PROTECTION AGAINST SOLAR OVERHEATINGS USING HIGH ASPECT RATIO OPENED VERTICAL CAVITIES

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ABSTRACT

The authors present the use of high aspect ratio vertical cavities opened on both ends in order to protect housing against solar overheating. They describe a part of their experimental study and show the gain is substantial as soon as one cavity is opened. Heat transfers through the opened cavity are then computed using a fluid mechanics code. The results show a good accuracy with experiments. The authors conclude about the useful purpose of this system for passive refreshment.

KEYWORDS

Solar passive system. Vertical cavities. Experimental and numerical studies.

INTRODUCTION

Solar walls, called Trombe walls, have been studied since 1967: air taken from the room is warmed-up by solar energy and sent back to the same room (Hocevar et al.,1979). The aim of this work is to utilize a solar passive system to reduce overheatings inside buildings. due to solar radiance through opaque vertical walls. That method, easy to realize, lies on natural convection phenomenon. The work we present in this paper, is based on an experimental approach of temperature and flow fields. We show too some results obtained computing heat transfer through the opened cavity.

EXPERIMENTAL STUDY

The experimental apparatus was componed by two rooms separated by the wall we studied (Massias et al.,1995). We controled the two rooms ambiance. A bank of halogenous projectors, whose emission spectrum is closed from the sun one, provided a quasi homogeneous lighting on the wall height (figure 1). The wall height, which was built with terra-cotta vertical hollow bricks, was H=1.75m; each air strip was L=35 mm thick and we could consider the third dimension as boundless. These high vertical cavities could be opened on both ends (top and bottom). We present the case of one cavity opened: the first insulated.

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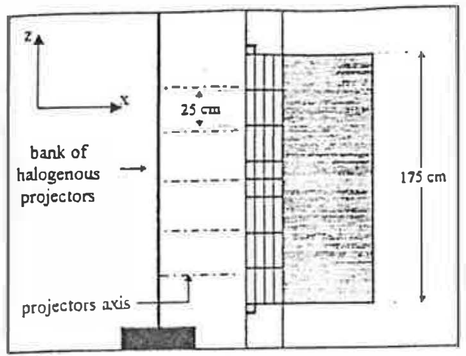

Figure 1 : experimental apparatus

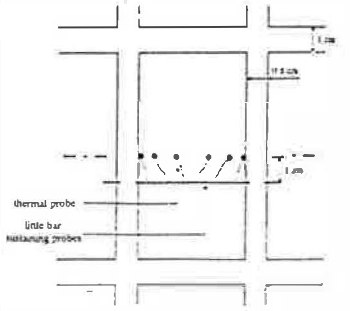

Figure 2 : thermal probes

Temperature field:

We used a hundred of K type thermal probes (0.5 mm diameter). We measured the temperature distribution through and along the internal and external wall faces. Figure 2 indicates the way we could reach temperature air fields inside the cavity. We present on figure 3 an example of results (measured at H/2), comparing the temperature profile obtained when all cavities were closed and when the first cavity was opened on both ends. We precise that in each case the ambiant conditions were the same.

We can notice an almost linear temperature distribution when all cavities were closed. In the other case, the temperature distribution is very particular in the opened cavity and becomes representative of conductive transfer through the other cavities: because of air flow, temperatures in the core are always lower than the faces ones. This induces very important temperature gradients: along the insulated side, this gradient is 3570.degree m becoming 1110 degree/m on the other side.

It seems important to see that the level of temperature field is different in each case while ambiant conditions were exactly the same. Due to the opening of the cavity ends. the level of temperature decreases of a value ranging from 5% to 10%, on the external (insulated) face and the inner face (x=200mm). This result is instructive for us as we would like to take into account the comfort degree of persons inside.

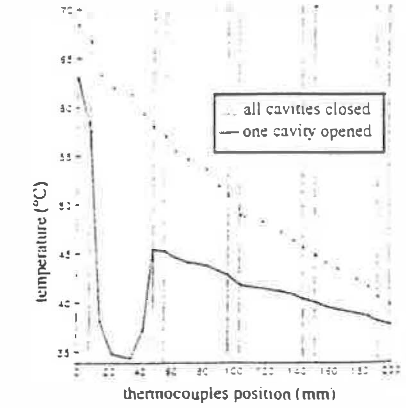

Figure 3 : experimental temperature profiles through the wall (z=H/2)

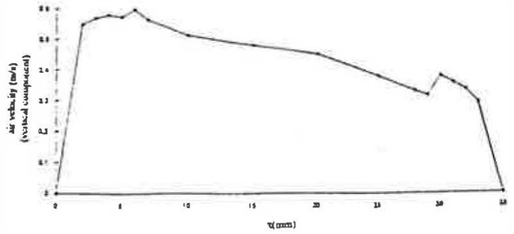

Figure 4 : experimental velocity profile through the opened first cavity (z=H/2)

Velocity and flow fields:

A hot wire anemometer was used in order to point out the velocity field inside the opened cavity. We present on figure 4 an example of velocity distribution ($z=H/2$). The figure shows, as for the temperature field, the existence of important ascending gradients along the two faces of the opened enclosure.

Moreover, we visualized the flow using a laser plane and particles (incense smoke) with the same density as air. We could notice the presence of vortex in the core opened cavity, which confirmed the setting of a turbulent regime as, in this example, $Ra_L \approx 1.2\ 10^9$ while $A \approx 50$.

NUMERICAL STUDY

We used a fluid mechanics numerical code. ESTET, developped by Electricité De France. This allowed us to solve the governing equations using a finite difference and finite volume scheme; that is to say: continuity equation. momentum equations and energy equations.

After a few tests, we chose a (k,ε) low Reynolds number turbulence model established by Launder and Sharma (Launder et al.,1974). We generated a 20000 nodes grid; this mesh was refined in the vicinity of the vertical faces. Our boundaries conditions were as follows:

- low extremity of the cavity:
  air temperature imponed is the one measured
  velocity profile corresponding to the measured one.
- insulated face (interface between air and terra-cotta insulated face)
  variation of the temperature with the cavity heigh due to the temperature profile provided by the probes.

We chose a local criterion for numerical convergence of 10^{-3}: maximum relative difference between two consecutive iterations.

We present on figures 5 and 6 temperature profiles and vertical component of velocity profiles plotted on different heights. These results showed that the variation of temperature with height on the opposite vertical face was not in good agreement with experimentation. We could then come to the conclusion about the necessity to take into consideration radiative transfers through the enclosure. The results obtained are presented on figures 7 and 8. Boundary conditions were exactly the same as before except we took into account vertical faces radiation. This time, computed results are closed from those we measured.

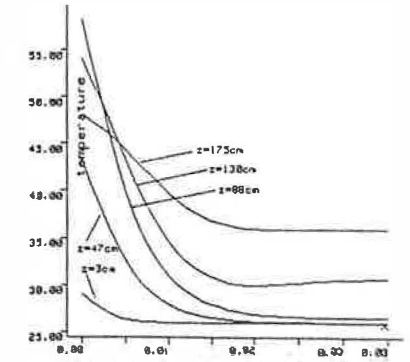

Figure 5 : numerical temperature profiles

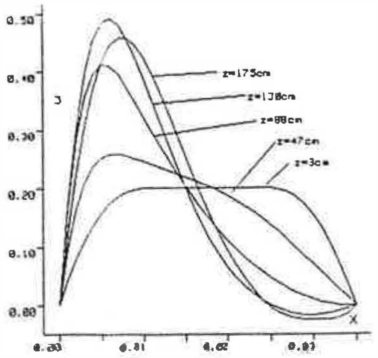

Figure 6 : numerical vertical component of the velocity profiles

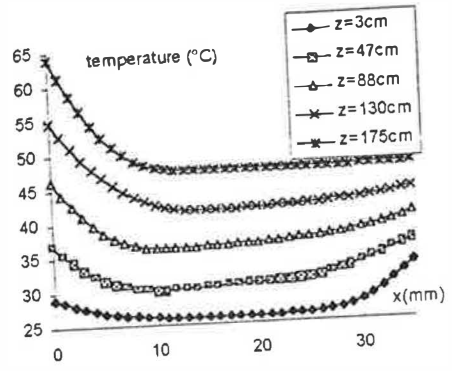

Figure 7 : numerical temperat re profiles considering radiative transfers

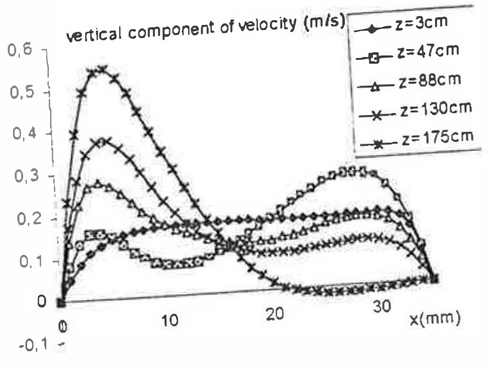

Figure 8 : numerical vertical component of the velocity profiles considering radiative transfers

CONCLUSION

This study about protection against solar overheatings indicated it is feasible to increase the comfort degree of a room occupant in summertime, using a simple and low-cost method. Indeed, we could notice that openeing at least one high aspect ratio vertical cavity allowed to diminish the resulting surface temperatures. Furthermore, we showed that a numerical study of the phenomenon can't release from coupled convective and radiative transfers. Now, we expect to take into account the solar radiance as boundary condition. computing conduction through terra-cotta and then convection and radiation heat exchanges inside air cavity. Besides, it seems important for us to estimate air moisture incidence on transfer in order to lead a complete study of this passive refrehsment system.

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