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Sensitivity study of an opaque ventilated façade in the winter season in different climate zones in Spain

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ABSTRACT

Energy efficient buildings need to take advantage of any renewable energy available. An opaque ventilated façade (OVF) is a kind of façade that absorbs solar energy and transfers it to the ventilation system. This way, the sensible ventilation load of the heating system can be reduced in the winter season. The energy saving of this system depends strongly on the weather variables, mainly solar radiation on the façade, ambient temperature and wind speed. In order to find the most convenient locations where the best OVF efficiency can be obtained, its performance has to be studied along a complete season. For this purpose in this study a sensitivity analysis with the most important weather variables was carried out and the energy saving values in 12 locations in Spain in the winter were evaluated using a numerical model previously validated with experimental data. The results showed that although the most influential weather variable was solar radiation, a combination of high temperatures and low wind speeds can also lead to important energy saving values. It was found that the most convenient locations for installing an OVF were those with low and medium winter severity climates, namely, in the southern and coastal regions of Spain (zones A3, B3, B4, C3 and C4).

1. Introduction

The energy consumption of buildings accounts for approximately 40% of the total amount of energy used in a country. This energy is mainly used in the heating, ventilation and air conditioning systems. Thus, installing devices based on the renewable sources of energy available for buildings is an interesting alternative to reduce the consumption of electricity and conventional fuels, and therefore to lower emissions of greenhouse effect gases.

Solar energy has been used traditionally throughout solar collectors, converting the solar radiation absorbed in thermal energy using a storage fluid or in electricity using photovoltaic panels. Solar energy is also usually transferred to the inner spaces directly through the building windows and through the façade walls by conduction heat transfer. However façades walls are traditionally designed to insulate the inner space from the environment in the winter so the solar radiation that is absorbed by the external surface of the façade is normally transferred to the ambient air by convection and long wave radiation interchange. The traditional way of using the solar energy to heat indoor spaces in the winter is by letting the solar radiation go in through transparent layers, mainly windows or glazed panels. However, high glazed façades have a high risk of overheating in the summer season, mainly in hot and dry climates.

One way to prevent overheating that has been widely studied in literature is the use of transparent double skin façades [1]. This kind of façades are generally made up of two glazed layers with an air gap in between. A shading system is placed in the air gap to absorb the solar radiation and transfer the heat to the air inside the façade. This air can be exhausted in case of overheating or introduced into the building to provide preheated ventilation air to the inner spaces. However the use of highly glazed buildings implies higher costs of materials, construction and maintenance, and still the risk of overheating in hot climates [2,3].

An opaque ventilated façade (OVF) is an interesting, simple and economical alternative for using the solar radiation in a building. In this kind of double skin façade both solid layers are opaque. The external one is used to absorb the solar energy and to transfer part of it to the air in the gap. The inner layer acts as the insulation layer. This way the risk of overheating in the summer is avoided and yet part of the solar energy can be used to heat the ventilation air in the winter season.

Many types of OVF's have been studied so far, and a review of them can be checked in Ref. [4]. In some cases the OVF is combined

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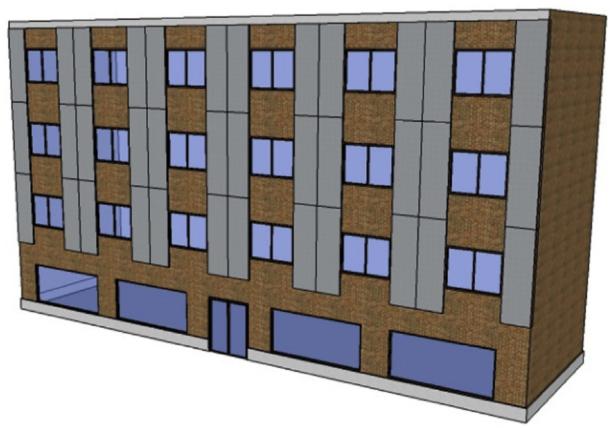

Fig. 1. Building sketch.

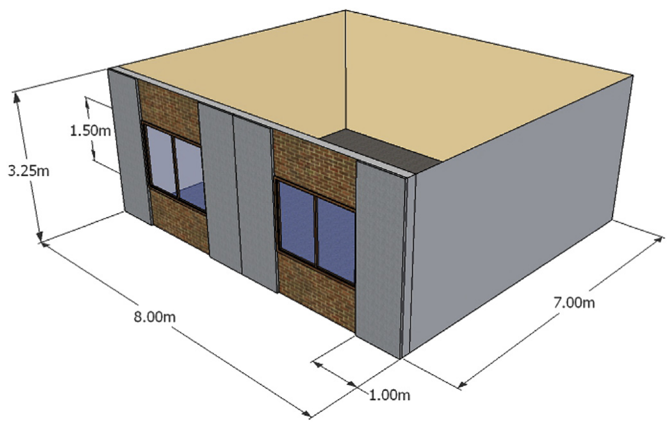

Fig. 2. Dimensions of the room studied.

with other energy systems [5–7]. Some OVF are called open joint ventilated façades [8,9], they consist in rows or tiles separated from each other a certain distance. The benefits of using this kind of façade can be read in Refs. [10,11]. The most popular OVF's are those in which its external layer is made of ceramic, clay or stone [12,13], but it could be also made of metal [14].

Another way of using the solar energy received by the building is the use of the so called unglazed transpired collector (UTC). This kind of solar collector appeared at the early nineties and have been installed in a number of buildings [15–18]. OVF's and UTC's are both opaque solar absorbers. An UTC reduces the external convection heat loss by suction of the external heat boundary layer [19]. A comparison between an OVF and an UTC was carried out in Ref. [20] showing that UTC's have better efficiency than OVF's. Nevertheless, an OVF is a simpler system, and when there is no need for high ventilation rates and materials and installation costs are critical, it can reduce the heating energy consumption considerably. Furthermore, an OVF can be a versatile system, as it can adopt several modes of operation depending on the aperture of its openings [21]. This modes of operation can work with mechanical or natural ventilation [22], which can be buoyancy or wind driven [23].

The annual energy saving that can be obtained by an OVF strongly depends on the location of the building and thus on its climate conditions. Therefore, it would be interesting to know which weather variables most influence the energy saving in order to establish which locations are more favourable for installing an OVF system.

The objective of this paper is to find the better locations for installing an OVF system and which weather variables influence the most on the reduction of the sensible heat demand of the building. To do this, a sensibility analysis was done to detect the most influential weather variable and simulations were carried out for a building with and without an OVF in the different climate zones in Spain.

2. Methodology

2.1. Numerical model

An experimentally validated numerical model of OVF was used to carry out the simulations of the building energy performance. The details of this model were explained in Ref. [24]. This model was included in the building model created using the building energy simulation software TRNSYS [25].

2.2. Case study

The selected building was a typical four storey box shaped office building, Fig. 1. The room studied was an office room of 8 × 7 × 3.25 m, see Fig. 2. The room had four OVF modules of 1 m width each, covering half of the surface of the south façade. The conventional part of the south façade had windows covering half its area. The entire north façade was conventional. The rest of walls, the floor and the ceiling limited with other similar office rooms. The materials used in each wall and their properties can be seen in Tables 1–3.

The room was provided with mechanical ventilation which entered the inner space through the OVF. The air gap of each module of OVF can be considered a 1 m width and 0.05 m depth duct. The air entered the OVF through the lower opening of the external layer and was introduced in the room through the upper opening in the insulation layer, see Fig. 3. The latter opening was opened or closed using a trap door. The air was exhausted from the room through a ventilation duct in the room ceiling, which went up to the roof of the building. This duct had a square cross section of 0.50 m width and roughness 0.1 mm. It had a grill with dynamic loss coefficient of 2.161.

Table 1
Thermophysical properties of wall materials.

Layer	Material	Thickness (m)	Density (kg/m^3)	Specific heat (kJ/kg K)	Conductivity (W/m K)	Thermal resistance (m^2 K/W)
1	Plaster	0.020	900	1	0.26	0.077
2	Hollow brick	0.070	1200	0.9	0.42	0.166
3	polyurethane	0.030	30	1.5	0.02	1.500
4	Air	0.020	1	1	0.02	1.000
5	Perforated brick	0.115	1600	1	0.65	0.177
6[a]	Air	0.050	1	1	0.02	1.000
7[a]	Galvanized steel	0.001	–	–	–	5.54×10^{-5}

[a] Only in the case with OVF.