STUDY OF AN AIR CONDITIONING AND HEATING SYSTEM INCORPORATING A CANADIAN WELL IN CONTINENTAL AREAS, CASES OF RABAT

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ABSTRACT

The area of energy-intensive building is a very important part of energy consumption (30%) and greenhouse gas emissions. Reducing energy consumption is urgent, not only for environmental reasons but also for economic reasons. Then we must now build a different energy future in the construction industry to do the experts say that we must now radically reduce the energy bill by insisting on the following two principles:

• Build respecting bioclimatic architecture;
• The involvement of renewable energies.

In this context, we have demonstrated the technical feasibility of a ground source system applied for the first time in the city of Rabat. Our work consisted firstly to conduct surveys of soil temperature on a site selected, then model the behavior of soil temperature and finally perform measurements on a concrete project of Canadian well done by us during the year.

In conclusion, arguably the ground Rabat also based on a body of water is favorable for the installation of pipe system. The temperature increase is quite encouraging: we averaged 8 °C in winter, allowing energy savings in heating and an average of 4 °C in summer, thereby saving energy in the cooling.

Keywords: Canadian Well, Temperature, Soil, Conditioning, Saving Energy, Modeling.

INTRODUCTION

Globally, the building sector alone accounts for around 35% of final energy consumption and contributes about one-third of CO2 emissions.

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. 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.

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.

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 project of 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.

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.

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\textsuperscript{11,12}. 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.

**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 2.50 m 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 to the slope (1\% to 3\%) in the sense of the flow, and provide absolutely smooth pipes.

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 3). The box output has two openings: one going to the ground Floor and the other to the first floor of the villa.

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. 

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 4).

![Figure 4: The evolution of soil temperature during one week of May 2009](image)

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

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temperature</td>
<td>8.1</td>
<td>25.5</td>
<td>15.5</td>
<td>17.4</td>
</tr>
<tr>
<td>Temperature at -1,00 m</td>
<td>14.9</td>
<td>19.9</td>
<td>16.7</td>
<td>5</td>
</tr>
<tr>
<td>Temperature at -2,00 m</td>
<td>13.6</td>
<td>18.8</td>
<td>15.5</td>
<td>5.2</td>
</tr>
<tr>
<td>Temperature at -2,50 m</td>
<td>13.5</td>
<td>18.4</td>
<td>15.5</td>
<td>4.9</td>
</tr>
</tbody>
</table>

And after these results we see that soil temperatures are more stable than the ambient temperature. A depth of 2.00 m for the Canadian wells is sufficient.

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, $T_{\text{air}}$ will be conveniently expressed

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

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

$m$: mean period temperature

$A$: amplitude of the temperature variation

$\omega$: Pulsation.

$\tau$: Phase shift

The results of this simulation are shown in the figure below (Figure 5).
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.

\[ T_{soil}(x, t) = m + Ae^{-\frac{x^2}{2\alpha}} \sin(\omega t - \omega \frac{x}{\sqrt{2\alpha}}) \quad (3) \]

With
- \( \alpha \): thermal diffusivity \( (k / \rho \cdot C) \)
- \( k \): thermal conductivity \( \text{en W} / \text{(m.K)} \)
- \( \rho \): density of soil in \( \text{kg/m}^3 \)
- \( C \): specific heat capacity of the soil in \( \text{J} / \text{(kg.K)} \)

The simulation results are shown below (Figure 6)

Soil temperature follows a sinusoidal variation. It is found that the ground penetrating diminish temperature 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.

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).

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:
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).

2. Test N°2
The second test was conducted during two days of January 2012 (31 January and 01 February). Temperature profiles are shown in figure below.

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 10)
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:

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 ∆T varies from 0 to 11°C. The minimum is reached during the day at 13h while the maximum is reached at night between 3 and 4 h (Figure 12).

4. Test N°4

The fourth test was conducted for two days of April (26 and 27 April) 2012. The temperature profiles are shown in Figure 13.
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).

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)
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 1.64°C.

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).

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.

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