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Opaque Ventilated Façades: Thermal and energy performance review

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ABSTRACT

The use of Opaque Ventilated Façades (OVF) has considerably increased in recently years as an envelope solution in a variety of building types, climates, and design configurations. It is considered an appropriate solution not only for renovation of existing buildings but also for new buildings.

The influence of ventilated façades in buildings is a constantly current issue in research always concluding the importance of the envelope in the reduction of energy needs in the whole building, and the importance of an accuracy model for the deep knowledge of the façade performance.

Currently, the main interest in OVFs is their ability to reduce cooling thermal loads in Southern European locations. Although reference literature recognizes energy savings associated to the use of OVFs in comparison with traditional solutions, previous energy studies consider a limited number of locations and standard solutions.

Trying to fill in an existing gap, this article includes information from different studies carried out in recent years which address the thermal and energy performance of OVFs.

It also explains the implications of both external ambient conditions and design decision (external layer material, joints, air cavity width…) in terms of the energy and thermal performance of OVFs. This paper also provides some key strategies for customizing the façade design according to specific climate conditions.

1. Introduction

Energy saving is a high-priority in developed countries. The building sector is in charge of 40% of the energy consumption in Europe [1,2]. The building envelope is the construction element that has the greatest impact on the overall energy consumption of the building [3,4]. It must be taken into account that the façade represents the interface between the exterior environmental factors and the interior demands of the occupants. While the last ones are mainly constant, the first ones change constantly [5].

In recent years, architecture has shown a special interest in ventilated walls. It cannot be denied that there is a considerably large amount of studies and journal papers related to "ventilated envelopes" [6–8] especially focused on Double Skin Façades [9–12] Building Integrated Photovoltaic [13–15], Solar chimney, Trombe and Solar Walls [16–18], or Façade Solar Collectors [19–21]. However, less attention has been given to Opaque Ventilated Façades (OVFs).

OVF has been chosen by architects and building contractors as an envelope solution in a variety of building types, climates, and design configurations. The system offers a wide variety of external cladding and the possibility to select a large variety of materials, colors, and size of tiles. Joints can be open or closed. In addition, the disposition of a continuous thermal insulation layer and the ventilated cavity offer some hydrothermal benefits. In addition, OVF provides benefits; there are less construction problems due to their industrialized components and better assembly control. This makes OVF a perfect solution for residential buildings, not only for new buildings, but also for retrofitting (Fig. 1).

An OVF is a multilayer industrialized double skin façade composed by two opaque layers and a ventilation channel in between. Table 1 shows the most common configuration of OVF.

The outer layer is usually composed of modular panels and there is a wide availability of tiles that can be integrated into it (e.g.: metallic, ceramic, stone or composite). In some applications the external panel is continuous or the joints between tiles are closed. In this case, the ventilation is possible due to the existence of some openings at the bottom and at the top of the cladding. In some cases joints are open, (Open Joint Ventilated Façades (OJVFs)), and joints enable exterior air to enter and leave the cavity all along the wall; in addition, the joints deal with any expansion caused by temperature changes (Fig. 2).

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Fig. 1. Examples of OVF in real buildings: (1) Ponsal Building (Pamplona. Spain). Ceramic OVF. Architects: S.A.S. (2) Social Housing Lezkairu (Pamplona. Spain). Metallic OVF. Architects: AH & Asociados. (3) Façade retrofitting (Pamplona. Spain). Stone OVF. Architects: Jacar.

Table 1
Different types and materials for opaque ventilated façades.

Layer	Types	More frequently used
Outer skin	Heavy	Ceramic, stone, concrete panels...
	Light	GRC panels, metallic, composite panels...
Air cavity	Naturally ventilated	From 4–10 cm
Thermal insulation	The thickness depends on each country's Standards	MW, EPS, XPS, PUR
Inner skin	Heavy	Brick, concrete...
	Light	Sandwich panels, gypsum boards..

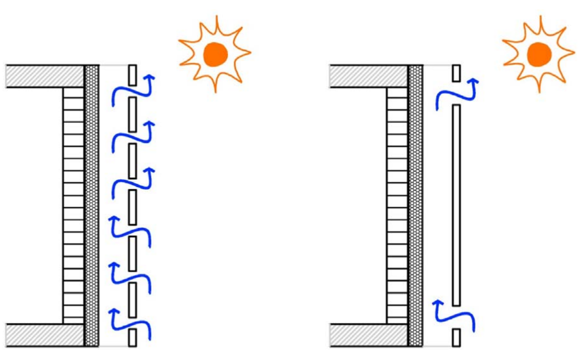

Fig. 2. Outer skin types: (1) open joints, discontinuous skin, (2) closed joints, continues outer skin.

The width of the ventilated channel could vary in terms of the substructure. The external cladding layer acts mainly as a radiation filter whereas the inner layer works as building insulation or thermal mass. All these possible configurations lead to a series of questions about performance, making it quite difficult to predict thermal performance.

The OVF is a system originally developed in Northern European countries. In these countries OVFs were designed to resolve problems regarding durability related to atmospheric agents by sealing the outer walls against driving rain, wind, and thermal excursion [22–25].

Currently, the main interest in OVFs is their ability to reduce cooling thermal loads in Southern European locations [26,27]. Although reference literature recognizes energy savings associated to the use of OVFs in comparison with traditional solutions [28], previous energy studies consider a limited number of locations and standard solutions. The number of studies related to the impact of OVF during the winter is small; this could be due to the fact that the benefits are questionable [29,30].

The influence of ventilated façades in buildings constantly current issue in research always concluding the importance of the envelope in the reduction of energy needs in the whole building [31], and the importance of an accuracy model for the deep knowledge of the façade performance [32].

This article includes information from different studies carried out in recent years which address the thermal and energy performance of OVFs. It explains the implications of both external ambient conditions and design decision (external layer material, joints, air cavity width...) in terms of the energy and thermal performance of OVFs. This paper also provides some key strategies for customizing the façade design according to specific climate conditions.

2. OVF thermal performance

The main difference in the thermal and energy analysis between a conventional façade and a ventilated system is the specific phenomena that occur inside the ventilated air cavity. Heat transfer in ventilated solutions is fully explained in [33] by Balocco, who developed a simple model to study ventilated façade energy performance.

The ventilated air cavity is a really an important element in the hydrothermal performance of the wall. As Falk et al. [34] and Davidovic [35] have demonstrated, the drying rate for ventilated cladding is faster than for sealed cavity façades.

Apart from conduction and radiation heat transfer processes, natural convection is one of the principal processes of heat transfer that affects OVF behavior [36–38]. Natural ventilation can be driven by two phenomena: buoyancy and wind. Wind driven ventilation is a consequence of the pressure difference in the façade surfaces produced by wind forces. Buoyancy-driven ventilation occurs as a result of the temperature differences between the bottom and the top of the air cavity height (Fig. 3).

As mentioned previously, outer skin could be made by open (OJVF) or closed joints tiles (CJVF). For the CJVF, the upward flow is completely continuous, homogeneous and symmetrical along the wall [39,40]. Notwithstanding, in the OJVF, the flow is discontinuous, inhomogeneous and much more complex [41,42].

Different modeling approaches are used to evaluate OVF energy performance including analytical, empirical, experimental, and CFD models. CFD simulation techniques enable designers to understand the behavior of the systems and to predict the final performance of the strategies used, avoiding trial-and-error methodologies. Nevertheless, researchers continue to carry out experimental studies mainly in order to improve the validation of their computational models.

It cannot be denied that the thermal performance of OVF depends on the **specific outer parameters** (climatic conditions: solar radiation, wind direction and speed and temperature) and on the **specific design** (geometries, materials...). While the design parameters can be chosen, the outer conditions are given and are continually changing. This is why it is really important to take into account their implications on the thermal performance. In order to analyze the effects of these factors on OVF thermal performance, an important simplification can be assumed: outer conditions can be simplified between summertime (sunny days and high temperatures) and wintertime (cloudy days and