Journal of Advances and Scholarly Researches in Allied Education
Vol. 16, Issue No. 6, May-2019, ISSN 2230-7540

Validation of Thermal Properties of Earth Tube Ground Heat Exchanger by CFD

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Abstract – Ground Air Tube Heat Exchanger are simple system have valuable feature to diminish energy consumption in uptown building which are operational with an active ventilation system. Through the conditioning system the air is equally passed through the tubes which are concealed under the ground. In this method air is pre-cooled for the era of summer. Solar energy gathered in soil may be utilised Ground Air Heat Exchanger, which have single tube or multiple tubes buried in ground. When the ventilation air drawn through tube(s), the air is heated in winter and cooled in summer due to the temperature difference between air and ground. By taking advantage of this free energy, we can reduce the energy consumption required for space cooling. The investigation model of Ground Air Heat Exchanger is made in Uni-Graphics NX 10 and a Computational Fluid Dynamics (CFD) methodology using ANSYS FLUENT 15.0 is used here to investigate the effect of air flow velocity and different inlet air temperature on the implementation of Ground Air Heat Exchanger system for summer cooling and it is validated by the experimental investigation.

Keywords: - Ground Air Heat Exchanger, Parametric Analysis, Earth's Undisturbed Temperature.

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1. INTRODUCTION:

Now a day, conservation of energy is a major challenge worldwide. The energy crisis of the mid 1970s dealt a harsh blow to developing countries including India. The most energy beneficial outcomes of crisis are that it stimulated interested in the change of power sources and renewable energy. Meanwhile, environmental concerns push this trend much further. To decrease greenhouse gas emission, which are considered to be reason behind global warming and source of pollutions, the specific target for reduction CO_2 emission [2, 3]. First of all focus on the producing electricity with higher efficiency. Old power plants are more rapid phased out and replaced by new, more efficient plant. Secondly, the attention is drawn on energy use. Abundance use of effective energy not only reduced the consumption of electricity, however additionally lowers the usage of main power source. Building residential or commercial mainly use energy to obtained comfort for their inhabitants. This comfort is visual, ergonomic, however chiefly thermal. To decrease the depletion of energy of the building, different type of methods are introduced in HVAC installations. Solar energy is being used by many forms in a source of heat and electrical energy. Solar gain within the building decreases the cooling needs and the size of air conditioning unit [4]. Additional methods are based on recuperating cold and heat. Most of the cases in several passive measures are combined .Where earth is a supplier of heat and warmth sink may be a well studied topic. Victimization the world as an element of the energy system or earth tempering will be accomplished through 3 primary methods: direct, indirect and isolated. The building envelope is in touch with the world in the direct system, and physical phenomenon through the building parts regulates the complete temperature. In the indirect system the interior of the building is conditioned by the air, which came from earth air device. The isolated system used earth temperature to extend the potency of an apparatus by moldering temperature at the compressing coil. A geothermic is associate example of isolated system. This thesis is targeted on indirect system. This system i.e. Ground Air Tube Heat Exchanger System, sometimes called earth tubes, and are an fascinating and capable technology. The air is passed by the tubes grounded in the earth. see figure 1.1)

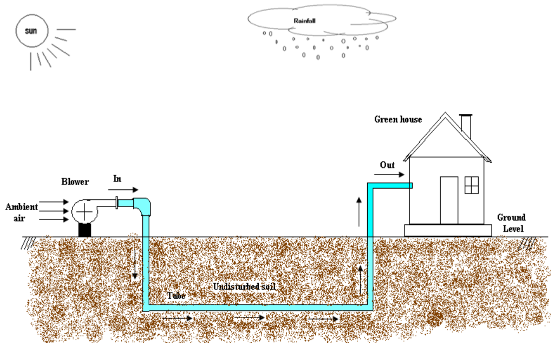

Figure - 1.1 Schematic diagram of an Earth Heat Exchanger for Cooling/Heating

2. EATHE APPLICATIONS:

All over the world, this procedure is applied in a variety of building. Most probably it is used in European countries. In greenhouse and livestock houses many EATHE system are been applied. For live stock house inactive heat and balanced heat production is very high due to concentration of animals in building. To maintain animal health, and consequently to improve the effectiveness of animal production, ventilation requirements are such important that it is essential to keep a high value of air flow rate. Building with EATHE and a solar chimney and made a conclusion that the thermal environment inside the building stays about 91% of the time within the thermo neutral zone. High temperature during the summer season and low temperature in winter are also adverse to greenhouse crops. The EATHE, which is one of the passive solar systems, has been installed in greenhouse as a warming and freezing system over last thirty years. They concluded that these application show good performance and effectiveness for both heating and cooling. In addition to reduce loads furthered a step to use EATHE system to collect condensation to compensate the water needs of a greenhouse as well as to condition the greenhouse.

Recently more and more EATHE system found them applied not only in residential buildings but also commercial and institutional buildings. All of these reports demonstrate that the EATHE technique has a promising contribution to reducing cooling and heating loads.

2.1 REVIEW MODELS:

2.1.1 Multi – Dimensional Models:

To predict the working of the EATHE system, Mihalakakou et al [1994], Bojic et al. [1997]. Gauthier et al. [1997] and Hollmuller et al [2003] have been developed some whole and lively models for ETAHEs. The structures are different from the prototype (2D, 3D, polar coordinates) and the humidity is transferred in the ground and in the air are accounted for, However, these methods of calculating are very difficult and their solutions are usually obtained by using commercial software such as TRNSYS, ANSYS, SMILE and FLUENT etc. Therefore, the applicability is limited because only few people are aware of calculation codes or software. They are chiefly used to demonstrate that EATHE is a fulfilling and real technology.

The heat transfer model is based on the following assumptions:

1. Transfer of heat is transient and fully three dimensional in the soil.
2. The thermo physical properties of the soil and other materials are constant.
3. Heat transfer by moisture gradient in the soil is neglected.
4. Heat transfer in the tube is dominated by convection. It is coupled with the hotness of the area of the surrounding soil by the boundary conditions at the tube surface.

2.1.2 One Dimensional Model:

Many one dimensional calculation models for EATHEs are found in literature. One dimensional features of the tube is used in the model. The algorithms are classified in two groups:

1. The algorithms that the calculation of heat transfer of air in the tube and after that calculating the temperature of tube in the ground mass. [56]. The necessary input data are:

► The geometry characteristic of the system

► The thermal characteristic of the ground

► The thermal characteristic of the air

► No interruption in temperature at the time of system operation.

2. Those formulas which only calculate the heat that is transferred through air in the tube. The main important input data are:

► The geometrical characteristic of the system

► The thermal characteristic of the air

► The sensation of heat on the surface of the tube

The relationship among inner or outer sensation of heat in the tube is consequent. There is no effect of heat from the earth in all the models can be taken in the description. Secondly the effect of dissimilar tube is unable to study. In the algorithm the ground divided into co-axial cylinder elements. The temperature of the ground is dependent upon the time. The tube is cut in parts. In another procedure the steady-state warmth stability is explained between a point in the ground and the tube. It is concluded that the dissimilar model give comparable results.

3. GATHE MODELLING:

The experimental model of GATHE is made in Uni – Graphics NX 10 as mentioned earlier. The reason of using the NX10 is that making model of pipe assembly in NX 10 is quite easy and less time consuming. The different dimensions of GATHE are taken from the experiments conducted by Bisnoiya et.al.

The model of GATHE based on above dimensions is made in NX – 10 are shown in
Figure 3.1. The image with position of different temperature sensors in pipe at which temperature of air is measured and dimensions of the pipe with the position of Inlet and the Outlet of air is shown in the further images. These images are the top, front and side view of the model. Figure 5.1 shows the Exchanger pipe setup buried in the soil. Figure 3.2 shows the burial depth and the one side length of the exchange pipe.

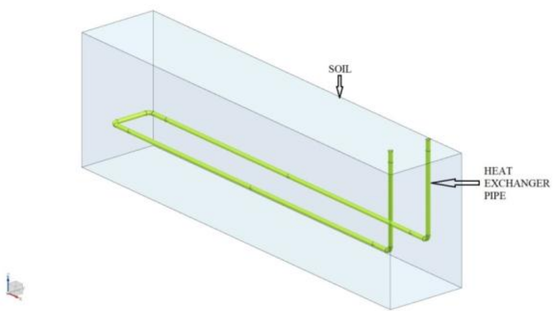

Figure 3.1 – Model of GATHE

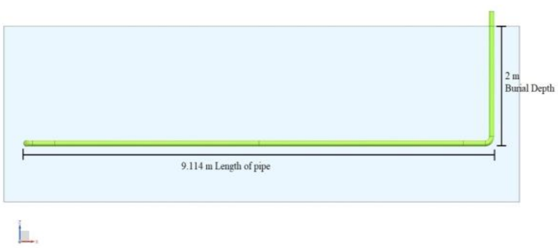

Figure 3.2 – Front View of the GATHE

The complete setup of Ground Air Tube Heat Exchanger is shown in the Figure 3.3. This figure shows the Inlet of air and Outlet of cold air. The figure also shows the points at which the temperature of air is checked throughout the exchanger unit. The temperature is measured from inlet to outlet on 6 points namely T1, T2, T3, T4, T5 and T6. All these points can be seen in the Figure 3.3

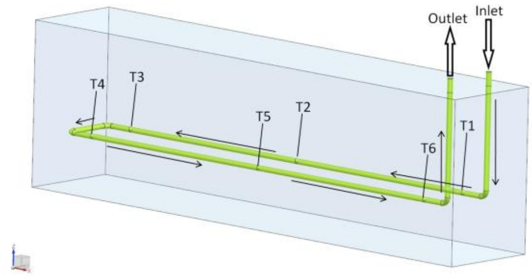

Figure 3.3 – GATHE model

4. SIMULATION:

The complete setup is exported in IGES file and same is imported in ANSYS Workbench 15. The CFD code FLUENT 15.0 is used for simulation GATHE model. For CFD modeling we are predicting that the temperature on the earth surface is equals to the atmospheric temperature and it is same as the inlet air temperature. Secondly Earth's undisturbed temperature is approximated to yearly regular temperature of the Bhopal region. It is also assumed that the pipe used is of uniform cross section, the obesity of the pipe is very small hence the heat in the material of pipe is unimportant and the sensation of heat outside the pipe in axial direction is uniform. We modeled our setup with three velocities and three different inlet temperatures. This model is then imported in ICEM CFD where the mesh of the model is generated. The tetrahedron mesh is generated and the model is discretized in 1246412 nodes and 6486145 elements. The GATHE boundary conditions might be provided in the mesh section through naming the portions of modeled GATHE i.e. Inlet, Outlet, Fluid Domain, Soil, tube.

Before meshing the model proper contact regions were identified and named those contact regions as the interfaces. It is checked that the soil is in contact with the pipe and the pipe should be in contact with the air domain to heat transfer to soil through pipe.

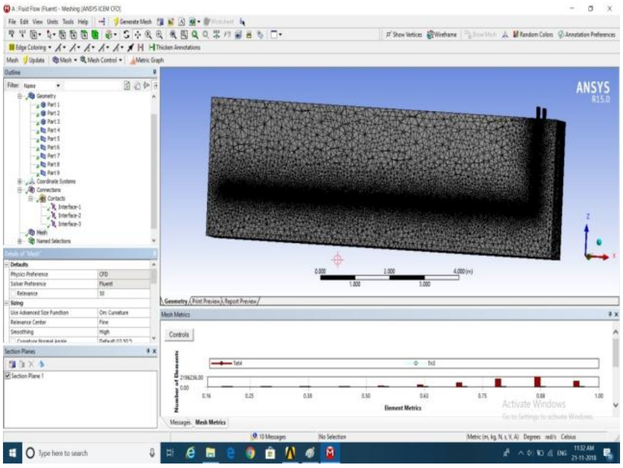

Figure 4.1: Meshing of the GATHE at Pipe Section

4.1 Boundary Conditions

Following are the boundary conditions that are used for simulation

Inlet: At Inlet of GATHE the flow type having subsonic property regime along with turbulence of medium category is considered. The values of velocity of air flow is 2m/s, 4m/s and 5m/s is taken with the static inlet temperature of the air as 40.4^{O}C, 38.8^{O}C and 39.9^{O}C respectively is defined at inlet. The density, specific heat capacity, dynamic viscosity and thermal conductivity of air is defined at static temperature at the inlet.

Outlet: The virtual force at outlet of GATHE pipe was taken as zero atm in subsonic flow regime.

Wall: The location as long as the pipe is defined where air temperature is to be measured. The temperature of the surface of pipe is uniform and taken equal to earth's undisturbed temperature 25.2^{O}C at the Bhopal region.

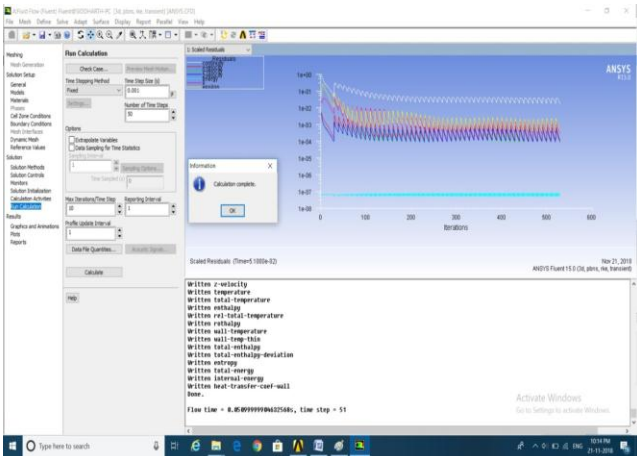

Figure 4.2: Complete Calculation for Simulation Model with 50 time step and 10 iteration / time step

5. VALIDATION:

The main calculations of the issue are resolved and the simulation result obtained from the CFD FLUENT modeling is checked for the thermodynamic characteristics of the GATHE. The accurateness of the computational model is verified by comparing the outcome from the current study with those experimental results obtained by Bisoniya et al [1].

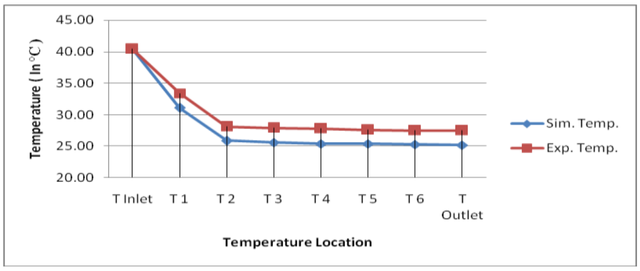

Figure 5.1: Comparison between Sim. Temp. and Exp. Temp. at 2m/s Air Flow velocity

Graph 5.2 shows the obtained result of ANSYS tool for the air flow velocity of 3.5 m/s and the inlet temperature of 40.4°C. In this combination of air flow velocity and the inlet temperature we see the good downfall in temperature; we obtained the temperature difference of 14.7°C in inlet and outlet temperatures.

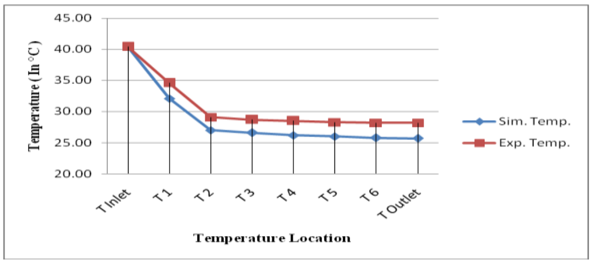

Figure 5.2: Comparison between Sim. Temp. and Exp. Temp. at 3.5m/s Air Flow velocity

Figure 5.2 shows the comparison between the simulated temperature and experimental temperature for the air flow velocity of 3.5 m/s and 40.4°C inlet temperature. Table 6.3 shows the obtained result of ANSYS tool for the same inlet temperature 40.4°C for little higher air flow velocity 5m/s. In this set of simulation the temperature fall is little bit as compared first two cases but satisfactory temperature difference of 13.8°C is noted for the GATHE system. Figure 6.3 shows the evaluation of simulated temperature and the experimental temperature. All the experimental temperature is for validation and is taken from experimental investigation obtained by Bisoniya et al[1].

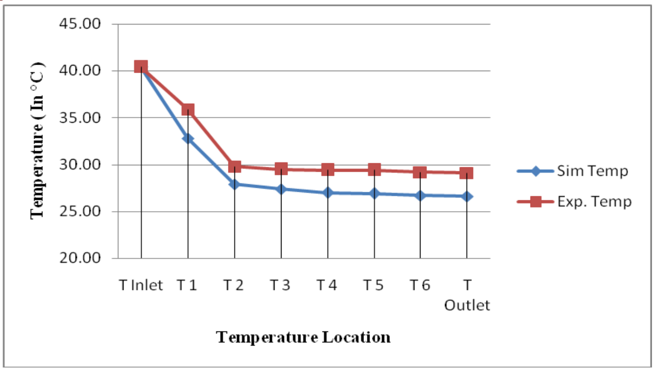

Figure 5.3: Comparison of Simulated Temperature & Experimental Temperature at 5 m/s Air Flow Velocity

6. CONCLUSION:

It was seen that the first three cases of air flow velocity 2m/s, 3.5m/s and 5m/s we can see that it shows decent contract with the investigational outcomes for the same inlet temperature. In the above observation we find the maximum temperature drop of 15.2°C and the lowest temperature drop of 13.8°C for the system. This temperature difference is due to the change in air flow velocity, when the air flow velocity is low as 2 m/s; the air in the GATHE system is in contact with earth for more time than it is flowing in 5m/s. Due to this time difference the cooling of air at high velocity, is low and at low velocity, cooling is high.

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