THE EFFECT OF WIND VELOCITY AND NIGHT NATURAL VENTILATION ON THE INSIDE AIR TEMPERATURE IN PASSIVE COOLING IN ARID ZONES THE EFFECT OF WIND VELOCITY AND NIGHT NATURAL VENTILATION ON THE INSIDE AIR TEMPERATURE IN PASSIVE COOLING IN ARID ZONES

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ABSTRACT

The effect of wind velocity and night natural ventilation in lowering the inside daytime air temperature in passive cooling in arid zones, were investigated by numerical calculations and experimental means for different values of air change flow rate due to infiltrations and natural ventilation and different wind speed. The numerical calculations based on the inside outside air temperature, wind speed, cracks and openings dimensions to determine the volume of air change per hour.
The experimental model was a test cell with door facing north and window in the opposite side facing south, the volume of the model was 9m³. The calculated and measured results show that 1.8 volume per hour of air change flow rate and 2m/s wind speed show a high concordance between calculated and measured inside air temperature, and can lower the inside air temperature by 3°c to 4°C compared to non ventilated test cell (Bencheikh & Bouchair 2004) .

Key words : Wind velocity, night natural ventilation, passive cooling, arid zones,

1. INTRODUCTION

Night natural ventilation potential for improving thermal comfort in buildings has been investigated by numerical and experimental means, (Santamouris and al. 1996 1997) introduced an interested method to calculate the energy contribution of night ventilation technique to the cooling load of a building. Many researchers investigate the improvement of space cooling by night natural ventilation such as: (Kolokotroni and al. 1998) used temperature and humidity charts to generate a pre-design tool for summer cooling evaluation of night ventilation. (Geros et al. 1999) carried out an experimental evolution of night ventilation effect on the inside air temperature for four buildings and simulations investigation to determine the effect of air change rate on night natural ventilation. (Givoni 1998) carried out experiment work to investigate the effectiveness of night ventilation in lowering the indoor day time temperature and many other researchers' worked on the same subject. This paper

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focuses on numerical calculation and experiment work to validate the theoretical results, on night natural ventilation effect in lowering the daytime inside air temperature.

2. NUMERICAL MODEL

2.1. Air flow rates calculation

Air flow into buildings is either by infiltration of outside air through cracks around exterior openings, or by natural ventilation through opened exterior openings. Any outdoor air that enters by way of infiltration or ventilation is assumed to be immediately mixed with inside air.

2 .1. 1 Infiltration

The determination of the amount of infiltration air is quite complicated and subject to significant uncertainty. The infiltration quantity is converted from a number of air change by hour (ACH) and unclouded in the inside air heat balance using the outside air current simulation time step.
There are three models for estimating the infiltration flow rate. The first is the design flow rate, the second is the effective leakages area base on (Sherman and Grimsrud 1980) , and the third is the flow coefficient model based on (Walker and Wilson 1998).

Infiltration design flow rate

The flow of air from the outside environment directly into the inside one is generally caused by cracks around exterior openings, temperature differences and wind speed. The basic equation (Coblens and Achenbach 1963) used to calculate infiltration.

$$Infiltration=(Inf_{design})(F_{schedule})(A+B)(T_{ai}-T_{ae})[CV+DV^2)] \quad (1)$$

Infiltration effective leakage area

Infiltration leakage area model is based on Sherman and Grimsrud [7]

$$Infiltration=(F_{schedule})\frac{A_i}{1000}\sqrt{C_s\Delta T+C_wV} \quad (2)$$

Where

$F_{schedule}$ is a value from the user-difined scheduls.

A_i is the effective air leakage area in cm² that corresponds to a 4Pa pressure differential.

C_s is the coefficient from stack-induced infiltration in $(\frac{L}{S})^2(\frac{1}{cm^4K})$.

ΔT is the absolute difference between inside and outside air temperature.

C_w is the coefficient for wind-induced infiltration in $(\frac{L}{S})^2(\frac{1}{cm^4K})$.

V is the local wind speed in m/s.

Infiltration by flow coefficient

The flow coefficient model is based on (Walker and Wilson 1998) equation.

$$\text{Infiltration} = F_{schedule}\sqrt{(cC_s\Delta T)^2 + [cC_w(sV)^{2n}]^2} \qquad (3)$$

c is the flow coefficient in m²/(s.Pa^n)

C_s is the coefficient from stack-induced infiltration in $(\frac{Pa}{k})^n$

n is the pressure exponent.

C_w is the coefficient for wind-induced infiltration in $(Pa.\frac{s^2}{m^2})^2$.

s is the shelter factor.

2 .1 .2 Natural ventilation

Natural ventilation is a controlled air change with the exterior environment through openings due to temperature differences, wind speed, and the opening area. The controlled natural ventilation calculation is based on three models.

Design flow rate

Design flow rate is based on the outside inside temperature difference, wind speed and openings area, the basic equation to calculate the design flow rate is;

$$\text{Ventilation} = (v_{design})(F_{schedule})(A+B)(T_{ai}-T_{ae})[CV+DV^2)] \qquad (4)$$

Ventilation by wind and stack with open area

The ventilation air flow rate is function of wind speed and thermal stack effect, along with the area of the opening, the equation used to calculate the ventilation rate is (ASHRAE 2006) .

$$Q_w = C_w A_{open} f_{schedule} V \qquad (5)$$

Where

Q_w = Volumerique air flow rate driven by wind $(\frac{m^3}{s})$

C_w = Opening effectiveness dimensionless

A_{open} = Opening area m²

$$C_w = 0.55 - \frac{(Effective\ angle - wind\ direction)}{180} * 0.25$$

If $(Effective\ angle - wind\ direction) > 180°$ the difference= -180°

The equation used calculates the ventilation rate due to stack effect is given by ASHRAE 2009 handbook;

$$Q_s = C_D\, A_{open} F_{schedule}\sqrt{2g\Delta H_{NPL}(|\,T_{ai} - T_{ae}|)/T_{ai}}$$

(6)

Q_s = Volumetric air flow rate due to stack effect m³/s.

C_D = discharge coefficient for opening dimensionless.

ΔH_{NPL}=Height from midpoint of lower opening to the neutral pressure level (m).

T_{ai} ,T_{ae} The inside and outside air temperature in degree (k).
The discharge coefficient for opening dimensionless C_D is given by (ASHRAE 2009) handbook;

$$C_D=0.40+0.0045|T_{ai}-T_{ae}|$$

The total ventilation rate by wind and stack air flow;

$$Q_{vt}=\sqrt{Q_s^2-Q_w^2}$$

3. EXPERIMENTAL WORK

The experimental set-up consisted of two identical test cells (a) and (b), a cubic room with 3m high and 3m wide as shown in figure (1). South wall is provided with a window and the North one is provided with a door, the window and door were closed during day time and opned during night to allow night natural ventilation . The experimental cell (b) was the basic reference unit. The roof was constructed of simple aluminum sheet painted white. The model situated in Laghouat Algeria (latitude +33.46°, longitude +2.56° and elevation 767 m).

Figure 1. (a) Room with cooling roof (b) Room without cooling roof.

An experimental study of the effect of night natural ventilation on day time inside air temperature was carried out for a typical summer day of June for Laghouat in Algeria. The first experimental work was done under clear sky and 0.25m/s wind speed during night time, the second day under cloudy sky and 0.81m/s wind speed, after three days of experiment the night natural ventilation had a good effect on in lowering the inside air temperature. The effect of air change flow rate and wind speed were studied and simulated for an average wind speed of 3m/s and a variable air change flow rate (1.8, 2.7,and 3.6 V/h). Figure (2) shows the variations of inside air temperature for constant wind speed 3m/s and variable air change flow rate , the inside air temperature decreases with the increase of air change flow rate. When the air change flow rate taken to its maximum for variable wind velocities, for velocity ≥3m/s the inside air temperature had the almost the same values as shown in figure (3).

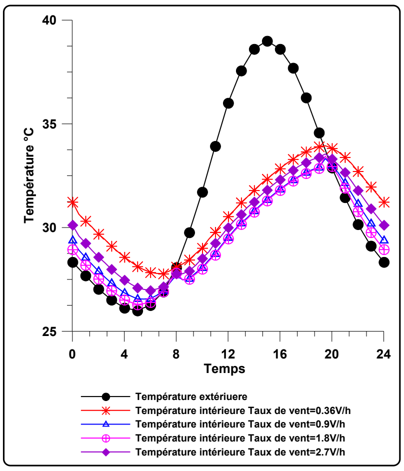

Figure 2: inside air temperature for 3m/s wind speed and variable air change flow rate

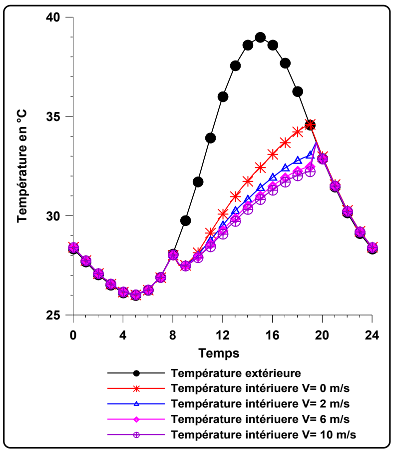

Figure 3 : inside air temperature for 7.2 V/h air change flow rate and variable wind spe

4. TEMPERATURE MEASUREMENTS

Air temperatures outside the room were measured using weather stations installed near the laboratory, far from the test cell by 150m. The temperature at different positions under the roof level has been measured by copper constant thermocouples connected to digital thermometer. Thermocouples fixed under the roof surface the end of the thermocouples were enveloped in thin aluminum paper to reflect the radiation from the surrounding interior surfaces. The readings of all thermocouples have been averaged to give the average temperature

5. RESULTS AND DISCUSSIONS

Figure (4, 5, 6 and 7) show the inside air temperatures variations for variable air change flow rate (0.9, 1.8, 3.6, and 7.2V/h) and variable wind speed (from 0 to 10m/s). After analyzing the results obtained by experimental and simulation, by comparing the results, the values of 1.8V/h of air change flow rate and 2m/s wind speed give the smaller error between measured and simulated inside air temperature as shown in figure (7).

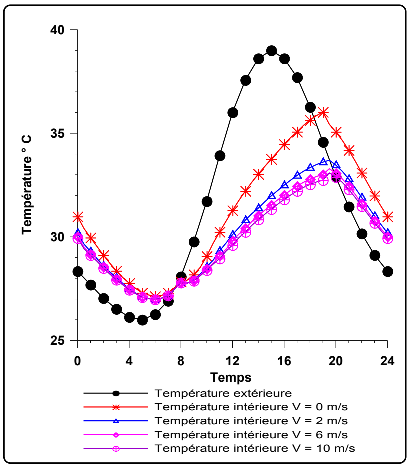

Figure 4: inside air temperature for 0.9 V/h air change flow rate and variable wind speed

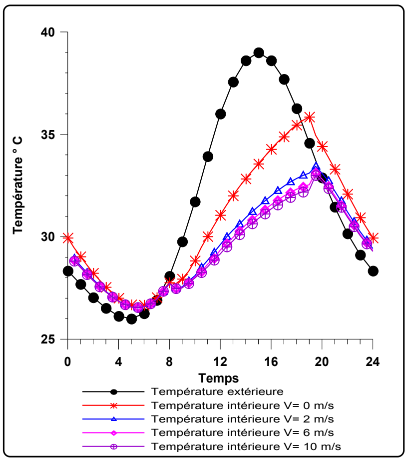

Figure 5: inside air temperature for 1.8 V/h air change flow rate and variable wind speed

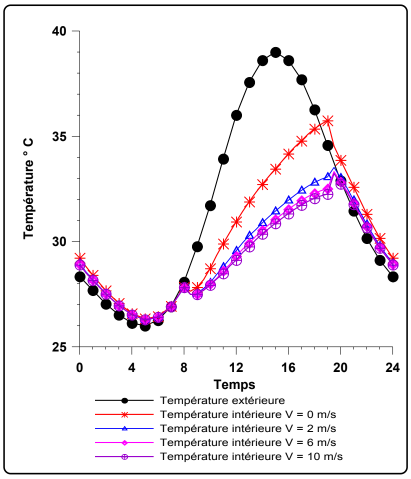

Figure 6: inside air temperature for 3.6 V/h air change flow rate and variable wind speed

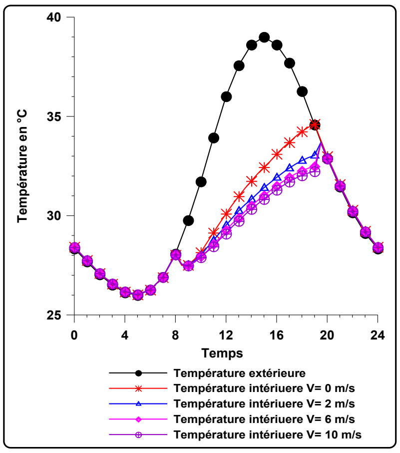

Figure 7: inside air temperature variation for 7.2 V/h air change flow rate and variable wind speed

Figure (8) presents the measured and simulated inside air temperature for non ventilated space, the two curves have almost the same values which mean the simulations are accurate. Figure (10) present the measured and simulated inside air temperature for night ventilated space for 1.8V/h air change flow rate and 2m/s wind speed, the two inside air temperature curves show a smaller error, these error were due to, wind speed was considered in simulation a constant value during simulation period, which is different to the reality, the wind speed was very variable from time to time and sometimes present a big differences which effect directly the air change flow rate which effect the inside day time air temperature. In the space without night natural ventilation and when the wind speed was assumed null for space with night ventilation the two curves of the inside air temperature measured and simulated have almost the same values as shown in figure 8. Figure 9 shows the inside air temperature for the space with and without night natural ventilation , so the night natural ventilation for space in arid zone participate in lowering the day time inside air temperature from 3to 6°C.

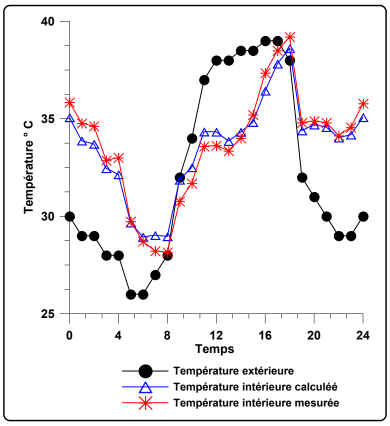

Figure8: measured and simulated inside air temperature without night natural ventilation (Bencheikh 2013).

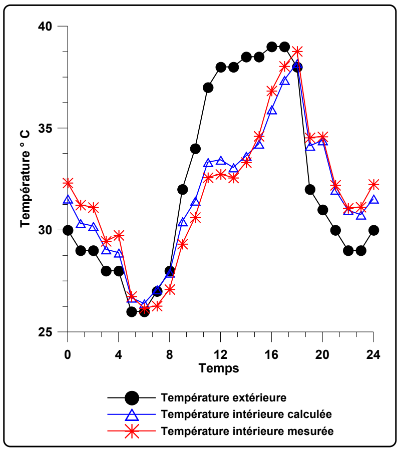

Figure 9: measured and simulated inside air temperature with night natural ventilation (Bencheikh 2013).

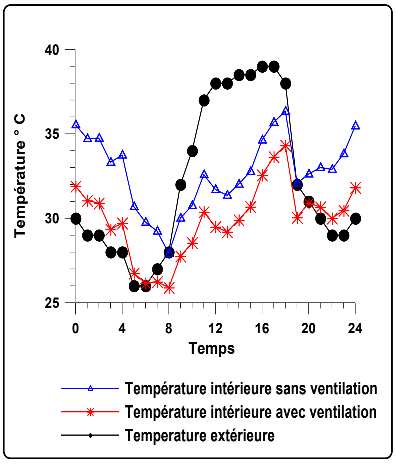

Figure 10: measured inside air temperature with and without night natural ventilation for space with cooling roof (Bencheikh 2013

6. CONCLUSION

In comparison between calculated and measured inside air temperatures in cell (b) without cooling system, without nocturnal natural ventilation, the two temperatures have almost the same values , however the calculated and measured ones in the same cell with nocturnal natural ventilation, present a small difference between calculated and measured temperatures during ventilation period as shown in figure 9, that due to wind speed variations during night time, which was in calculations usually considered constant value. Measured and calculated temperature in cell (a) with cooling system, with and without nocturnal natural ventilation, presents a small differences in two periods time, from 6.00 Am till 15.00Pm and form midnight till 4.00 Am which correspond to the evaporations and condensations periods. The differences were due to that the quantities of water vapor and condensate water were not exactly well known. Under hot arid conditions a full scale test cell for an evaporative reflective roof used to improve space cooling in buildings has been tested. The experimental results examined the effectiveness of such a roof cooling system in comparison to a bare roof. The results showed that cooling inside buildings can be improved by the application of such a cooling design. It was also seen that combining evaporative reflective roof with night ventilation increases such cooling more significantly

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