Experimental Evolution of Earth Tube Heat Exchanger Cooling of Bhopal

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ABSTRACT

Earth tube heat exchanger systems can be used to cool the building in summer climate (March to May) and heat the buildings in winter climate(Jan to Feb). In a developing country like India, there is a huge gap in demand and supply of electricity and rising electricity prices have forced us to look for cheaper and cleaner alternative. Our objective can be met by the use of earth tube heat exchangers and the system is very simple which works by moving the heat from the house into the earth during hot weather and cold weather vice-versa. Measurements show that the ground temperature below a certain depth remains relatively constant throughout the year. Experimental investigations were done on the experimental set up in Bhopal. Effects of the operating parameters i.e air velocity and temperature on the thermal performance of horizontal ground heat be exchanger are studied. For the pipe of 9 m length and 0.08 m diameter, temperature falling of 3.93^{O}C-12.6 ^{O}C in hot weather and temperature rising of 6 ^{O}C-10 ^{O}C in cold weather have been observed for the outlet flow velocity 12 m/s. At higher outlet velocity and maximum temperature difference, the system is most efficient to be used.

Ground Coupled Heat Exchanger:

A ground coupled heat exchanger is an underground heat exchanger that can capture heat from and dissipate heat to the ground. They use the earth's near constant subterranean temperature to warm or cool air or other fluids for residential, agricultural or industrial uses. They are also called earth tubes or earth-air heat exchangers or ground tube heat exchanger. Earth tubes are often a viable and economical alternative or supplement to conventional central heating or air conditioning systems since there are no compressors, chemicals or burners and only blowers are required to move the air. These are used for either partial or full cooling and their use can help building meet passive house standards. The temperature field in the ground is influenced by different quantities absorption of the solar radiation depends on the ground cover and color, while the long wave radiant loss depends on soil surface temperature.

The net radiant balance between solar gain and long wave loss is usually positive in summer and negative in winter. This causes heat to flow down from the surface into the ground in the summer and upward to the surface during the winter. The net radiant balance also determines the relationships between the averages of the earth surface and the ambient air temperatures. By shading the soil in summer while partially exposing it to the sky in winter, for example, with trees, it is possible to lower the ground temperature in summer to a greater extent while possibly increase the ground temperature in winter somehow.

Positive-displacement blowers:

Positive displacement blowers have rotors, which "trap" air and push it through housing. These blowers provide a constant volume of air even if the system pressure varies. They are especially suitable for applications prone to clogging, since they can produce enough pressure (typically up to 1.25 kg/cm^2) to blow clogged materials free. They turn much slower than centrifugal blowers (e.g. 3,600 rpm) and are often belt driven to facilitate speed changes.

General Explanation

Earth tubes are low technology, sustainable passive cooling-heating systems utilized mostly to preheat a dwelling's air intake. Air is either cooled or heated by circulating underground in horizontally buried pipes at a specified depth. Specifically air is sucked by means of a fan or a passive system providing adequate pressure difference from the ambient which enters the building through the buried pipes. Due to ground properties the air temperature at the pipe outlet maintains moderate values all around the year. Temperature fluctuates with a time lag (from some days to a couple of months) mainly relative to the depth considered. Temperature values remain usually in the comfort level range (15-27 °C). This technology is not recommended for cooling of hot humid climates due to moisture reaching dew point and often remaining in the tubes. However there are southern European coastal regions as in Greece where the climate remains hot and dry. In such locations these systems could have impressive results.

The material of a pipe can be anything from thin wall 'sewer' plastic, metal or concrete. However concrete should better be avoided in order not to be dependent on carbon filtration UV sterilization for the musty air coming out of concrete earth tubes.

The effectiveness of a buried pipe system is mainly related to the following parameters:

- Ground temp. at depth of the installed exchanger
- Thermal diffusivity of soil
- Pipe length, width
- Inlet air temp.
- Thermal conductivity of pipes
- Air velocity

An earth-to-air heat exchanger (EAHX) consists in one or more tubes lied under ground in order to cool (in summer) or pre-heat (in winter) air to be supplied in a building. This air is often outdoor air necessary for ventilation, but also useful to partially or totally handle the building thermal loads. The physical phenomenon is simple.

Ground heat transfer mechanism

The temperature field in the ground is influenced by different quantities absorption of the solar radiation depends on the ground cover and color, while the long wave radiant loss depends on soil surface temperature. The net radiant balance between solar gain and long wave loss is usually positive in summer and negative in winter. This causes heat to flow down from the surface into the ground in the summer and upward to the surface during the winter. The net radiant balance also determines the relationships between the averages of the earth surface and the ambient air temperatures. By shading the soil in summer while partially exposing it to the sky in winter, for example, with trees, it is possible to lower the ground temperature in summer to a greater extent while possibly increase the ground temperature in winter somehow. The performance of ground coupled air heat exchanger is directly related to the thermal properties of the ground. The ground has thermal properties that give it a high thermal inertia. The heat transfer mechanisms in soils are, in order of importance: conduction, convection and radiation. The temperature field in the ground depends on the soil type and the moisture contained respectively.

Studied the effect of soil type and moisture content on ground heat pump performance and found that the performance of a ground heat pump system depended strongly on the moisture content and the soil type (mineralogical composition). Alteration of soil moisture content from 12.5% of saturation to complete dryness decreased the ground heat pump performance, and any reduction of soil moisture within this range has a devastating effect. The Graphical Representation of Variation of the average COP vs degree of soil saturation shows Fig. 1 below.

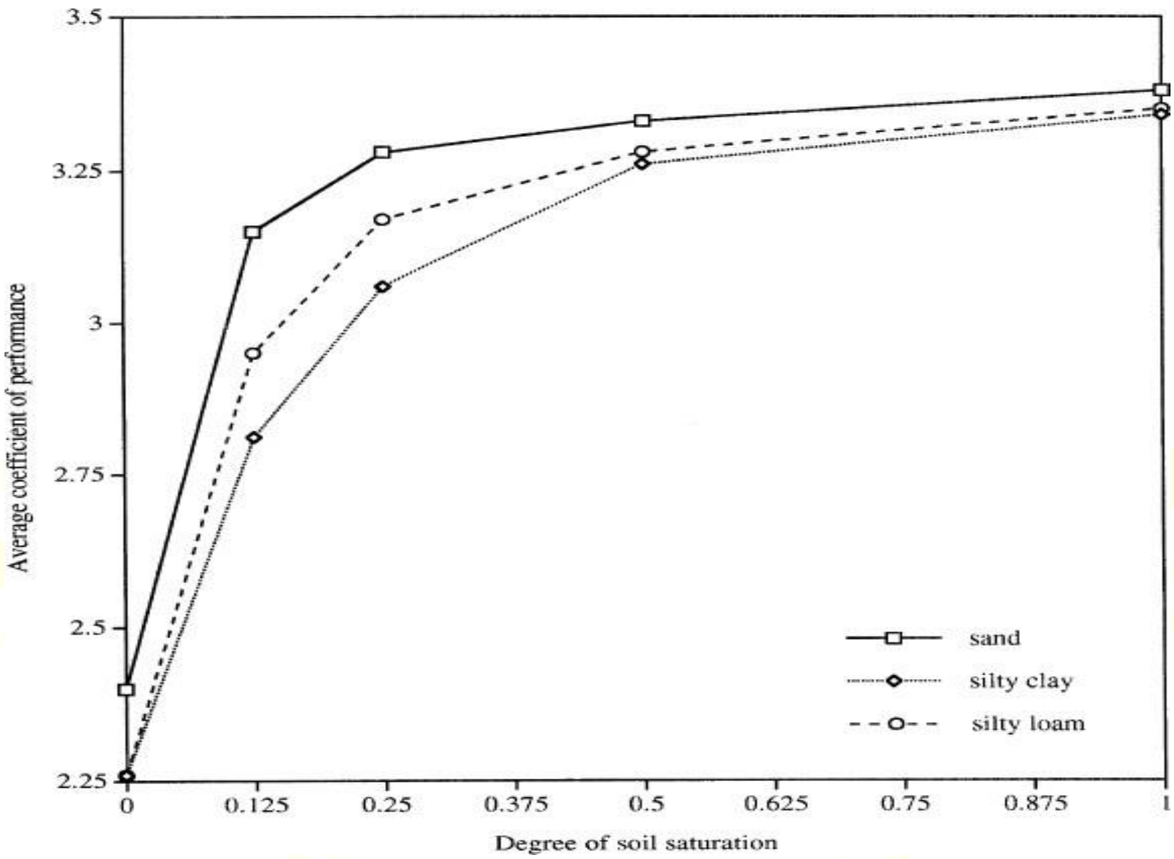


Fig. 1: Variation of the average COP vs degree of soil saturation.

Investigated the performance evaluation and life cost analysis of earth to air heat exchanger integrated with adobe building for New Delhi composite climate. The following conclusions were made from the experiment:

The adobe house has considerable energy saving potential for Indian climatic conditions. These adobe houses can be easily adopted for all locations, especially in hot and dry climatic regions of semi-urban and rural areas all over the world for achieving the thermal comfort.

The total annual energy saving potential of adobe house for three conditions: (i) before renovation, (ii) after renovation and (iii) with EAHE for six rooms for renovated adobe house was calculated as 4182kWh/year, 4946kWh/year and 10321KWh/year respectively. This results in mitigation of CO_2 emissions nearly equal to 7 tons/year, 8 tons/year and 16 tons/year respectively. Hence, annual carbon credits that can be earned by the adobe house for three conditions are €140/year, €160/year and €320/year respectively. The Comparison of annual energy saving potential (i) before renovation (ii) after renovation shows Fig. 2 & Seasonal energy efficiency ratio (SEER) of EAHE for heating/cooling shows Fig. 3

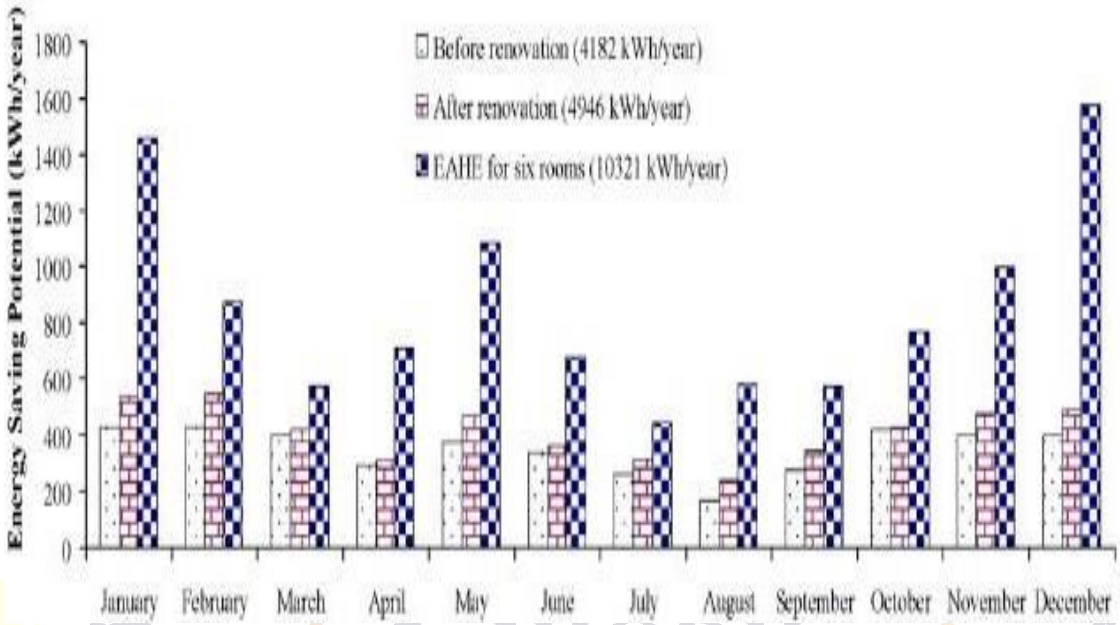


Fig. 2: Comparison of annual energy saving potential (i)before renovation (ii) after renovation (iii) with EAHE for six rooms after renovation.

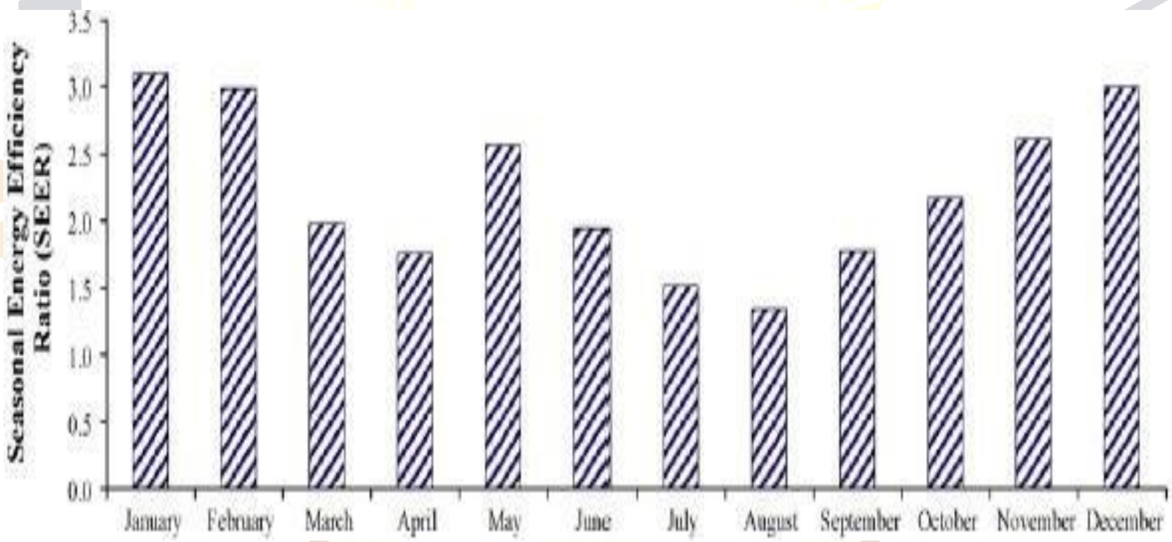
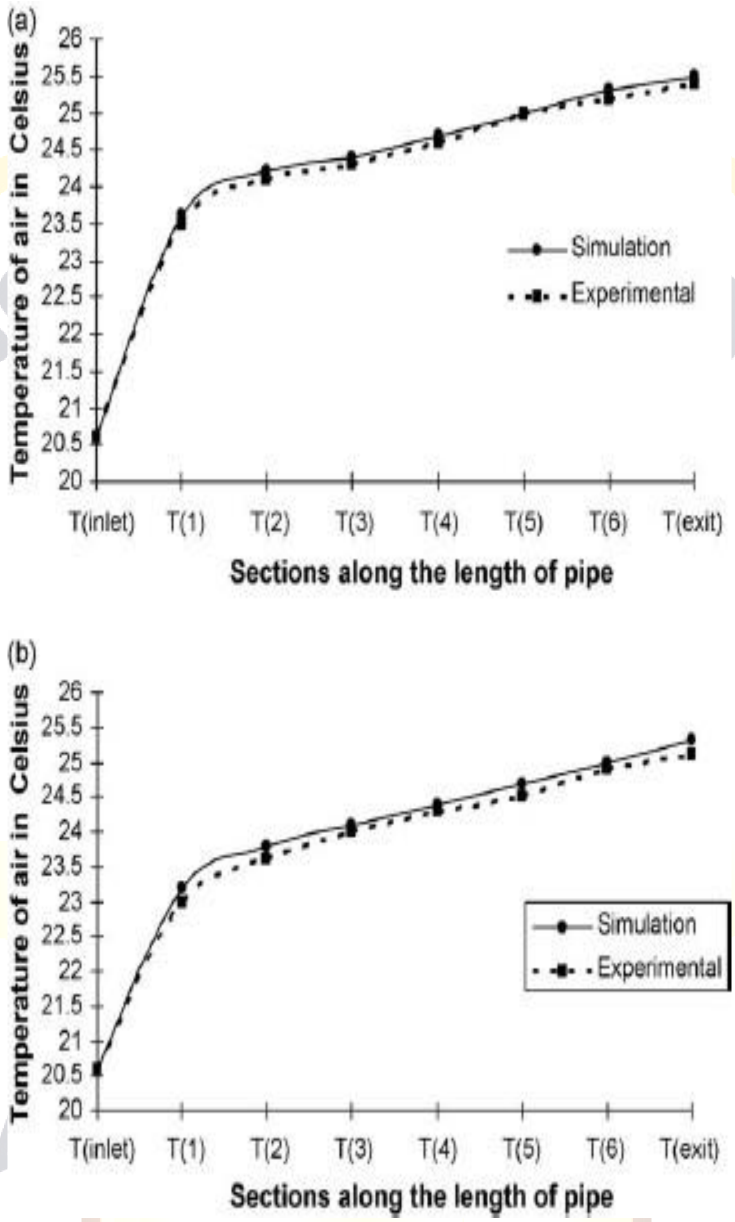


Fig. 3: Seasonal energy efficiency ratio (SEER) of EAHE for heating/cooling



Temperature distribution along the length of the pipe for exit velocity 2.0 m/s for (a) steel pipe (b) PVC pipe

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