ENERGY EFFICIENCY AND INTERIOR COMFORT OF THE BUILDING WITH PASSIVE GEOTHERMAL HEATING IN TEMPERATE CLIMATE

Ismail Arroub[1*], Ahmed Bahlaoui[1], Soufiane Belhouideg[1]

[1,]Team of Applied Physics and New Technologies (EPANT), Polydisciplinary Faculty, Sultan Moulay Slimane University, Beni Mellal, Morocco,ismail.arroub@gmail.com, 0000-0003-4263-2877, 0000-0003-2949-8618

ABSTRACT

The objective of this work is to analyze the energetic efficiency of an individual building including an area of 109 m2 multi-zone, located in the region of Beni Mellal, Morocco, which is characterized by a very hot and dry climate in summer and a quite cold one in winter, by passive heating techniques. This study was performed using TRNSYS simulation software during the winter period of typical year. Our simulation consists in developing a comparative study with or without an earth-air heat exchanger (EAHX), in order to determine the best thermal performance. Our work aims to reduce the energy demand for heating and to improve the thermal comfort of the building by reducing the hours of under cooling. The results of the simulations show a significant potential for air heating. Indeed, for the coldest day of January (retained for this study), when the outside temperature is 2 °C, the heated temperature after using the EAHX in the studied area of the building is 11.5 °C. Moreover, the EAHX is an efficient system for building air heating in temperate climate like in Beni Mellal region.

Keywords: *Energy efficiency, building, earth-air heat exchanger, passive heating, TRNSYS*

1. INTRODUCTION

In recent years, the environmental concerns and limited convectional resources have led to identifying alternative sources of energy such as hydro, wind, magneto hydrodynamic (MHD), geothermal, ocean power, solar energy. Geothermal technologies can lead to important energy savings mainly related to heating and cooling in buildings. It is well known that the use of ground coupled heat exchanger leads to an efficient, economical, environmentally friendly design. For this reason, the use of geothermal systems has been extensively analyzed in the literature, especially for the improvement these systems can lead to heat and cool the buildings [1].

To supply comfortable Circumstances in the Buildings of sufficient ground space, a passive technology of cooling or heating, known as an EAHX can be utilized efficiently and effectively. It is also nominated earth tube heat exchanger, ground source heat pump, ground tube heat exchanger or Canadian well. The idea of utilizing ground thermal inertia for air conditioning is not a new method, but a modified concept that goes back to the last decades. The air used is oftentimes outside air for ventilation, but also rentable for totally or partially managing the construction thermal loads. The climatic conditions affect strongly the system performances.

The performances of EAHXs are evaluated numerically or experimentally [2,3], and in particular [4]. reports an analysis of data monitoring campaign on an EAHX system installed in a school building, in order to evaluate the influence of the EAHX system on soil temperature. However, Morshed et al. [5] developed two GAHE systems (one in dry soil and the other in wet soil using a dripping arrangement) and observed tha t the coefficient of performance of wet GAHE system is 20.9% higher than dry GAHE system. Similarly, Agrawal et al. [6,7], compared the performance of dry GAHE system and wet GAHE system and found that the performance of wet GAHE system is better than dry GAHE system in winter as well as in summer season.In the paper, the geothermal system for a residential user has been investigated through dynamic simulation performed using a model developed in TRNSYS software [8]. Therefore, we analyze the effect of integration the EAHX in a building for the coldest period (January 2020) in city of Beni Mella

2. METHODOLOGY

2.1. Weather data and location

The meteorological data used in this study were taken from a typical year weather file for the city of Beni Mellal, (32.36°N, -6.4°E). The atmospheric temperature is presented in figure 1, for the month of January of 2020. The ambient temperature of this month varies between 2.1 °C and 24.9 °C which are the lowest and highest temperatures observed during this period at 13th and 26th of January respectively. The large amplitude of the temperature perturbations is the characteristic of a hot temperate climate.

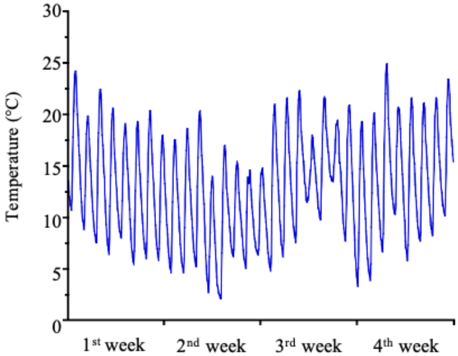

Figure 1. Ambient temperature (°C) for the period from 1st to 31th January.

2.2. Reference building

The studied building, is a detached villa type building, it is located in Beni Mellal and it is North-facing. Figure 2 present 2D architectural plans of the house which dimensions. Its floor area is of 109 m2 with a ceiling height of 2.8 m. The ground floor consists of four bedrooms, a living room, a bathroom, a hall and a balcony as shown in Figure 2.

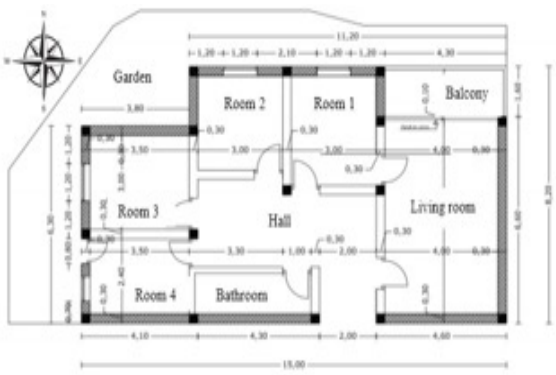

Figure 2. Building 2D plan

2.3. Dynamic simulation models

The dynamic thermal simulation was carried out through TRNSYS which designates Transient System Simulation software to simulate the building. The systems are simulated using components called “types” that are interconnected through time-dependent inputs and outputs. The building was simulated using Type 56 (TRNBuild) and connected to the soil using an Earth-Air Heat Exchanger (EAHX) Type 556 [15]. A time step of 1h was used to reduce computation time.

The building was Split into 7 thermal zones as it is presented in figure 3. Each room was specified as a thermal zone in order to find detailed information on each one of them. The study is made for room 1 and the simulation starts on 1st January and ends on 31th of the same month for the year of 2020.

For the computational study, the effect of the inclination pipe and its vertical parts is not considered into account since the horizontal part of the pipe is long enough. Thus, the EAHX is formed by only 1 pipe of PVC (polyvinyl chloride) with 35 m length. The pipe is assumed horizontal, and inhumed at the mean depth of 2.5 m. The thermo-physical characteristics of the PVC pipe, soil and air at average ambient temperature (20 °C) are reported in Table 1.

Table 1. Physical properties

	Thermal conductivity (W/m.K)	Specific heat (kJ/kg.K)	Density (kg/m^3)
Soil	1.4	1.3	1400
Air	0.025	1.01	1.16
PVC	0.17	1.3	1400

3. DISCUSSION

In this part, the essential results obtained by means of the dynamic thermal simulations carried out in this study are plotted and discussed in detail. The results concern the variations of the temperature with and without the EAHX in continuous operation over the period of the year 2020 (the month of January of 2020), as mentioned above. It should be noted that the results are presented for the room 1.

Figures 3 illustrate the temperature evolution for the month of January in the room 1, with and without integration of the EAHX. The air temperature in the building has a minimum value surroundings 7 °C in the coldest day localized on January, but with the integration of the EAHX, this temperature undergoes an increase to 12°C. We note that the EAHX could be used also for the air precooling; for example, for the months of June and July, but this aspect is not treated since we are only interested in the building heating.

As a complement, figure 4 present the time evolution of the evaluated temperature, in the studied room, during a typical day of winter (the coldest day of the year) corresponding to January 13th of 2020. It is noted that the minimum / maximum temperature, in the studied room, is obtained for the 13th July and equal to 7.6 °C / 13.5 °C. This affects the thermal comfort zone caused by the lack of heating. The air temperatures obtained, in the room 1, after integration of EAHX is vary within the range of 11.5 °C – 14.8 °C; which gives a fairly significant difference of 3.9 °C between the temperature inside the studied room and that of the heat air (see figure 4).

Note that the ambient air temperature in the outside which occurs at 13th Junuary is 2 °C, while the temperature of the air heated by the EAHX is 11.5 °C; which gives a fairly significant difference of 9.5 °C (see figure 1 and figure 4). Consequently, the above results show that the earth - air heat exchanger is a system more adapted to air heating in the buildings inside Beni Mellal city.

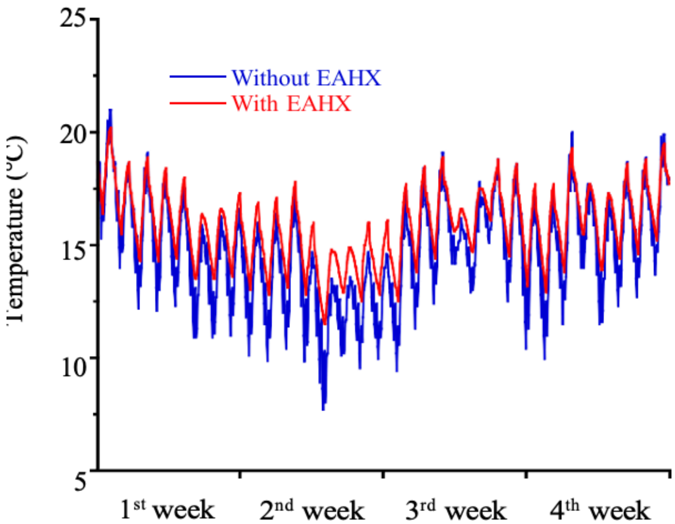

Figure 3. Temperature (°C) inside the room 1 for the period from 1st to 31th January

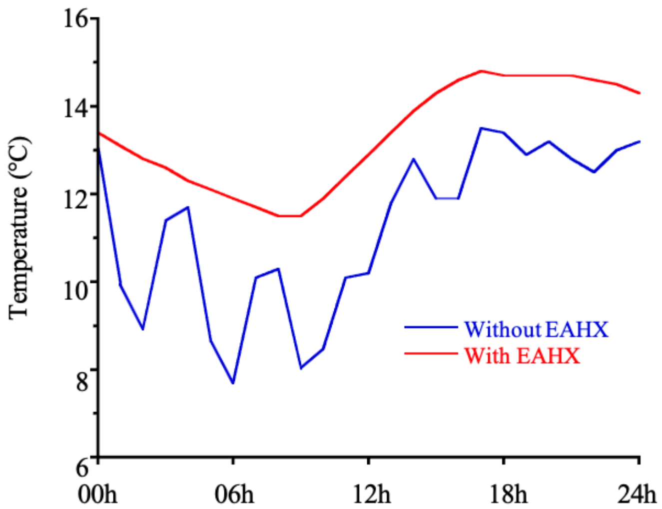

Figure 4. Temperature (°C) inside the room 1 for the coldest days of the year.

4. CONCLUSION

A numerical simulation of a case study of a house located in Beni Mellal (Morocco) was performed. The house was designed to be energy efficient by integrating a passive technique. A numerical model of the house has been developed in the frame of TRNSYS software. A parametric study was conducted to high-light the beneficial effect of Ground-coupled heating method by integration of an earth-air heat exchanger. The results show that the EAHX is an efficient system for building air heating in temperate climate like in Beni Mellal region. The ambient air temperature in the outside for the coldest day is 2 °C, while the temperature of the air heated by the EAHX is 11.5 °C; which gives a fairly significant difference of 9.5 °C.

REFERENCES

[1] D'Agostino D., Mazzarella L., What is a nearly zero energy building? Overview, implementation and comparison of definitions. J. Build. Eng. 2019; 21; 200–212. https://doi.org/10.1016/j.jobe.2018.10.019.

[2] Khabbaz, Mohamed, Benhamou, Brahim, Limam, Karim, Hollmuller, Pierre, Hamdi, Hassan, Bennouna, Amin, Experimental and numerical study of an earth-to-air heat exchanger for air cooling in a residential building in hot semi-arid climate. Energy Build. 2016; 125; 109-121, https://doi:10.1016/j.enbuild.2016. 04.071

[3] Menhoudj, Sayeh, Mokhtari, Abderrahmane−Mejedoub, Benzaama, Mohamed-Hichem, Maalouf, Chadi, Lachi, Mohamed, Makhlouf, Mohammed, Study of the energy performance of an earth—air heat exchanger for refreshing buildings in Algeria. Energy Build. 2018; 158; 1602-1612, https://doi.org/10.1016/j.enbuild. 2017.11.056.

[4] Grosso, Mario and Chiesa, Giacomo, Horizontal earth-to-air heat exchanger in Imola, Italy. A 30-Month- long monitoring campaign. Energy Procedia, 2015; 78; 73-78, https://. doi:10.1016/j.egypro.2015.11.117.

[5] Morshed, W., Leso, L., Conti, L., Rossi, G., Simonini, S., Barbari, M., Cooling performance of earth-to-air heat exchangers applied to a poultry barn in semi-desert areas of South Iraq. Int. J. Agric. Biol. Eng. 2018; 11, 47-53, https://. doi: 10.25165/j.ijabe.20181103.3047.

[6] Agrawal, K.K., Yadav, T., Misra, R., Agrawal, G. Das, Effect of soil moisture contents on thermal performance of earth-air-pipe heat exchanger for winter heating in arid climate: in situ measurement. Geothermics 2019; 77; 12-23, https://doi:10.1016/j.geothermics.2018.08.004.

[7] Agrawal, K.K., Misra, R., Yadav, T., Agrawal, G.D., Jamuwa, D.K., Experimental study to investigate the effect of water impregnation on thermal performance of earth air tunnel heat exchanger for summer cooling in hot and arid climate. Renew. Energy, 2018; 120; 255-265, https://doi.org/10.1016/j.renene.2017.12.070.

[8] Klein, S.A.; Beckman, W.A. TRNSYS 18: A Transient System Simulation Program; Solar Energy Laboratory, University of Wisconsin: Madison, WI, USA, 2017.