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Thermal evaluation of a perforated panel for solar collector model for air pre-heating

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Abstract. *Perforated solar windows pre-heat the fresh air introduced in the building when the air is forced to pass through this solar heated perforated facade. The type of solar collector in this case is a perforated window, which has two attributes: let the natural light in and heats the introduced fresh air. The Plexiglas sheets form a heated cavity, collecting the Sun's energy. An experimental campaign on an innovative solar window was performed in the laboratory of Building Services from Technical University of Civil Engineering Bucharest. The solar window with lobed perforations was analyzed against the one with round perforations and the results indicated that the systems can attain a high thermal performance.*

Key words: solar window; air heating; lobed perforation;

1. Introduction

Nowadays, humans use five times more energy than 50 years ago, considering the number of people, the urbanization of certain parts and a developing industry [1]. Estimates from the International Energy Agency, without further action to limit this consumption, it is expected to increase with 33% by 2040 worldwide, growth driven primarily by India, China, Africa, the Middle East and Southeast Asia[2].

The efficiency and energy prices also are major concerns nowadays. Therefore, economic and environmental research was accelerated towards innovative and clean technologies. All these energy consumptions, whether it's heating or cooling demand, can be translated in terms of CO_2 emissions [3-5].

In this context the use of renewable energies is an interesting solution for satisfying the two requests: indoor quality and energy efficiency. Among these renewable energies, the usage of solar passive systems is easy to implement and accessible in the zones with solar potential [6]. These systems can have a significant contribution to attain high envelope performances and in the same time to save energy either for winter heating or for summer cooling. The multitude of solutions for using thermal energy from the Sun has important advantages but also disadvantages that maintains the research in this area.

Ventilated windows are another solar thermal recovery device which seems to offer new possibilities of development in this domain. Indeed, in countries having a cold climate during the winter, using a double window in building façades is a current practice. Transforming these double windows in passive air heating systems has the advantage of providing pre-heated air for winter ventilation which, otherwise, would enter the building at outdoor air temperature [7-9]. The air channel between the two windows is then used as a path to the ventilation air, further connected or not to another ventilation device (Fig. 1a).

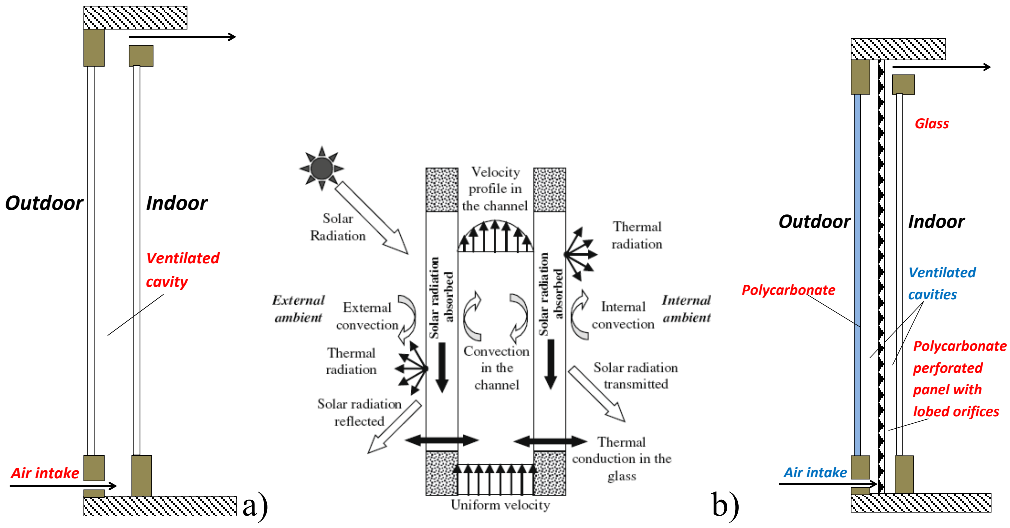

Fig. 1 Ventilated windows: a) schematic drawing of a simple ventilated window, b) layout of convective heat transfer in a ventilated window [10], c) innovative ventilated window

This air is pre-heated within the air channel between the windows by heat that is lost from the building and also by solar gains inside the window, before it is delivered inside warmer than it is outside. Part of the heat loss from inside through the window is returned back to the room by the air flow, acting as a heat recovery unit. Incident solar radiation upon the window warms its components being part of that heat removed by the air flow delivering it into the room, acting as a solar collector.

In their studies, Carlos et al. [7-9] putted an evidence a heat loss reduction up to 30% in the cases when a ventilating windows system is used compared to classical, non ventilated, double windows. In hot climates, if the heated air is evacuated in the exterior, the air flow from natural or forced convection (Fig. 1b) act as a protection screen improving thermal insulation of the window [10].

2. Methodology

As seen in Fig.1c, we propose a new type of perforated window which allows a better mixing between the heated air and the aspirated airflow from the exterior. The purpose of this article is to evaluate the thermal performance of such a setup and to compare the results between two types of perforations: round and lobed ones.

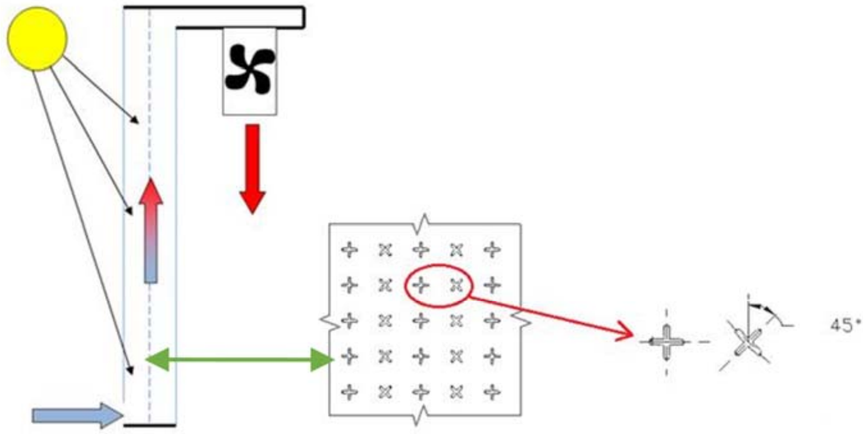

Fig. 2 Functional scheme of the experimental setup with the details of the lobed perforations on the Plexiglas sheet

The experimental campaign was performed inside a laboratory. The system is composed by two parts: the Plexiglas box with the perforated sheet inside and the exhausting system (Fig 3). The insulated box is attached through a circular pipe to an exhausting fan, forcing the air to pass through the window, fact which will accelerate the mixing between the interior air and the aspirated airflow. The airflow is varied with a direct current electrical source, obtaining values from 63 to 210 $m^3/h/m^2$.

Fig. 3 Experimental setup in the laboratory

The source of light was generated by six halide lamps of 500W each, which were simulating the sun radiation. The studies [11] indicate a radiation level of 800 W/m^2 so the lamps were evenly disposed to cover uniformly the metal plate.

The cases studied refer to classical circular and lobed perforation, as seen in Fig. 2. The equivalent diameter, D_e, of each perforation is 5 mm and the space between two orifices is $4D_e$. This lobed geometry, studied for innovative air inlets, has the advantage that for the same effective area (same equivalent diameter D_e) the perimeter of the lobed perforation is significantly larger than the circular one, while the airflow mixing is increased due to specific vortical structures in the air jet.

The airflow was determined by an Iris type damper for measuring airflows induced by the DC source to the fan. The mean velocity was integrated on the surface of the duct section, obtaining the airflow. Several thermocouples type K coupled to ALMENMO 2890-9 station were used to evaluate the temperature of heated air at the outlet and ambient air.

3. Results

The results indicated an interest in using this kind of air heating systems, with an increase in the temperature between 6.5 and 13°C for the two cases studied. The stabilization time was for all the points measured of about 17 min, as seen in Fig 4 a) and b) for the airflow of 63 $m^3/h/m^2$ or 30 m^3/h. Approximately the same conditions were obtained for the two studied cases, but the purpose of this investigation is to evaluate the air temperature increase between the ambient air and the air inside the box, near the extraction fan.

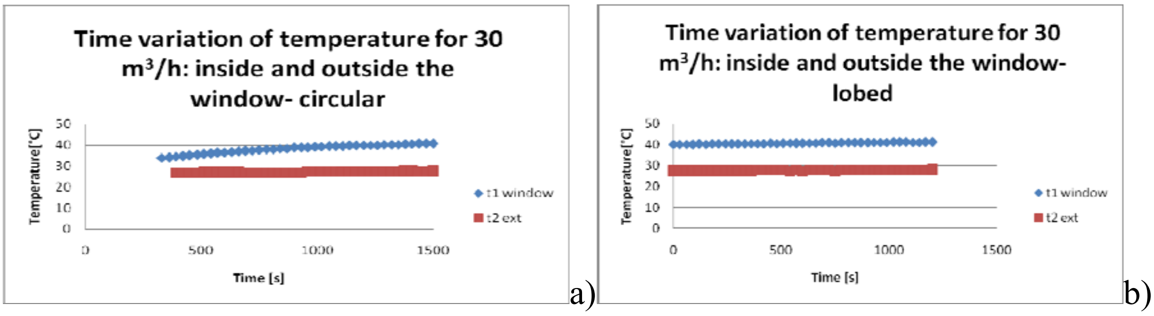

Fig. 4 Temperature increase variation over the stabilisation period of approx. 17 min for the circular and lobed case

When comparing the temperature difference for all the points of measure, we can observe that this difference decreases with the increase of airflow value, starting for example with 12 °C for 63 $m^3/h/m^2$ and ending at 6 °C for 210 $m^3/h/m^2$, for the circular case.

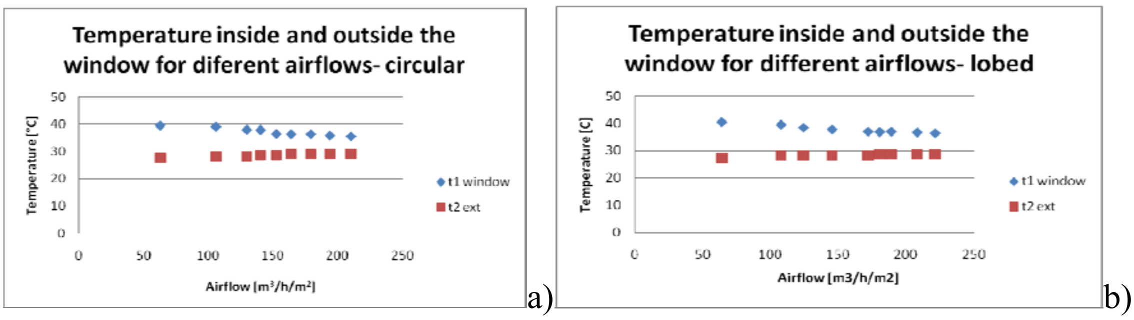

Fig. 5 Temperature difference between heated air and ambeint air for the circular and lobed case when changing the airflow

The same tendency can be observed for the lobed case, with an increase in the measured temperature difference, especially for higher airflow values.

The projection of the temperature increase for the two cases studied can be better seen in Fig. 6, when comparing the results. The lobed perforations, with the advantage of the higher induced airflow rate, allows a better mixing between the ambient air and the air heated inside the cavity of the window. This kind of device, with perforated panel inside the window, has never been tested before considering the existing literature. The temperature rise between 6 and 13°C could be interesting for indoors which require lower temperature like industrial deposits.

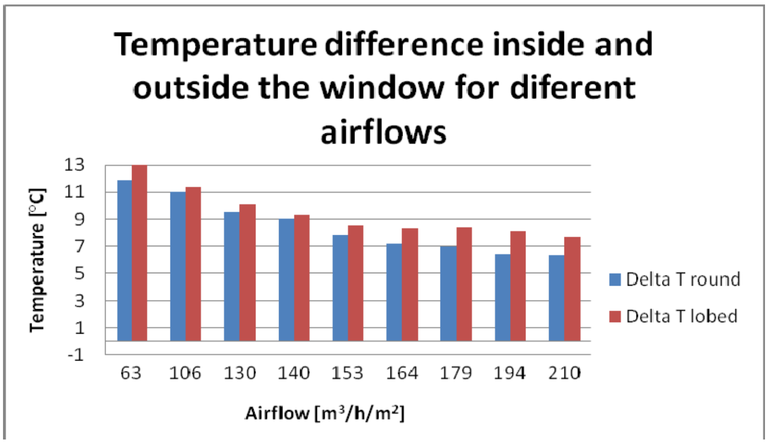

Fig. 6 Temperature difference between heated air and ambient air for the two cases studied

4. Conclusions

A new ventilated window system was tested in laboratory conditions. The perforated sheet inside the window allows a better mixing between the aspired air and the air heated but the radiation between the external sheets. The temperature rise, of maximum 13°C can be attained for the lobed case, for 63 $m^3/h/m^2$. The study needs further investigations, considering the materials used, perforations type and to integrate the temperature rise into the global energy efficiency of the system

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