J. Mater. Environ. Sci. 5 (5) (2014) 1461-1469
ISSN: 2028-2508
CODEN: JMESCN

Study of the behavior of a heat exchanger Air/Ground: Canadian Well

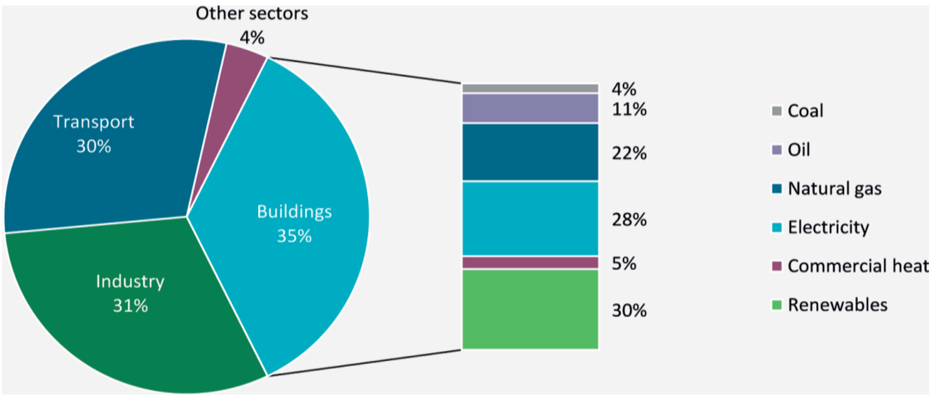
N. Touzani[1*], J.E. Jellal[1], A. Touzani[2]
[1]*Water Treatment Laboratory Civil Engineering, Mohammedia School of Engineering, Rabat, Morocco.*
[2]*Rheology Laboratory and Industrial Energetic, Process Engineering, Mohammedia School of Engineering, Rabat, Morocco.*

Received 25 Jan 2014; Revised 22 May 2014; Accepted 2 June 2014.
[*]*Corresponding Author. E-mail: najiatouzani@emi.ac.ma; Tel: (+212661455509)*

Abstract
The improvement of the energy performance of buildings and the optimization of their design with respect to summer comfort has nowadays become indispensable. Canadian or Provencal wells fit into this context. The principle of such a well is to circulate fresh ventilation air in a buried conduit with a fan, before injecting it into the building. The case study focuses on a Canadian well that has been achieved in a villa in Hay Riad (Rabat), still under construction. Several equipments needed for the study of Canadian wells and construction of thermal modeling aspects in air conditioning / heating of the house were installed. A series of experiments were performed on the facility to evaluate the performance of the Canadian well over an entire year (heating and cooling) as follows: The measurement of changes in soil temperatures at several levels, the extent of outdoor and indoor temperatures, and the gains generated etc...
The modeling of the Canadian well showed several important features of the evolution of soil temperature and the blowing inside the building. The average temperature and its period remain unchanged in depth; the amplitude of the temperature variation decreases exponentially with depth, this decrease is even faster than the pulse is high, the phase shift increases with depth, and the energy gains are important (gains of 10°C were achieved for a fan power of 100W). An energy balance has concluded that the Canadian well adapted well to the city of Rabat which also relies on a favorable water table.

Keywords: Exchanger air / soil, Canadian well, Temperature, Air, Conditioning, Energy performance.

1. Introduction
Globally, the building sector alone accounts for around 35% of final energy consumption and contributes about one-third of CO_2 emissions, as the following graph [1]:



Source AIE, 2010

Figure 1: Final energy consumption by sector and buildings energy mix, 2010

It is estimated that the potential for energy savings in this sector worldwide is around 40%, and largely through cost-effective measures. In Morocco the heating and air conditioning of buildings is about 15% of demand of final energy [2-3]. In this context, the control of energy demand in the building requires above all a neat job of the envelope by combining insulation, sun protection and use of thermal mass [4] .Once these basic measurements are taken, the use of techniques of preheating and passive cooling or low-power auxiliary

take an interest. The concept of Canadian wells allows in principle to meet these two demands: it consists in air flow from the outside to the building, which is forced through a prior record of buried tubes (or equivalent system), the inertia of the soil being used as a seasonal shock absorber. If we look closer, the tension between constraint and climate comfort thresholds, however, induces a fundamental asymmetry between preheating and cooling potential of using soil as buffer stock [6-7]. The aim of our study is to demonstrate the technical feasibility of a Canadian well applied to the city of Rabat. Given the absence of geothermal data, our work was first to conduct surveys of soil temperature on a chosen site, then model the behavior of soil temperature and finally perform measurements on a concrete Canadian well that we made . The principle of the Canadian well is to use the thermal inertia of the soil to heat or cool the external air before introducing it into the house. This is a form of environmental conditioning which allows for substantial energy savings in the house [8-9]. The method is simple: take the air, make it circulate into the soil, where the temperature is constant (10 ° C and 18 ° C depending on the season) and blow it in the house. In summer, the air will be cooled through the difference of temperature. In winter, conversely, it is reheated. The atmosphere inside the housing will be more pleasant in summer and less difficult to heat in winter [10-11].
The different calculations on the evolution of soil temperature at several levels and on the insufflations inside the building perfectly illustrate the benefits that can be drawn from the modeling of Canadian well [12-13]. A site was found (villa located in Hay Riad) where the owner agreed to install our equipments and carry out work in his house which was under construction. This work consisted of installing a network of air distribution inside the house and excavations in the garden. These excavations were to make trenches 2.5 m deep and 40 m long. Then came the phase of installation of equipment (PVC pipes, fans, box etc. ...). Once the work completed, we conducted a series of experiments on the installation.

2. Materials and methods

A Canadian well was built in a villa in Hay Riad (Rabat) under construction. The laying of the pipeline was completed in June 2010 on trenches of 70 cm wide and 2.50m maximum depth. The canalizations used are PVC pipes of 20 cm in diameter and 6 meters in length and rely on a sand bed of 20 cm. Also, one can find different types of pipe: Concrete, Steel, Cast Iron, Polyethylene, Polypropylene (PP) and Sandstone**.**
The embankment was carried out using the excavated land cuttings, screened by a masonry screen.
The total length of the pipe is 30 meters. It starts from the water well constructed in the garden to finish at the building entrance (side Moroccan lounge ground floor). At the deepest point (- 2.50 m) a siphon was placed to drain condensation water which may occur at the level of the pipe. (Figure 3) Below the drain, dry well was carried out using rubble. In fact, during the cooling of outside air once in the pipe, condensation will take place according to the humidity.
This phenomenon occurs especially in summer because hot air stores more humidity than the same volume of cold air. It is therefore necessary during the excavation to pay attention that the slope (1to 3%) is in the same direction as the flow, and provide absolutely smooth pipes.

Figure 2: The trench and pipe lying.

Figure 3: The elbow to the laying of the siphon.

All of the pipe results in a metal box of 0.7 x 0.7 x 0.7 m. this box is manufactured by galvanized sheet metal and insulated by glass wool (sandwich panels). Inside the box a suction fan 100 W equipped with a switch is placed (Figure 4). The box output has two openings: one going to the ground Floor and the other to the first floor of the villa.

Figure 4: The Box for blowing.

The air blown by the fan is circulated through pipes of corrugated aluminum of 100 mm diameter**.** The air inlet must be located away from sources of pollution (roads, parking, trash ...) and high enough to avoid breathing dust.

2.1. The nature of the soil and its moisture

The heat capacity and conductivity of the soil have an important impact on the effectiveness of the system.
These characteristics depend on the composition of the soil and its moisture and water migration within it. The thermal capacity of the soil is the average calorific its various components: minerals, organic matter, air and water. The water has a capacity and a thermal conductivity greater than those of the other constituents of the soil; moist soil is more inertial than dry soil and more easily transmit its heat or cool the air in the pipes of the well. This allows to increase the performance of heat exchangers air / ground. It then suffices to moisten the soil by watering to increase its capacity thermal storage and exchange with the air in the well.
The floor of Rabat is sandy clay type wet well which allows to optimize the amount of energy that can recover well.

2.2. Soil temperature

During the month of June 2010, we recorded the temperature of the soil at various depths. The results are gathered in the following figure. The tests were carried out in the week from 24/04/2009 to 02/05/2009. Temperatures were recorded every 5 minutes.
The results show an evolution in saw tooth for soil temperatures and that of the atmosphere (Figure 5).

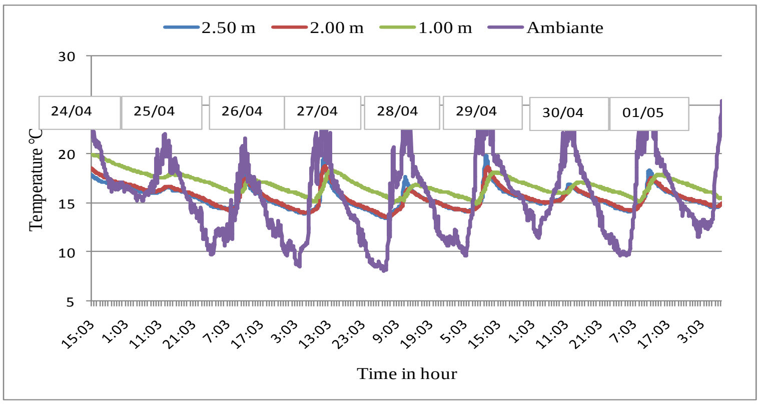


Figure 5: The evolution of soil temperature during one week of may 2009

Soil temperature is more stable than that of the atmosphere. These temperatures have the characteristics summarized in the table 1.

Table 1: Soil temperature and the atmosphere temperature in°C

TEMPERATURE	Minimum	Maximum	Average	Amplitude
Ambient Temperature	8.1	25.5	15.5	17.4
Temperature at -1,00 m	14.9	19.9	16.7	5
Temperature at -2,00 m	13.6	18.8	15.5	5.2
Temperature at -2,50 m	13.5	18.4	15.5	4.9

And after these results we see that soil temperatures are more stable than the ambient temperature. From 2.00 m, there is no significant temperature variation. A depth of 2.00 m for the Canadian wells is sufficient.

2.2. Modeling Thermal structure of the soil model

The floor model considered here has been widely used in the literature (MIHALAKAKOU et al, 1977. Benkert et al, 1997.) . It quite simply is to consider the soil as a semi- infinite solid, surface excited by a sinusoidal signal temperature. In fact, in this model, the solutions are sinusoidal as well with the same period and excitation as the temperature signal but whose phase and amplitudes vary with the depth considered. Overall, the greater the depth, the greater the sinusoidal signal is muted and delayed. The analytical solution of this Model is established. The propagation model of heat conduction in a semi-infinite solid proposes an analytical solution when the surface temperature of the solid is sinusoidal. Accordingly, all the stresses of the problem must be reduced to constant or sinusoidal functions of time. The outside air temperature, T**air** will be conveniently expressed

$$T_{air}(t) = m + A \sin(\omega t - \tau) \quad (1)$$

m: mean period temperature

A: amplitude of the temperature variation

ω : Pulsation.

τ : Phase shift

By fitting equation (1) with the experimental results, we obtain the following values:

m: mean period temperature =16 °C.

A: amplitude of the temperature variation =7.9 °C

ω : Pulsation= 4, 42254 .10^{-3}

τ : Phase shift =- 1.61479

Equation (1) become

$$Tair(t) = 16 + 9.7 \sin(t \times 0.00442254 - 1.61479) \quad (2)$$

The results of this simulation are shown in the figure below (Figure 6).

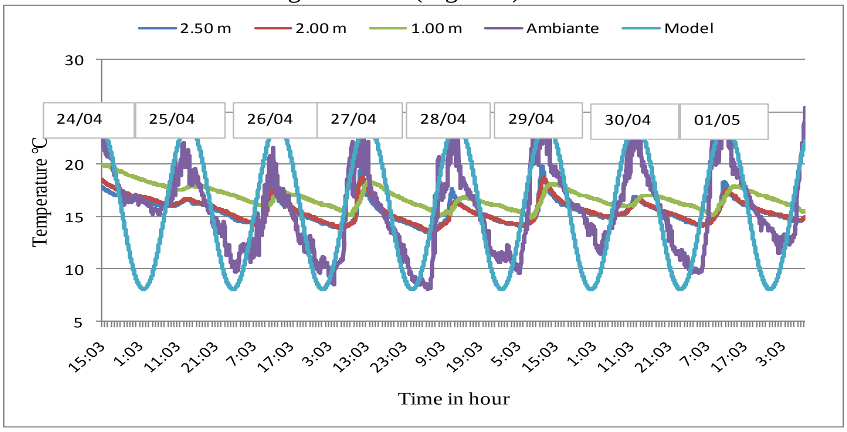


Figure 6: Simulation of the soil temperature and ambient temperature

By solving the heat equation for a transient semi-infinite environment whose surface temperature is Imposed by equation (1) we obtain the temperature function of depth.

$$Tsoil(x, t) = m + Ae^{-x\sqrt{\frac{\omega}{2\alpha}}} \sin(\omega t - \tau - x\sqrt{\frac{\omega}{2\alpha}}) \quad (3)$$

With

- α: thermal diffusivity (k / ρ.C)
- k: thermal conductivity en W / (m.K)
- ρ: density of soil in kg/m^3
- C: specific heat capacity of the soil in J / (kg.K)

The simulation results are shown below (Figure 7)

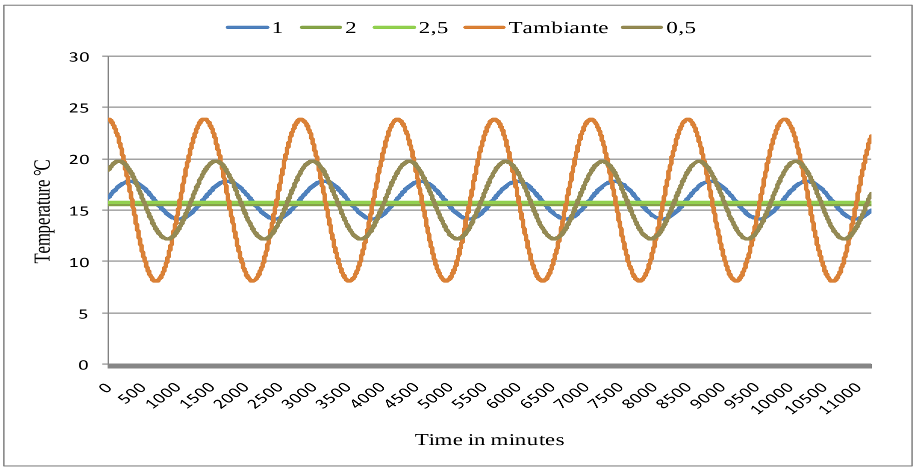


Figure 7: Simulation of soil temperature

Soil temperature follows a sinusoidal variation. It is found that the temperature penetration in the ground decreases with depth which is in perfect agreement with the logic as the attenuations are much larger gradually as the depth increases (temperature variations are much lower than the depth of the system is important. In these conditions, the depth to be used in our study is 2 meters.

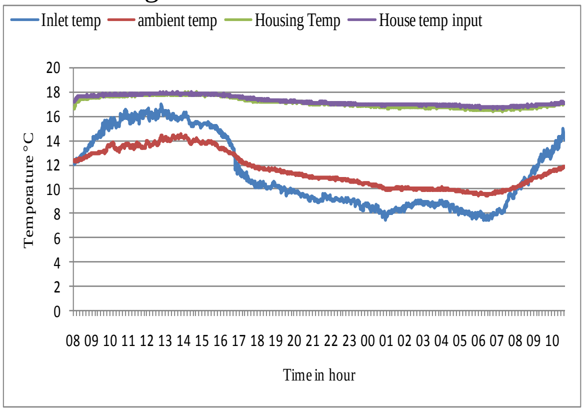
3. Blowing tests

Tests were performed on blowing several days to determine the temperature profiles at various locations:
- Ambient Temperature.
- Inlet temperature of the Canadian well.
- Temperature in the chamber (outlet Canadian well).

3.1. Test N°1

Winter

The first test was conducted during two days of December 2011(03 and 04 December). Temperature profiles are shown in figure below:



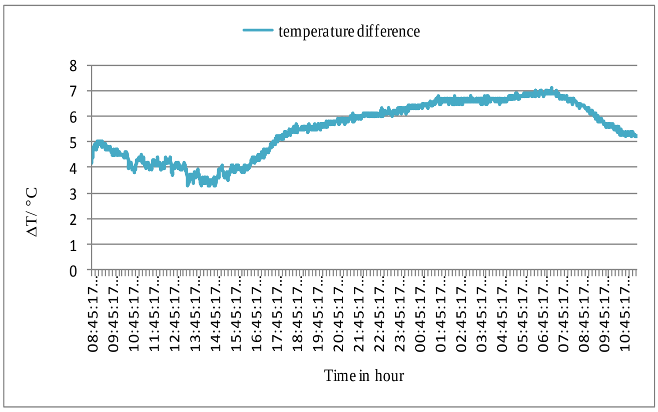


Figure 8: Profile of 03 and 04 December 2011 **Figure 9:** Temperature difference (03 and 04 December 2011)

We notice that the ambient temperature fluctuates with an amplitude peak to peak of 8.5 ° C with an average of 11.6 ° C while blowing air into the house fluctuates with an amplitude of 1.5 ° C and a average of 17.1 ° C. The temperature difference between ambient air and air blown varies from 3.4 to 7 ° C. The minimum is reached during the day at 14h00 while the maximum is reached during the night at 19h00 (see figure below)

3.2. Test N°2

The second test was conducted during two days of January 2012(31January and 01 February). Temperature profiles are shown in figure below.

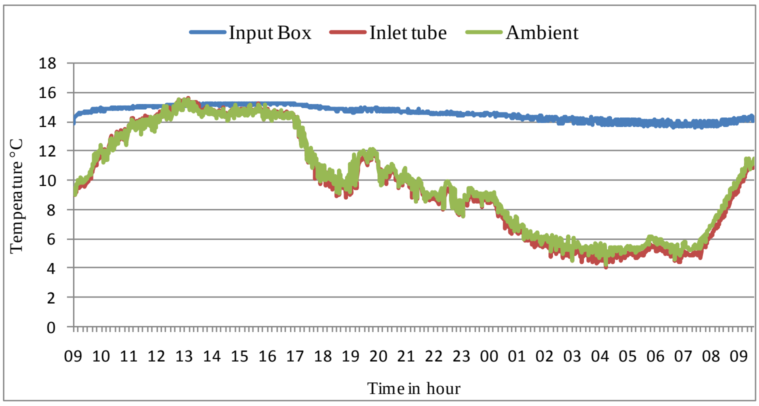


Figure 10: Profile of 31 January 2012 and 1 February 2012.

We notice that the ambient temperature fluctuates with a peak to peak amplitude of 11°C with an average of 9.9°C while blowing air into the house fluctuates with an amplitude of 1.0°C and a average of 14°C.
The temperature difference between ambient air and air blown varies from 0 to 10°C. The minimum is reached during the day at 13.10 while the maximum is reached during the night to 5am (Figure 11)

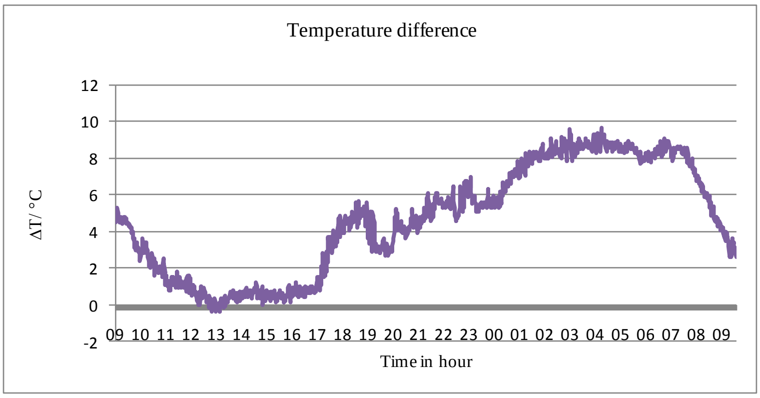


Figure 11: Temperature difference (31 January and 01 February 2012).

3.3. Test N°3
The third test was conducted for six days of February 2012 (from 05 January to 01 February). Temperature profiles are shown in figure below:

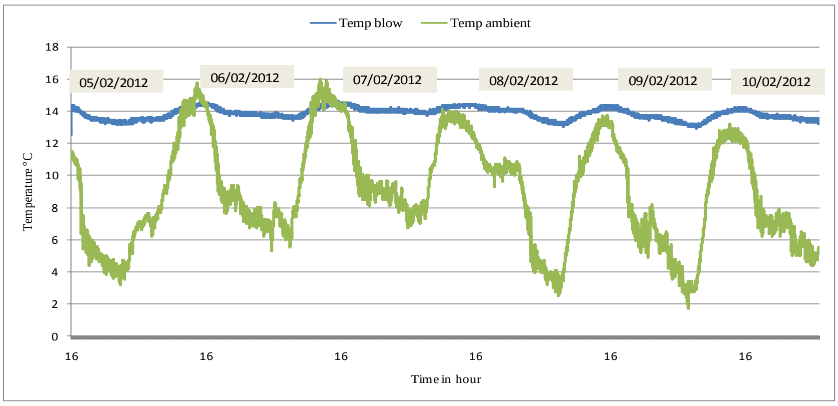


Figure 12: Temperature profile (from 05/02 to 11/02/2012)

We notice that the ambient temperature fluctuates with peak to peak amplitude of 12.5°C with an average of 8.9°C while blowing air into the house fluctuates with an amplitude of 1.5°C and an average of 13.8°C.
The temperature difference between ambient air and air blown ΔT varies from 0 to11°C. The minimum is reached during the day at 13h while the maximum is reached at night between 3 and 4 h (Figure 13)

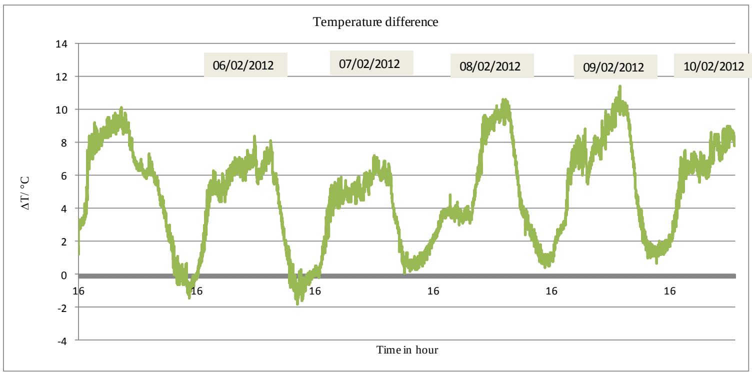


Figure 13: Temperature difference (from 05/02 to 11/02/2012)

3.4. Test N°4

Springer

The fourth test was conducted for two days of April (26 and 27 April) 2012. The temperature profiles are shown in Figure 14.

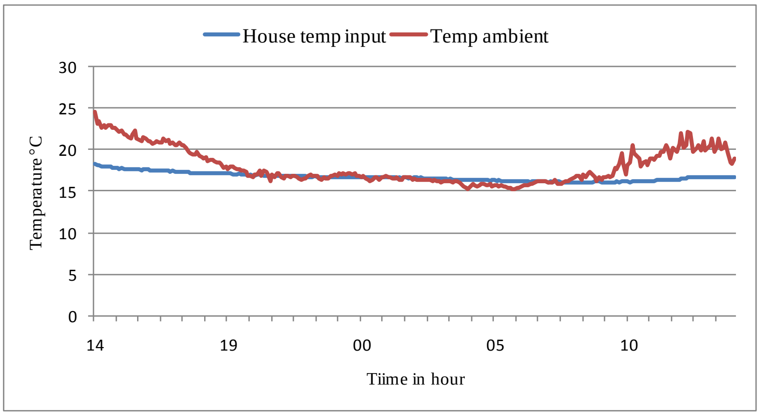


Figure 13: Profile of 26 and 27 April 2012

These records the ambient temperature fluctuates with a peak to peak amplitude of 10 ° C while blowing air into the house fluctuates with an amplitude of 2 ° C and an average of 15.5 ° C. It is noticed after the temperature difference between ambient air and the supply air varies from -1 ° C to 5.2 ° C. The minimum is reached overnight at 05h while the maximum is reached during the day between 13 and 14 h (Figure 14).

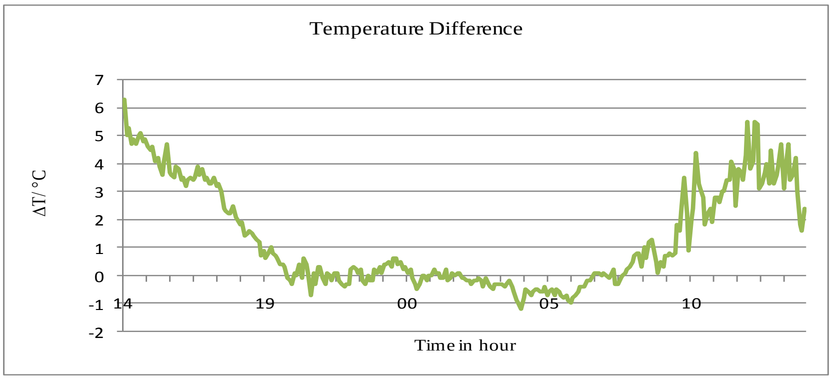


Figure 14: Temperature difference (from 26/04 to 27/04/2012)

3.5. Test N°5

Summer

The fifth test was conducted for four days of August 2013(from 12 to 16 August). Temperature profiles are shown in figure below (Figure 15)

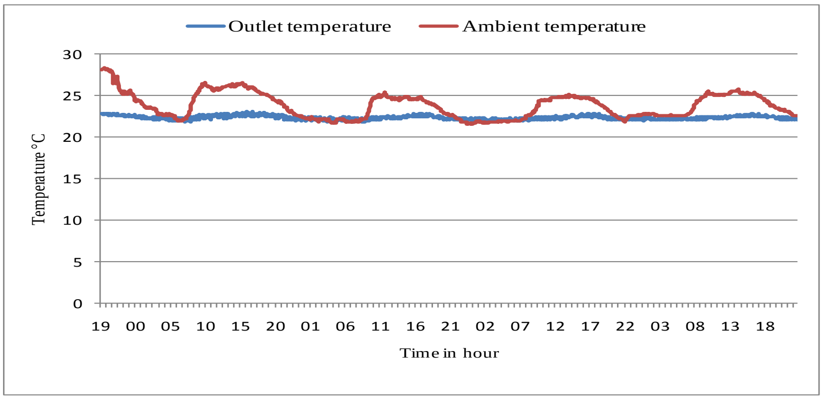


Figure 15: Temperature profile (from 13/08 to 16/08/2012)

We notice that the ambient temperature fluctuates with a peak to peak amplitude of 7°C with an average of 3.6 °C while blowing air into the house fluctuates with an amplitude of 5.4°C and a average of 1.64C.The temperature difference between ambient air and air blown varies from 0 to 8°C. The minimum is reached during the day at 06 h while the maximum is reached at day between 15 and 16 h (Figure 16).

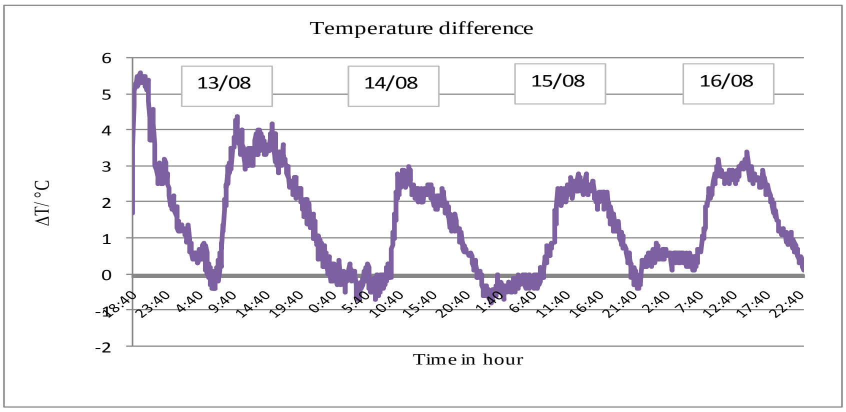


Figure 16: Temperature difference (from 13/08 to 16/08/2012)

From these tests we may make the following conclusions:
For the winter season:
• The winter season can always gain energy and this 24h/24.
• The difference in temperature between the ambient air and the blowing air is between 0 and 11 ° C.
For the spring season:
• The spring season provides an energy gain only during the day and this between 7am and 18h.
• The temperature difference between ambient air and the blowing air is between 0 and 5 ° C.
For the summer season:
• The summer season can always gain energy and this 24h/24.
• The difference in temperature between the ambient air and the blowing air is between 0 and 8 ° C.

Conclusions and recommendations

The advantage of the air-ground heat exchanger is important, as it improves throughout the year, thermal conditions sought. Whether used in heating mode in winter or cooling in summer, it operates effectively on the amortization of thermal amplitudes.This system promotes a comfortable ambience for individuals limiting thermal stresses. The profitability of the exchanger can be reached. It allows a more homogeneous atmosphere in terms of temperature and gain in growth and feed efficiency. The results are used to understand the functioning of the air-ground heat exchanger during the season so we can draw the following conclusions:

One can argue that the ground in Rabat also based on a body of water is favorable for the installation of Canadian well, the soil is clay sandy and wet as water and organic matter are higher than that of minerals so moist and rich in organic matter soil heat capacity elements store the heat better than dry soil rich in minerals.

The thermal conductivity of a soil depend not only its composition but also the disposition and shape of its constituent particles, bonds between these particles and the water content of the soil will be more heat conductor it will be wet. The thermal conductivity of soil can vary over time, particularly in response to changes in water content due to climate variations and change of season. The gain in temperature is quite encouraging: we averaged 8 ° C in winter which allows saving energy in the heating and averaged 4°C in summer which allows saving energy in the cooling.

Acknowledgements-This research was conducted in the laboratory of water Treatment G.Civil and Laboratory of Industrial Energy Process Engineering School of Engineers Rabat Mohammedia; it was supported by the Agency (ADEREE). I want to thank all those who have contributed directly or indirectly to the completion of this work, in particular: Jamal Eddine.JELLAL, supervisor, Professor of Higher Mohammedia School of Engineers and Abdellatif TOUZANI Co supervisor Professor of Higher Mohammedia School of Engineers, who proposed me about teaching education thesis, which was attended by the realization of this Canadian wells in June 2010 and which have guided my thoughts throughout these four years. I am particularly grateful for the confidence they have placed in me, for all the time they spent in proofreading early drafts of this thesis, for their advice that I have learned a lot about the profession of researcher and working methods. A special thanks to the owner of the villa which has agreed to install equipment and carry out work in his house that was under construction.

References

1. *Transition to sustainable building -Strategies and Opportunities to* 2050, IEA, ISBN 978-92-64-20241-2 (2013).
2. Bensmail.O. *Réglementation thermique Bâtiment Maroc*, (2012).
3. Al-Ajmi E., Loveday D. *Building and Environment*. 41 (2006) 235.
4. Amitrano D. *Science de la nature*. Université, J Fourier, Grenoble (2006).
5. Badescu V. *Renewable energy*. 32 (2007) 845-855.
6. Bansal.V., Misra.R., Das Agarwal.G., Marthur.J. Applied Energy. 103 (2013) 1-11.
7. Bojic M. *Renewable Energy*. 20 (2000) 453-465.
8. Bojić M., Trifunović N., Papadakis G., Kyritsis S. *Energy*. 22 (1997) 1151-1158.
9. Badescu V., Sicre B. *Energy and Buildings*. 35 (2003) 1077-1086.
10. CETIAT. *Les puits canadiens/provençaux*, Guide d'information, (2008).
11. De Paepe M., Janssens A. *Energy and Buildings*. 35 (2003) 389-397.
12. *Direction de la météorologie Nationale, Zonage climatique du Maroc destiné à la réglementation de thermique de bâtiment*, (2010).
13. Gauthier C., Lacroix M., Bernier H. *Solar Energy*. 60 (1997) 333-346.
14. Ghosal M.D., Tiwari G.N. *Energy Conversion and Management*. 47 (2006) 1779-1798.
15. Hollmuller P., *Utilisation des Echangeurs Air-Sol pour le Chauffage et le Rafraîchissement des Bâtiment*.Université de Genève. Thèse de doctorat. (2002) 125.
16. Hollmuller P., Lachal B. *Energy and Buildings*. 33 (2001) 509.
17. Kunetz J., Lefebvre L. Rapport de projet tutoré de 5ème année. INSA de Toulouse. (2004) 54.
18. François D., Vuataz. ADER,.L'énergie au futur. (2002).
19. Loyau F., *Puits canadien et ventilation basse énergie, principe et réalisation*. (2009).
20. Mihalakakou G.,Santamouris M., Asimakopoulos D. *Solar Energy*.53 (1995) 301-305.
21. MihalakakouI G., Santamouris M., Lewis, J.O., Asimakopoulos, D.N. *Solar Energy*. 60 (1997) 181-190.
22. Moummi N., Benfatah H., Hatraf N., Moummi A., Yousef Ali S. *Energies Renouvelables* 13.(2010) 399
23. Romuald J., *Le puits canadien ou puits provençal*. (CETE) (2005).
24. Serres L., Trombe A., Conilh J.H. *Building and Environment*. 32 (1997) 137-148.
25. Thiers S., *Bilans Energétiques et Environnementaux de Bâtiments à Energie Positive*. Thèse de Doctorat, Ecole Nationale Supérieure des Mines de Paris (2008).
26. Thiers S., Peuportier B. Journées thématiques SFT-IBPSA. France (2007).
27. Tzaferis., Liparakis D., Santamouris M., Argiriou A. *Energy and buildings*. 18 (1992) 35-43.
28. Zweifel G. *Hochschule für Technik+Architektur Luzern (HTA Luzern). How*. 6 (2004).

(2014) ; http://www.jmaterenvironsci.com