains higher in winter than the atmospheric temperature and lower in summer than the atmospheric temperature which may be used for the heating of air

in winters and cooling of air in summers (Bartaria et. al., 2015)[9]. Earth air heat exchanger technique has also many great aspects of research for its effective and economic use. Till date its system utilization is in need of design and performance data.

2. Earth Air Heat Exchanger

The energy usage from the renewable sources can be reduced through numerous alternative methods in buildings for achieving comfort conditions. One of the efficient techniques to reduce the heating and cooling energy requirements is usage of Earth air heat exchanger. The earth can be used to pre heat or cool the air before supplying to the building. The earth at a depth of 2 to 3 meters has almost constant temperature throughout the year (Bartaria et. al., 2016)[10]. This is known as undisturbed temperature of the earth and it remains higher than the outside air temperature in winters and lower than the outside air temperature in summers. So, the temperature difference may be used to heating of outside air in winter and cooling of air in summers.

2.1Types of earth air heat exchanger

The EAHE systems are commonly classified as an open loop or closed loop EAHE system. In open loop EAHE system, outside air is drawn from the cooling tubes buried into the ground as shown in figure 1. The tubes are typically 30 m long straight pipes. An open loop system provides fresh outside filtered air and it can be made almost as effective as a closed loop system (upto 80-90%) for providing cooler or hotter air into the room. Thos passive method of ventilation improves indoor air quality (IAQ) in the room. In a closed loop EAHE system air from inside the home is supplied in a loop typically 30 to 150 m of tubes buried into the ground.where it will exchange heat from the ground and returns again into the room. The closed loop system is more effective than the open loop system as the room air is circulated again and again into the exchanger for cooling and heating from the ground as shown in figure 2. The air will require to be filtered before again circulating into the room for freshness and removal of the room air impurities [10].

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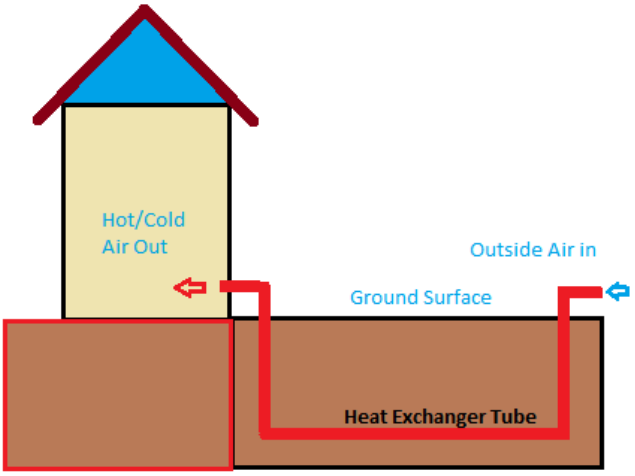

Figure 1: Open Loop EAHE System

2.2 Working principle of Earth air heat exchanger

The working principle of earth air heat exchanger (EAHE) is based on the heat transfer from the earth to air or vice-versa due to the temperature difference between the undisturbed temperature of the earth and outside atmospheric air [9]. The use of the earth as a sink has been done since the ancient times. In about 3000 B.C., The IRANIAN ARCHITECTS have used wind towers and underground air tunnels for the passive cooling in about 3000 B.C.[11,12]. This technology has also been used by the ancient Greeks and Persians (Mihalakakou et. al., 1994), (Santamouris et. al., 1995) and (Santamouris et. al., 1996)[13],[14],[15]. For instance the Italians in the middle Ages used caves called colvoli, to precool /preheat the air before it entered the building. In the earth air heat exchanger arrangement as shown in figure 1 & 2, tubes for carrying air are buried under the earth surface at some depth between 2-3m. The ambient air passes through these tubes before discharging it into the room to be heated or cooled. The ambient air which is having higher temperature in summer is cooled while passing through these underground pipes in summer and heated when the cold atmospheric air is passed through these tubes in winter [16].

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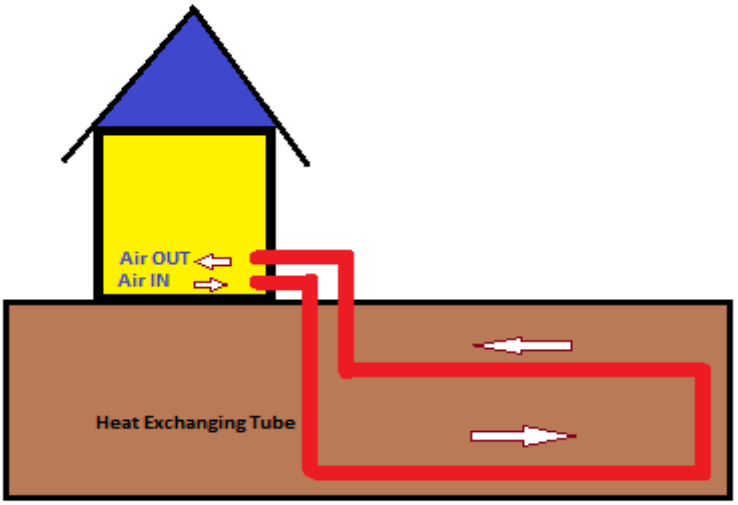

Figure 2: Working of Earth Air Heat Exchanger

2.3 Design of EAHE

Since last two decades many research works have been conducted to find the design solution of EAHE system for its effective use. Some of the important parameters are the year round atmospheric temperature of the location and the soil conditions. For the required air flow rate to heat/cool the room the tube diameter is determined. The selection of material of the tube is also important as the roughness of PVC, Steel or Concrete tube will affect the heat transfer accordingly. The HAHE design equations have been developed and procedures for the calculation of the heat transfer through the tube (De Paepe and Janssens, 2003) and (Badescu and Isvoranu, 2011). The required length of the tube and the pressure drop can be calculated [17],[18].

2.4 Air Flow through the tubes

The design of EAHE includes the estimation of air flow required through tube. The size of the tube and the number of tubes required for the air flow will then be determined. These will not be the unique values as they will vary according to the heat transfer and the power supplied for the flow. For the required flow rate of air Q of density ρ and the inner radius of tube as ri,, the mean velocity of the air, v and the mass flow rate,m will be given by equations (1) and (2) respectively.

$$V = \frac{Q}{\Pi r_i^2} \quad (1)$$

$$m = \rho \Pi r_i^2 V \quad (2)$$

3. Performance of EAHE

The earth air heat exchanger (EAHE) is a metal or plastic pipe buried at certain depth in ground that exchanges heat with ground for cooling or heating of atmospheric air. It works as a passive cooling system when hot air flows from a room into the buried pipe, where heat is transferred from the soil into the air, thus the air is cooled and it enters the room again as a cooler air[19] [20]. The performance of EAHE system is mainly influenced by the design parameters such as, tube material, size of the tube, air velocity, buried tube depth, air temperature, type of soil and soil temperatures [10], [21].

The method for the estimation of soil temperature is found in Annex A of BS EN 15241,2007 [22]. Soil temperature from an advanced analytical equation (Cucumo et al., 2008) is estimated more accurately from the daily average temperature and daily temperature fluctuations [23]. For the estimation of the heat transfer to or from the soil, the soil temperature is needed. The design of an efficient EAHE system needs estimation of the design parameters carefully and accurately. In the last two decades, intensively research work has been done on the design parameters affecting the performance of the EAHE system.

4. Conclusion

In this paper the passive ventilation with the use of earth air heat exchanger technique is presented. The working of the EAHE in as a open loop and close loop system is presented. The performance of EAHE system is mainly influenced by the design parameters such as, tube material, size of the tube, air velocity, buried tube depth, air temperature, type of soil and soil temperatures The design of EAHE includes the estimation of air flow required through tube. The heat transfer to and from the soil is determined for the desired heating and cooling of air for the desired indoor thermal environment in the room. The design of an efficient EAHE system needs estimation of the design parameters carefully and accurately. It is found that since last two decades many studies have been performed for the design estimation of the EAHE system and determining of the system performance. It is concluded that EAHE design parameters affect the performance and they must be carefully estimated.

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