An Experimental Analysis: Thermal Performance of Underground Heat Exchanger System for Enhancing Comfort by Cooling & Heating During Winter & Summer Season

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ABSTRACT
Cooling the outdoor air through buried pipes by means of earth-air heat exchanger (EATHE) has been recognized from last 10 years have the capability for enhancing comfort of building and in the mean time decreasing demand of energy. This is due to one of the important thermal property of earth is that at the depth of about 1.5m to 2m, the temperature of ground remains almost similar all round the year. The temperature of earth interior remains higher than the surface temperature of earth in winter season and vice versa in summer. When atmospheric air is passed through buried pipe it comes in contact with soil temperature hence comes out from EATHE system having the temperature of soil is always constant. The conditioned air is allowed to enter into the room through outlet piping and duct system.

Key Words: Heat exchange, EATHE, Conditioned air, Earth temperature, Atmospheric Air.

I INTRODUCTION

Conservation of energy is one of the most significant global challenges now a day. The energy crisis of the mid 1970s dealt a harsh blow to developing and developed countries including India. The most energy beneficial outcomes of crisis are that it stimulated interest in the diversification of energy sources and renewable energy. Meanwhile, environmental concerns pushed this trend much further. In order to reduce greenhouse gas emission, which are considered to be cause of global warming and source of pollutions, the specific target is to reduce CO_2 emission.

Because of the high thermal inertia of the exterior climate are damped deeper in the ground. Further a delay arises between the temperature fluctuations within the ground and at the surface. Thus at a sufficient depth the soil temperature is lower than the outside air temperature in summer and higher in winter. When the fresh air is drawn through the earth tube heat exchanger the air is thus cooled in summer and heated in winter. In combine with another system and better thermal design of the building, the earth air heat exchanger can be used to preheat air in winter and avoid air conditioning units in building in summer, which result in a major reduction in electricity consumption of a building.

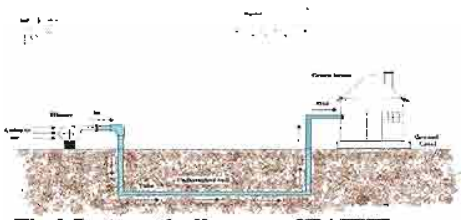

Fig.1 Systematic diagram of EATHE

II OBJECTIVE

The main objectives of the thesis are as follows:

(a) To apply this technology suitable to Bhopal climate.
(b) Finding out the variation in outlet air temperature with different velocity rate.
(c) To develop a transient thermal network model for finding the transient temperature profile around an earth tube in order to determine the optimal depth of the earth air tube heat exchanger systems and the rapidly change of temperature of soil due to prolonged usage.
(d) To perform an extensive literature review to identify the research and development status of this technique and current guidelines for designing earth air tube heat exchanger system.

III DESIGN GUIDELINE OF EATHE

(a) Important Design Parameter:
(i) Influence of the climate and soil composition
(ii) Inlet air temperature varies with length of pipe
(iii) Inlet air temperature varies with radius of pipe
(iv) Inlet air temperature varies with depth of pipe
(v) Inlet air temperature varies with air velocity inside pipe

(vi) Influence of the tube material

(b) Arrangement of EATHE:

(i) **Open loop type** -In open loop type system, ambient air delivered through tubes buried in the ground for preheating or pre cooling and after that the heated or cooled air is entering the building. The inlet temperature changes as the outside temperature fluctuate.

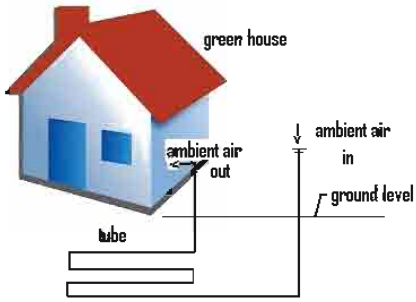

Fig. 2 open loop type EATHE

(ii) **Closed loop type**-In closed loop type systems, air delivered through tubes buried in the ground from inside the building for preheating or pre cooling purposes. Using a closed loop effect in the best efficiency and reduces problem with humidity condensing inside the tubes.

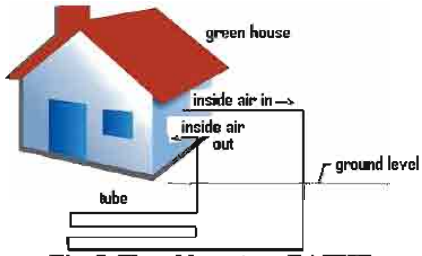

Fig. 3 Closed loop type EATHE

(iii) **Horizontal Closed loop type-** A horizontal closed loop placed a series which spread horizontally in the ground. A long horizontal Series heat exchanger, Parallel heat exchanger, Trench heat exchanger and Slinky coil heat exchanger are placed horizontally inside the same trench.

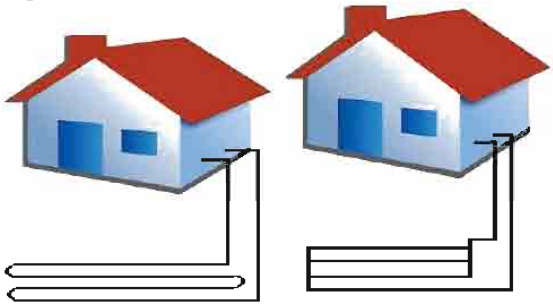

Fig. 4 Horizontal Closed loop type EATHE

(iv) **Vertical Closed loop type-**A vertical closed loop area is made up of pipes that run up and down in the ground. A long vertical Series heat exchanger and Parallel heat exchanger are placed horizontally inside the same trench.

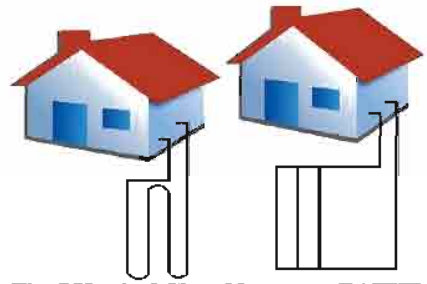

Fig. 5 Vertical Closed loop type EATHE

(v) **Experimental Set-up**-The installation of tube was done on an open field. The Soil at the site was tested and found to be sandy-silt (sand 47%, silt 42%, clay 13%). Wetness content at the time of dig was 12.43%. Experimental set-up consists of an EATHE, fan house, temperature sensors and instruments.

Fig. 6 Air Outlet

Fig. 7 Air inlet

Fig. 8 Tube Placed Inside Earth

Fig. 9 Digital temperature Indicator

Fig. 10 Digital Vane type Anemometer

Fig. 11 Indoor/ Outdoor thermo/Hydro Clock Meter

(c) Fabrication:

(i) **Materials Used For Parts:** All the parts which are used in our Earth Air Tube Heat Exchanger system are made of mild steel. There is one pipe of 8 inch diameter, four pipe of 6 inch diameter, one pipe of 3 inch diameter, one insulating pipe, seven bands and four flanges as shown in table.

Table 1
Tube Details

Components	Specification/Model	Units/mtrs/lit
6" pipe	M.S.	4
8" pipe	M.S.	1
3" pipe	M.S.	1
6" Elbow/Bend	M.S.	7
3" Elbow/Bend	M.S.	1
6×2.5" Reducer/Socket	M.S.	1
8×3" Reducer/Socket	M.S.	1
3×2.5" Reducer/Socket	M.S.	1
Nipple	G.I.	1

Plate (Flange)	M.S.	2
Plate (Flange)	M.S.	2
Nut and Bolt	M.S.	10
Drill Tool	H.S.S.	4
Paint	Black bituminous	10 lit.
Paint	White synthetic	1 lit.
Sand paper	100,80,60 no.	8 meter
Welding rod	-	270 nos.

(ii) Specification of Fabrication

Pipes:-

- 3 pipes for heat exchanging (6"or 152.4 mm)
  Inner diameter- 0.1554 m
  Outer diameter- 0.1584 m
  Length- 6 m
  Thickness- 3 mm
- 2 header pipe (8"or 203.2 mm.)
  Inner diameter- 0.2042 m
  Outer diameter- 0.2122 m
  Length- 3 m
  Thickness- 4 mm
- One insulation pipe (3"or 76.2 mm.)
  Inner diameter- 0.0762 m
  Outer diameter- 0.0822 m
  Length- 6 m
  Thickness- 3 mm
- Elbow/Bend
  Angle 90^0
  Inner diameter- 0.1554 m
  Outer diameter- 0.1584 m
  Thickness- 3 mm

IV RESULT & DISCUSSION

The hourly variations of temperature for ambient air, greenhouse air once operating with earth air tube heat exchanger (EATHE) for typical summer day. It's seen that the lowest as well as peak temperatures for atmospheric air, greenhouse air with (EATHE) varied between 28.5–41.6, 28.2–46.3 and 28–44.3^{0}C, respectively, confirming the considerable fluctuations of temperature within the greenhouse as compared to ambient air and greenhouse.

The temperature of ground on the above day at the depth (3 m) in which the EATHE system was installed was recorded to be about 20.6^{0}C. By investigative closely the daily temperature profiles of greenhouse air, it was found that the delivery temperatures of EATHE were 7.5–16.2^{0}C lower than the suction temperatures from 10:00 a.m. to 5:00 p.m. As a result of which, the temperatures of greenhouse air were maintained in the range of 28–30.9^{0}C for providing healthy environment human comfort during summer period. The predicted values of greenhouse air have been validated with the experimental values for the above typical day and that showed fair agreement. After knowing the suction and delivery temperatures of EATHE as well as the mass flow rate of the circulating air in the buried pipes, variation of cooling potentials offered by the system were also calculated. The curve in the figure represents cooling potentials obtained from EATHE. Further, the time periods above and below that line indicate the cooling potentials during a summer day.

Similarly the hourly variations of temperature for ambient air, greenhouse air with EATHE for a typical summer day have been depicted. The cooling potential obtained from EATHE. However, overall temperatures of greenhouse air were dropped by 8–12 °C than greenhouse with EATHE during daytime for cooling in summer period. The experimental and analytical value of the air temperatures in greenhouse predicts good results. The temperature of air around 8 – 10^{0}C more than to undisturbed soil temperature is obtained at a pipe length of about 24 m from inlet irrespective of thermal conductivity of soil under steady state condition. The approximate 24 m length of the EATHE pipe required to obtain the maximum possible drop in temperature.

V CONCLUSION

(a) EATHE is a type of horizontal open loop system consists of a 24 m long and 0.1554 m inner diameter with wall thickness of 3 mm and the pipe is made up of mild steel. EATHE is buried 3 m deep below surface. An industrial blower of 260 Watt was used to force ambient air through it. The air velocity was taken between 4-6 m/s.

(b) As a result of an EATHE system which was able to drop the delivery temperature at of 7.5 – 16.2 ^{0}C and greenhouse temperature is maintain at 28 – 30.9 ^{0}C. The earth-air-tube model showed a good agreement with the work performed by others. The basic soil temperature in May was 26.6°C.

(c) An underground earth tube with a lesser air velocity should result in reduction earth-tube inlet temperatures. Pipe length, pipe depth and air velocity inside pipe change to have more influence on thermal performance. However, pipe radius and air flow rate as well as cooling heat transfer rate also affect the performance of EATHE.

(d) The total average COP in the experimental period is found to be range of 2.86 to 6.77. COP value was calculated as mean of 4.06, 4.34 and 5.28 for different air velocity like as 4 m/s, 5 m/s and 6 m/s respectively. Based on the outcome it

can be confirmed that EATHE holds considerable promise as a means to cool ambient air for a variety of applications such as the livestock buildings and greenhouses.

(e) The difference between experimentally and theoretically value of an outlet air temperature are 2-3.19, 1.3-3.21 and 0.71-4.91 for different air velocity of 6 m/s, 4 m/s and 5 m/s respectively. The predicted and experimental temperatures of greenhouse air in the developed system showed fair agreement. It is completed that there is possible for EATHE systems to make a useful involvement to energy saving.

VI SCOPE FOR FUTURE WORK

(a) Designing the system with solar panel system so as to obtain reduced electricity consumption.
(b) Designing the pipe taking copper, silver and other highly conducting metals for improving heat conduction.
(c) Modifying the design & material of blower fan blades.
(d) Making the system fully automatic by using software, control panel and thermostats.
(e) By changing pipe and blower dimensions.
(f) By using the zigzag design of pipes

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