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Energy performance of a ventilated façade by simulation with experimental validation

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HIGHLIGHTS

- An existing office building was monitored for a year.
- A model of a ventilated façade by TRNSYS simulation tool was validated.
- Air flow parameters inside the ventilated façade were identified.
- Recovery of the hot air inside the façade for input into the building was studied.

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ABSTRACT

A model for a building with ventilated façade was created using the software tool TRNSYS, version 17, and airflow parameters were simulated using TRNFlow. The results obtained with the model are compared and validated with experimental data. The temperature distribution along the air cavity was analysed and a chimney effect was observed, which produced the highest temperature gradient on the first floor. The heat flux of the external wall was analysed, and greater temperatures were observed on the external layer and inside the cavity. The model allows to calculate the energy demand of the building façade proposing and evaluating passive strategies.

The corresponding office building for computer laboratories located in Valencia (Spain), was monitored for a year. The thermal behaviour of the floating external sheet was analysed using an electronic panel designed for the reading and storage of data. A feasibility study of the recovery of hot air inside the façade into the building was performed. The results obtained showed a lower heating demand when hot air is introduced inside the building, increasing the efficiency of heat recovery equipment.

1. Introduction

Losses and heat gains through building façades have a significant influence on the annual consumption of heating and cooling of buildings. Moreover there is a recent trend among some architects to consider façades as being sophisticated membranes worthy of careful design.

Although the origins of Double-Skin Façades (DSF) date back to the early twentieth century there is a growing tendency among architects and engineers to use them [1] and they must be taken into account to ensure rigorous calculations of the energy demands in new and existing buildings.

Many other terms exist that are synonymous with DSF, such as active façade, double envelope, rainscreen or ventilated façade. The European standard EN 13119:2007 "Curtain walling. Terminology", associates the term DSF to the existence of glass skins separated by a cavity but not to the need for a ventilated cavity [2]. In this sense the term "ventilated façade" would be more appropriate for the façade analysed in this work. It consists of an opaque external layer composed of lightweight and thin cladding panels with open joint between them and an opaque internal skin which acts as thermal and acoustic insulation. Between both layers there is an air cavity

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drained and ventilated (see Fig. 1). The air cavity of opaque DSF has received less attention than the other configurations with glass [3] and there are still very few studies that focus on their energy performance [4].

Several recent studies have focused on the use of natural ventilation in buildings as an alternative system to reduce energy demand. The heated internal air that is generated inside the air cavity can be introduced inside the building if it is convenient, thus reducing the heating energy demand and the heating energy consumption of the building. This internal warm air can be introduced using an inlet opening through which the ambient air comes in, and one or two exhaust openings for returning the air to the outside or introducing it into the building. Airflow can be produced naturally through the façade due to the wind effect or thermal buoyancy. Additionally, on sunny days part of the solar radiation absorbed by the façade is transferred to the air in the gap.

The use of DSF in the construction sector and their thermal benefits have been widely studied quantitatively over the last 30 years [5–7].

In this paper a façade which uses this system was modelled with a Transient Systems Simulation Program (TRNSYS) [8] and its add-on for airflow simulation in buildings, and monitored. Haase et al. [9] provided a similar research developed for hot and humid climates (Hong Kong) and glass façades. More recently López et al. [10] employed the same simulation software for modelling an experimental module of an opaque ventilated façade.

Once the building is modelled and validated with experimental data, this model is used to reduce the energy demand of the building with ventilated façade.

In the present work, it has been studied a lightweight cladding, specifically a sandwich panel comprising two aluminium sheets bonded to a polyethylene core with a thickness of 4 mm. To develop this study, a full year of data was collected from the four sides of an office building located in Valencia (Spain). Once the model was validated, it was used to carry out simulations, by varying different parameters such as the degree of air ventilation inside the cavity, allowing to reduce the building energy demand.

2. Experimental monitoring

2.1. Features of the building under study

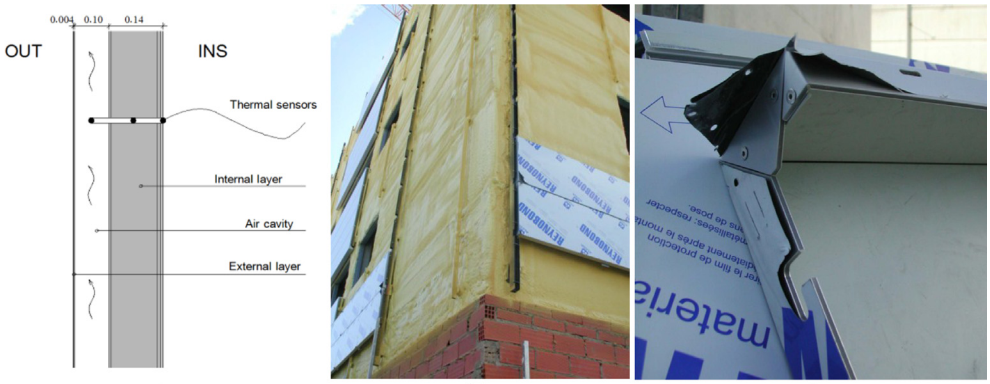
An existing office building for computer laboratories was monitored for a year. The building is located in Valencia, Spain (latitude 39.28°N, longitude 0.22°E). All the enclosures in the building have a floating external sheet which acts as a rainscreen. The building has a rectangular base measuring 92 m long and 17.50 m wide, with three storeys, measuring a total internal height of 16 m. The building is free-standing, orientated about 20° East. For the purpose of clarity, the orientations have been named North, South, East and West, although they are in fact orientated North–Northeast, South–Southwest, East–Southeast and West–Northwest, respectively. In order to study the behaviour of the rainscreen wall components in different seasons and their thermal performance, measurements were taken during the period from January 1st to December 31st 2009.

Table 1
Thermal properties of the external wall layers. Tabulated values provided in ISO 10456:2007 [11].

Layer	Thickness (m)	Thermal conductivity (W/m K)	Density (kg/m^3)	Specific heat (J/kg K)
Composite panel. Alucobond®	0.004	5.65	980	1350
Ventilated air cavity	0.10			
Rigid polyurethane foam (PUR/PIR)	0.04	0.031	12	1500
Mortar panel	0.01	0.23	1200	1500
Mineral Wool	0.08	0.036	50	1000
Plasterboard of natural gypsum. Pladur®	0.016	0.25	900	1000

The façade of the analysed building is composed with an external cladding layer. The cladding layer is made of panels surfaced with natural aluminium and a mineral-filled core with a total thickness of 0.004 m; plate rigidity is ensured by folds and rivets at the edges. The panels are all 0.59 m wide by 3.5 m long (length varies at the corners and window jambs). An inner sheet gives the panels water and air tightness and also allows for the rainscreen to be fixed to it (to the internal layer). This sheet is made of a prefabricated mortar panel, rock wool insulation and an inner plaster panel with a total thickness of 0.14 m. Between the internal and external leaves there is a ventilated cavity with 0.10 m of thickness (see Fig. 1). This façade system is used in all the orientations that were analysed. All the properties of the materials of the external wall of the building under study are given in Table 1.

The reflectance values were obtained using a LAMBDA 35 UV/Vis Systems Spectrometer (Perkin–Elmer). From the results obtained in the measurements, an average value was calculated from the integration of the area below the curve of the specular reflection of the material vs. the wavelength. This entire procedure



a) b) c)

Fig. 1. a) Components of the ventilated enclosure with weight-reduced screen. Black dots represent points where temperatures were measured (thermal sensors), b) image of the corner, c) external layer.