SIMULATION OF AN AIR HEATING/COOLING SYSTEM THAT USES THE GROUND THERMAL POTENTIAL AND HEAT RECOVERY

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The paper presents a general description of the earth to air heat exchangers and the results of the simulations carried out for this geothermal system connected with a house. The earth to air heat exchanger is used in both seasons and has an important part in complying with the passive house standards. This is not only one of the best solutions to achieve certain standards of different types of buildings (passive houses, positive energy houses) but is also one of the cleanest options that reduce pollution.

Keywords*:* ground thermal energy, earth to air heat exchanger, mechanical ventilation, heat recovery

1. Introduction

Even though geothermal energy is seen as "new renewable energy", it is an old form of energy. In different parts of the world, geothermal energy has been used in many applications. Thousands of years ago, at Pompeii, The Romans used geothermal energy to heat the buildings [1]. There are documents proofing the usage of geothermal energy on other continents, in countries such as China and Japan.

Geothermal energy fields are divided in low and high energy fields. There are two types of systems that use the low fields: open and closed systems. The earth to air heat exchanger is an open geothermal system which became more popular in the 80's when the Darmstadt Institute from Germany developed the passive house concept [2]. In the 70's a French architect discovered that this technique was firstly used by a tribe living on the territory of Canada [3]. Applications of the EAHX are spread all over the world and many of them in

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European countries, North America and India [4] [5] . These geothermal systems are built not only for homes but also for heating and cooling the commercial spaces and greenhouses. The most part of papers available on websites and international journals presents studies on earth to air heat exchangers used in countries such as Germany, Greece France, Belgium, India and Canada.

The EAHX seems to be a very interesting technique in cooling and heating the office buildings. [6] focuses on its performance in the cooling season. In this season, during the day, the EAHX combined with natural ventilation reduces the load by precooling the supply air.

The ground to air heat exchanger may be part of the ventilation system of a passive house. In [7] the ventilation system which comprises an EAHX and a heat recovery is modelled in order to simulate its influence on the comfort and the temperature. A. Ribeiro carried out a study of an earth to air heat exchanger implemented to Net Zero Energy Building. In this case, the EAHX combined with natural ventilation, consists in concrete pipes buried at 3m below the ground. A simulation of the system was implemented based on Retscreen methodology [8].

[9] developed a model for a system comprising an earth to air heat exchanger connected to a solar chimney. The model includes other three sub-models: one for the EAHX, one to predict the model of the solar chimney and another one to predict the overall natural ventilation rate of the room.

2. The components of an earth to air heat exchanger

Earth to air heat exchangers are used to heat the space by bringing outdoor air into interior space through underground pipes. This can be also used in the summer when the air is cooled and possibly dehumidified as it flows.

Depending on the climatic area, the exterior air temperature can vary between -20 ºC and 40 ºC during one year while the temperature of the ground varies with only a few degrees.

The earth to air heat exchanger extracts heat from the ground in the winter and rejects it in the summer. The system is also known by other names such as: ground to air heat exchanger air to soil heat exchanger, ground tube heat exchanger, earth channel, earth tube etc. In the French literature it is named “puits canadien” or “puits provençal”.

The exterior components have a great influence on the quality of the required ventilation air. These components such as an air inlet tower, a grille and filters must be placed at a certain distance from the parking area and from the trees around the house. The most important component of the earth to air heat exchanger is the geothermal collector. In order to reduce as much as possible the weather influence on the ground temperature, the geothermal collector is usually buried at depths between 2m and 4 m. The criteria for choosing a collector refers to: strength, tightness, durability and thermal properties. There are two types of geothermal collectors: flexible and rigid collectors.

The range of materials used to make the collector is quite large. One of these materials is concrete. The concrete tubes of 3 m or 6 m long are connected with bitumen. Even though the tube has a long life and is neutral in terms of health, it is preferable to avoid concrete because of the thickness and the high roughness of the inner surface.

The flexible tubes are made of: polyvinyl chloride, polyethylene or polypropylene. Even if the price is low compared with other materials, the polyvinyl chloride contains chlorine in high concentration, cadmium and other chemicals dangerous for health. A better option is the PP used in a wide variety of applications.

The system used to remove the water is another component of the EAHX. While the air is passing through the tube, water vapours condense on the inner surface, turning into small drops. If the water remains inside the channels, a perturbation of airflow appears and the quality of the air is affected by growth of bacteria and fungi. There are two possibilities to remove the water from the inside of the collector. The first solution, that involves a condensation tower, is adopted for houses without basement. In this configuration, a condensation tower and a pump shaft deal with the water which results when the air is cools inside the pipe. The second solution, adopted for the houses with basement, has a siphon placed at the lowest point of the installation to drain the condensate.

There are two types of ground heat exchangers: the traditional one with air as a working fluid and a second one with water.

The second type also called brine to air heat exchanger has four main components: an underground pipe, a brine to air heat exchanger, a control device and a pump. Usually, the length of the pipe in meters is half of the air volume in m^3/h. In the brine to air heat exchanger, the heat taken from the ground is transferred to the fresh ventilation air.

3. Earth to air heat exchanger of Politehnica House

The investigated system is implemented within an experimental house built in the campus of the University Politehnica of Bucharest. The house is built in order to meet the conditions required by the passive house standards. One of these requirements refers to the energy demand for space heating, which must not exceed $15kWh/m^2/year$. In order to achieve this goal, several solutions must be adopted.

The Politehnica House is very well insulated and has a very tight envelope. In this case, due to the high level of insulation, there is no air leakage and the outside air does not enter the house uncontrollably. A mechanical ventilation system (MVHR) is absolutely necessary to supply the fresh air and to remove the exhausted air.

To reduce energy consumption for heating, the air is preheated in two steps: first in the ground heat exchanger and the second in a heat recovery unit connected to the geothermal system.

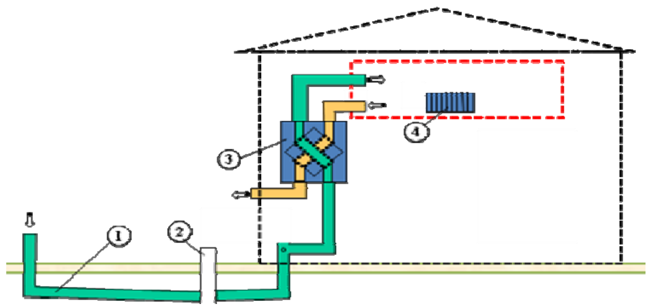

Fig. 1. The HVAC system of the Politehnica House
1-earth to air heat exchanger ; 2- condensation tower ; 3- MVHR unit; 4-electric radiant panel

The material chosen for the geothermal collector is a high density PP. This is called Awaduct Thermo and is provided by Rehau. On the inner surface of the collector, very small particles of silver are incorporated during a special process. As it is known, the silver particles have an antimicrobial effect.

The chosen pipe has an outer diameter of 200 mm and a wall thickness of 7.8 mm. The tube has an enhanced thermal conductivity (0.28 W/m/K) to ensure a better heat transfer between the air and the ground.

After passing through the geothermal collector, buried at 2 m below ground surface, the fresh air enters a heat recovery unit. A double flux heat recovery unit installed in the house is connected to the EAHX. A volume flow (165 m^3/h) is drawn inside the geothermal system by a fan.

In the winter, an electric auxiliary heater placed after the heat recovery is turned on and heats the fresh air.

The configuration of the EAHX pipe from the Politehnica House is shown in the fig. 2. To benefit of the heat regeneration of the ground provided by sun, the main side of the tube is buried on the east side of the building in an unshaded area. In the fig. 3 a picture from the installation of the main side of the EAHX is presented. The air intake can be seen in the background.

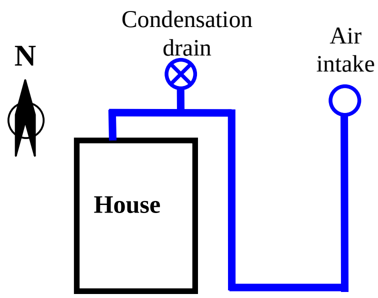

Fig. 2. Configuration of the earth to air heat exchanger

Fig. 3. Installation of the main side of EAHX tube

4. Scheme of the HVAC system connected to the house

In order to find out the thermal load of the house, simulations are carried out using TRNSYS software.

First, a project of the house is made in TRN build. This software requires a high number of thermal and geometrical properties of the house. A few of these parameters refer to the thickness and the thermal conductivity of the walls.

In order to reduce as much as possible the heat loss, the walls of the building were very well insulated. Materials such as the mineral wool and polystyrene which are among the best insulation materials were used to build the envelope of the house. The properties of the materials used to insulate the walls are presented in table 1.

Table 1

Properties of the insulation materials

Wall type	Insulation material	Thickness [mm]	Thermal conductivity [W/m.K]
Roof	mineral wool	400	0.034
Outside walls	mineral wool	300	0.034
Floor slab	mineral wool	150	0.034
	XPS polystyrene	180	0.04

The house has triple glazing windows with very low heat transfer coefficient (U=0.7 W/m^2.K) and low solar heat gain factor (g=0.5.) The windows glass is covered with a low E layer and bio cleaner layer. The space between the glass layers is filled with argon (90%) and air (10%).

In TRNSYS, each component of the studied system is represented by a "type". Every type is described by a mathematical model. The connections between the elements are defined in accordance with the influence between them. The TRNSYS diagram corresponding to the air heating system presented in fig. 1 is illustrated in fig. 4.

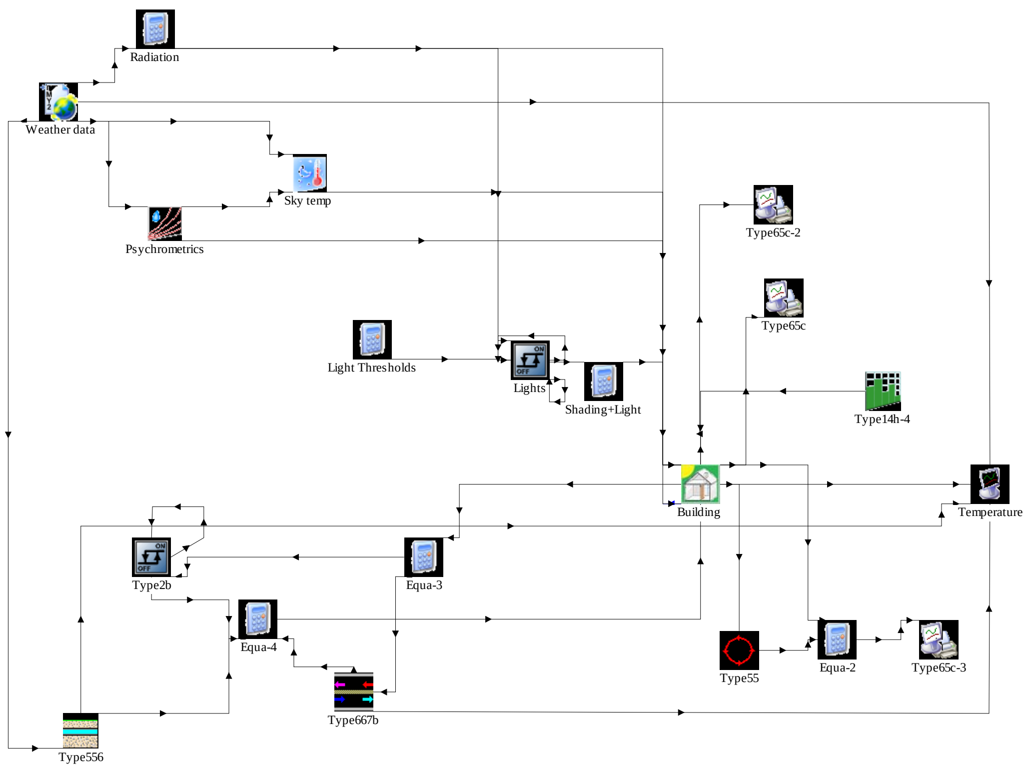

Fig. 4. Scheme of the HVAC system created in Simulation Studio(TRNSYS)

Each component of the HVAC system is represented by a type: type 556 for the EAHX, type 3a for the fan and type 667 for the MVHR.

5. Contributions of the earth to air heat exchanger to the thermal load of the house

The first simulation was carried out taken into account only the MVHR unit. The MVHR unit also has a great role in reducing the thermal load of the house. The value obtained for the thermal load after the first simulation is 13.8

kWh/m^2/year. According to the second simulation (fig. 5), the thermal load is reduced with 2.4 kWh/m^2/year due to the EAHX.

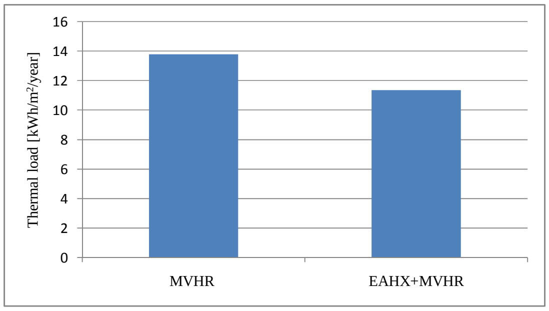

Fig. 5. Comparison between thermal loads

A heating peak demand around 8,5 W/m^2 is obtained in January and December at outside temperature lower than -13 ºC. Compared with the value calculated in the first case (air preheated only by the MVHR unit), this one is reduced with more than 20% due to the EAHX (fig. 6).

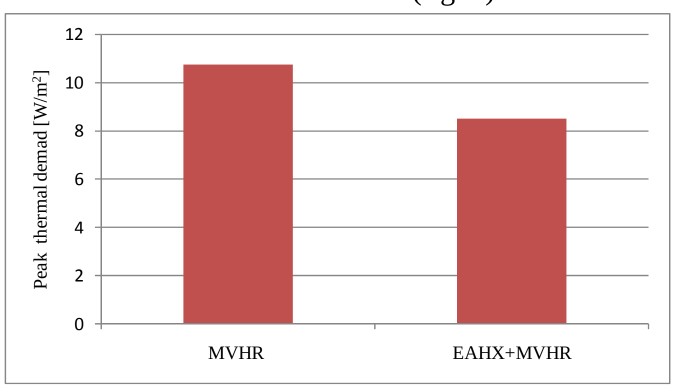

Fig. 6. Comparison between peak thermal demands

6. Simulations of the earth to air heat exchanger in the cooling season

In order to emphasize the importance of the EAHX using during the cooling season, the first simulation is performed without connecting it with the MVHR unit. The result of this simulation shows (see table 2) high temperatures inside the most important zones of the house. The system comprising the EAHX and the MVHR unit reduces these temperatures with more than 1.5 ºC. In this case, the use of a by-pass for the MVHR unit is the viable solution in order to obtain the thermal comfort inside the house. According to results presented in table 2 the highest temperatures are under 26^{o}C.

Table 2

Results of the simulation performed in the cooling season

	Thermal zone			
	Living + kitchen	Bedroom 1	Office	Bedroom2
Orientation	south	east	east	east
MVHR	30.6	30.4	30.2	29.7
EAHX + MVHR	29	28,9	28.7	28.2
EAHX + MVHR (by pass)	25.5	25.4	25.7	25.3

6. Conclusion

The TRNSYS simulations carried out for heating season show a great potential of this geothermal system in reducing the thermal load. The EAHX is suitable not only for heating the house but also for cooling it in the summer. In the summer, the best solution to maintain the inside air temperature under 26 ºC consists in using the EAHX and applying a by-pass for the MVHR unit. According to these simulations, the Politehnica House achieves the passive house standards with the help of geothermal energy and air-to-air heat recovery.

Acknowledgements

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