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FULL ELEMENT FOR LABORATORY STUDIES ON BUILDING VENTILATED WALLS

BY

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Abstract. Energy consumption reduction in the residential sector represents an assumed objective by the European Union. In recent years, attention to passive ventilation solutions for walls and roofs has greatly increased because ventilated systems permit energy savings. The choice for the best ventilated façade geometry must be investigated experimentally because on site measurements are affected by atmospheric conditions while laboratory measurements permit a greater control of the influencing parameters. In this paper the element realized in the Civil and Industrial Engineering Department laboratory is presented with some preliminary results concerning air velocities, temperature distributions and thermal resistances in the channel.

Key words: ventilated façades; full scale testing; air channel; air velocity.

1. Introduction

A ventilated façade includes a ventilated air layer that is connected with the adjacent spaces, in order to ventilate the wall and even the interior of the building (Radu *et al.*, 2009). The ventilated façades consist of the bearing wall, the insulating layer, the façade and a ventilated air space within. The materials

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used for the outer layer can be of different types: wood, brick, stone, fiber cement, ceramic tiles, aluminum, composite materials and glass.

A detached layer from the bearing wall and a ventilated airspace have some advantages namely: reduced energy consumption for both cooling and heating, smaller wind pressures on the façade, better sound insulation, suitability for thermal rehabilitation works and increased drying capacity.

Using ventilated systems for walls doesn’t eliminate the need for the thermal insulating materials but the effect of the energy consumption reduction is equivalent to saving the insulating material and therefore to decrease the exterior walls thickness. The potential for reducing energy consumptions is significant, which motivates thorough going studies on the air flow regime that cannot be satisfactory achieved only through *in situ* observations of buildings or by numerical simulations. Experimental studies of heated vertical plane channel have been also undertaken by Popa *et al.* (2006) and Cherecheş *et al*. (2006).

2. Problem Description

Ventilated façades energy efficiency depends on the distribution of the pressure, velocity, temperature and humidity fields inside the air channel. These distributions depend on several factors: solar radiation, wind speed and direction, environment topography, physical properties and roughness of the materials, channel height and cross-section, tightness/permeability of the claddings, the size, shape of the inlet/outlet openings and the type of the air flow.

In Romania just a few buildings with ventilated façades have been made mainly because the bad seismic performance and higher construction costs, therefore little information exists about this subject. Determination of the optimum geometry of the ventilated air channel and materials for the climate in our country must take into account the cold winters and hot summers. In summer the air exchanges in the cavity must allow the ventilated air to carry heat and water vapours, while in winter, on the contrary, ventilation should be less intensive so the air layer could contribute to the thermal resistance of the external wall.

In order to analyse different air space geometries influence on air exchange rate, a full scale element has been developed in the Civil and Industrial Engineering Department laboratory.

3. Description of the Experimental Element

The element has a height of 2.60 m and a width of 1.00 m. The support and heating plate system consists of an 18 mm thick chipboard panel. It can be easily moved in order to obtain different thickness of the air channel. The outer layer was made of softwood boards fitted tongue and groove, equivalent for an airtight façade.

On the entire height of the panel, 3 mm wide and 4 mm deep channels were made in which a stainless steel wire was introduced. Later the channels were filled with plaster for fixing. The distance between the wires on the height of the panel was of 3 cm, in order to obtain an even distribution of the heat on the panel; the checking was made using an IR camera.

The panel was heated to +60ºC by applying a voltage up to 240 V on the steel wire. The temperature inside the laboratory was maintained around +20ºC. Therefore, a temperature difference of 40ºC could be obtained. This is the situation for the winter climatic zone IV, when the wall temperature is about +20ºC and the outdoor air temperature, –21ºC.

The laboratory equipment used to describe the system was placed on the element according to Fig. 1 and consists of the following instruments: hot wire anemometer, two flux meters and eleven copper–constantan thermocouples.

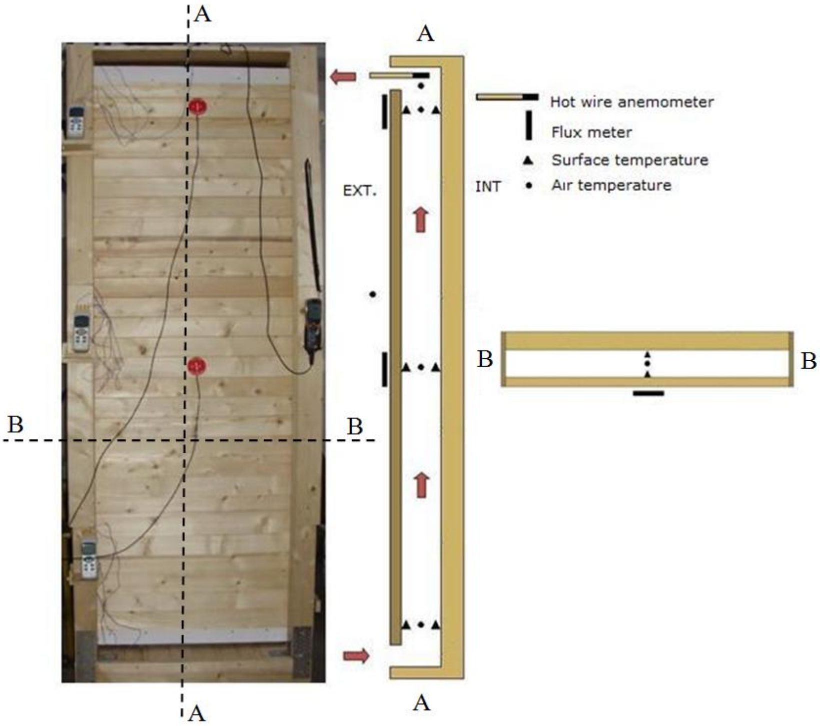

Fig. 1 – Frontal view of the experimental element (left) and the positioning of laboratory equipments seen in vertical section (middle) and horizontal (right).

The hot wire anemometer measuring range is between 0…20 m/s with an accepted error of ±0.03 m/s representing +4% of the average speed. The accuracy of thermocouples in the temperature range is of 0.5%. The flux meter error for the +20ºC exterior temperature is of ±5%.

4. Results

Data recording has been made considering a steady-state heat transfer when the plate temperature has not changed with more than 0.2ºC in a given period of time. The instruments were positioned in the middle of the element so that the influence of the corner areas was negligible (Nore *et al.*, 2008).

Minimum/medium/maximum air velocities were measured perpendicular to the flow area at the position of the outlet opening. Air and surface temperatures in the channel have been recorded simultaneously.

By moving the heated panel different thicknesses of the air channel have been obtained. The airflow velocity varied accordingly to Fig. 2.

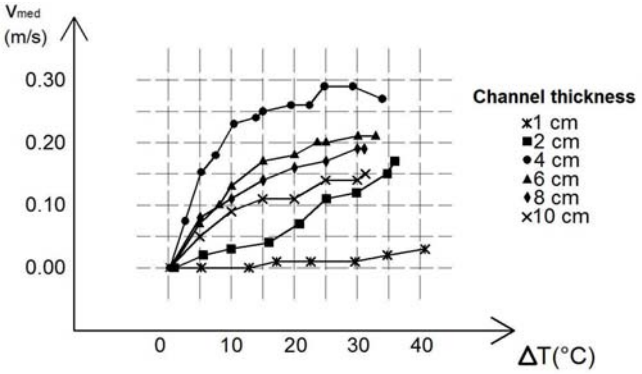

Fig. 2 – The airflow velocity, V, dependence *vs.* the temperature difference, ΔT, between the heated plate and the outside air and on the channel thickness, measured at the upper side for an airtight façade with 2 cm high inlet/outlet ventilation openings.

In order to analyse the effect of the inlet and outlet opening size on the air velocity, the 2 cm air thickness of the ventilated channel has been chosen (Fig. 3). This choice was made for reasons related to the use of spacers of this dimension on which various outer layers are applied.

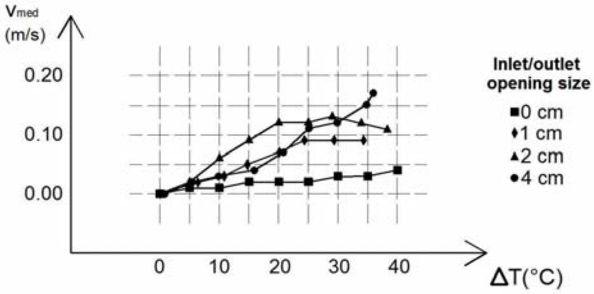

Fig. 3 – Air velocity measured at the upper side for an airtight façade with a 2 cm thick ventilated air channel *vs.* different temperature differences between the heated plate and the outside air.

In natural convection, air flow is driven by the effect of buoyancy. The air layer near the heated plate becomes lighter and begins to flow upward and sweeps the wall. The capacity of ventilated façades to drain heat from the system is estimated function of the heat flow, $Q(W)$, transported by convection based on the following relation:

$$Q = vS\rho c_p (T_{\text{out}} - T_{\text{ext}}), \tag{1}$$

where: v represents air velocity measured at the upper side, [m/s]; S – flow section, [m^2]; ρ – air density, [kg/m^3]; c_p – specific heat, [J/kg·K]; T_{out} – air temperature measured at the outlet opening, [K]; T_{ext} – external air temperature, [K].

From the above relation it can be observed that the heat flow depends linearly on the air temperature measured at the upper side of the channel, while the external air temperature is considered constant on the entire duration of the experiment. The variation of the outlet air temperature *vs.* the temperature on the heated panel is presented in Fig. 4.

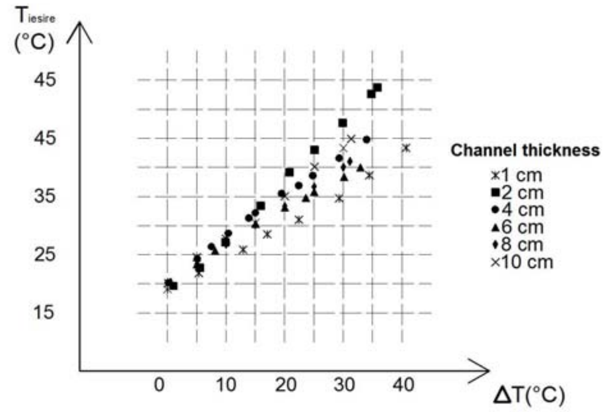

Fig. 4 – Measured outlet air temperature function of the temperature difference between the heated plate and the outside air.

If the temperature distribution inside the channel and the heat flux are known, the thermal resistance of the unventilated airspace can be evaluated namely

$$R_a = \frac{\Delta T}{q}, \tag{2}$$

where: R_a represents the thermal resistance of the unventilated air, [m^2.K/W]; ΔT – temperature difference, [K]; q – heat flux, [W/m^2].

When the temperature on the heating plate is increased the temperature inside the channel also increases. This makes the thermal conductivity of air to rise and the thermal resistance of air through conduction to decrease. The variation of the air thermal resistance inside the channel is presented in Fig. 5.

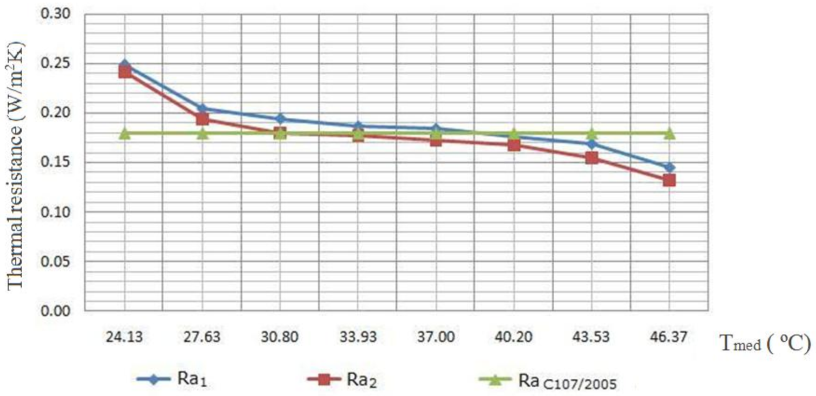

Fig. 5 – The influence of the average air temperature in the channel, T_{med}, on the thermal resistance of an unventilated air layer measured at the top (R_{a1}) and middle (R_{a2}) for a 4 cm thick channel, compared to the thermal resistance given by C107/2005.

5. Conclusions

Air velocity is a good indicator for evaluating convection. The obtained results are in goal agreement with those of EN ISO 6946 (2007), which state that for an unventilated air channel with thicknesses smaller than 2 cm, heat transfer is achieved mainly by conduction and radiation (Fig. 6).

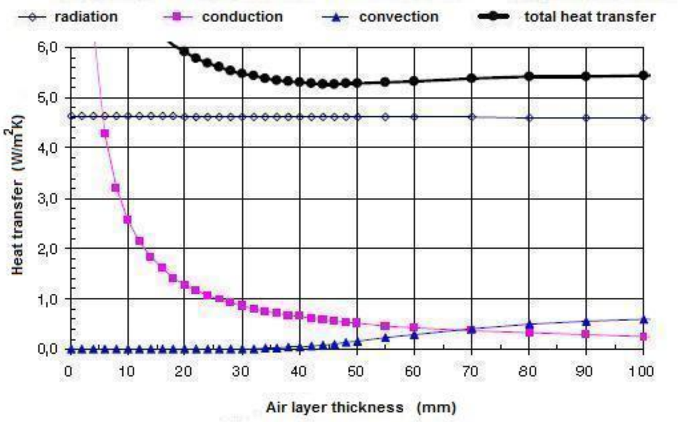

Fig. 6 – Estimated heat transfer for various thicknesses of the air cavity for an unventilated air layer bounded by ordinary materials ($\varepsilon = 0.9$) (Uvsløkk & Arnesen, 2008).

The lowest air velocities measured at the upper side were obtained for the 1 and 2 cm thick layers and the highest for 4 cm thick air layer. The velocities obtained for the thicknesses of 6, 8 and 10 cm varied between these values. It was observed that the increase of the inlet/outlet openings surfaces resulted in bigger air velocities since the local pressure losses were smaller.

The highest temperatures at the upper side of the model were obtained for the air layer thickness of 2 and 4 cm. For greater thicknesses, and also for that of 1 cm, the resulting values were lower. Larger values of the temperature difference ($T_{\text{out}} - T_{\text{ext}}$) will increase the heat transfer by convection. However, bigger thicknesses allow that larger quantities of heat to be transported can be drained through the channel.

The differences between the thermal resistance proposed for an unventilated air layer in C107/2005 and the mean results obtained from the experimental measurements differed with 1% and 5%. Thermal resistance of air measured at the upper side of the channel was higher than that obtained at the middle side of the element.

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ELEMENT PENTRU STUDIUL LA SCARĂ NATURALĂ A PEREȚILOR VENTILAȚI

(Rezumat)

Reducerea consumului de energie în sectorul construcțiilor rezidențiale reprezintă un obiectiv asumat de Uniunea Europeană. În ultimii ani atenția acordată soluțiilor pasive de ventilare a pereților si acoperişurilor a crescut deoarece acestea permit economii de energie. Alegerea dimensiunii optime a geometriei fațadelor ventilate trebuie analizată experimental deoarece investigațiile *in situ* sunt afectate de condițiile meteorologice. Se prezintă un element realizat în laboratorul Catedrei de Construcții Civile şi Industriale pentru experimentări legate de funcționarea pereților cu structuri ventilate şi unele rezultate preliminare privind viteza aerului, distribuția temperaturilor şi rezistențele termice ale aerului în canal.