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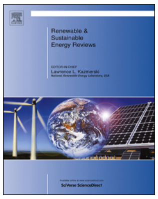

Perspectives of double skin façades for naturally ventilated buildings: A review

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ABSTRACT

This paper identifies the parameters affecting the thermal and energy performance of buildings with double skin façades (DSFs). It reviews the state of the art of current body of literature about the application of DSF technologies in order to provide guidelines to optimise such designs in naturally ventilated buildings. Three groups of parameters are identified as having significant impact on the DSF performance: the 'façade' parameters, which comprise the features of the cavity and the external layer of the façade; the 'building' parameters, which are those related to the physical configurations of the building; and the 'site' parameters, which are related to the effects of the outdoor environmental conditions on the building and the DSF behaviours. For each group of parameters, a comprehensive table is compiled summarizing the main findings of the studies that directly and indirectly contribute to the understanding and implementation of such technology. Guidelines established for the design of naturally ventilated buildings indicated potential application of DSF for improving the indoor thermal comfort even in warmer regions. However, further investigations expanding the analysis beyond the cavity are needed in order to evaluate the influence of the DSF on the thermal comfort in the user space.

Contents

Abbreviations: DSF, double skin façade; ACH, air change per hour; UAE, United Arabic Emirates; BES, building energy simulation; SC, shading coefficient; ETTV, envelope thermal transfer value (W/m²); CFD, computational fluid dynamics; WWR, window to wall ratio

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1. Introduction

The global consciousness about energy efficiency and sustainability in the construction sector has raised interest in the passive systems applied to buildings. A 'passive building' is one in which indoor environment is regulated not by the operation of mechanical heating and cooling systems but by the structure and architectural design of the building and its components [1]. The integration of passive design strategies are likely to occur at the conceptual design level, by determining the elements that have critical influence on building performance, such as its form and orientation, wall-window ratio, glazing type and shading, among others [2].

Among the passive solutions, the double skin façade (DSF) has recently become a popular technology. The motivation for using DSF comes from the desire to combine the transparent façade of modern buildings with energy efficiency. However, its implementation is accompanied by significant challenges due to the complexity of the thermal and airflow phenomena involved in its behaviour as well as the adaptability of these solutions to climatic conditions of different geographical regions [3,4].

According to Wong et al. [5] most of the studies about the DSF performance have been carried out in temperate climate conditions. However, the possibility of using the technology as means to introduce natural ventilation to buildings in the tropics has been suggested [6–8]. Nevertheless, guidelines or recommendations for modelling DSFs are still in the early stages of development, especially in hot and humid climate. Therefore, further research is required for a better understanding of the processes involved in DFS and the implication of its use in different climates [9,11].

In the present paper the parameters influencing the performance of buildings with DSF are identified. The aim of this study is to review the body of literature from the last decade on studies about experimental and computational simulation of DSFs to draw conclusions about their implementation in naturally ventilated buildings.

2. Concept and functionality of the double skin façade

The concept of DSF was introduced in early 1900s, but little progress was made until the 1990s [12]. The history of DSF is not particularly established and knowledge on the physical processes involved is still lacking. Although its use is more popular in places with more stringent building energy performance regulations, most countries do not have any standard guidelines on how to design and assess the performance of DSF, which can be a barrier for its implementation [11,13].

A DSF consists of a normal façade, an air cavity and an additional external skin usually made of glass. It is a common practice to implement a shading system within the cavity between the two layers of the façade. To De Gracia et al. [14] the main factors that encourage air movement in buildings with DSF are the movement of the surrounding wind and the pressure difference due to the thermal buoyancy that occurs in the cavity. The phenomenon of thermal chimney within the DSF occurs due to the density difference between the warmer air inside the cavity and the cooler air outside. The air inside the cavity is warmed up by the solar radiation and exhausted to outside from the top of the cavity. In naturally ventilated building, fresh air is often drawn from windows on the opposite side of the DSF, which passes through the occupant space before being extracted into the cavity of the DSF [15,6].

One of the advantages of DSF is the promotion of the natural ventilation which provides good indoor air quality and improves thermal comfort without any electricity demand [16,17]. However, the design of DSF for naturally ventilated buildings is delicate due to the interaction of thermal processes and the airflow mechanisms, which depend on the properties of various components of the façade structure and the building itself [18,19]. Therefore, predicting the performance of a DSF is not a trivial exercise and its application requires even more considerations when it is applied to naturally ventilated buildings.

Different aspects of the DSF have been reviewed presenting the advances in its design [10,20,21], the availability of computational models [14] and the existing research methods used to study its performance [22]. Additionally, a number of studies have been undertaken and reported on the behaviours of DSF over heating and cooling seasons [23,8,24]. On the other hand, some studies focused on specific aspects, which are outside the scope of this study, such as daylighting [25,26], smoke escape [27,28], photovoltaic applications [29,30], condensation [31] and the effect of plants within the cavity [32].

In spite of the potential positive effects of implementing the DSF, there are some concerns about its application such as: the costs for its design, construction and maintenance, which are considerably higher than a traditional single façade [21,33]; the increase of the weight of the structure; the sound transmission from room to room or floor to floor through the cavity; the fire regulations and the reduction of useful office space [34].

3. Façade design parameters

This section summarises the influence of the DSF components on the building performance such as cavity depth, position and type of shading devices, glazing materials, structure of the façade as well as the size of the cavity openings. The decisions about the façade design have an impact on several aspects of the building like its thermal characteristics, ventilation strategy and shading control [10].

3.1. Cavity depth

When properly designed, the cavity has the potential to significantly reduce the building energy consumption. However, a poorly designed cavity can result in uncomfortable indoor temperatures and additional energy consumptions [35]. One of the factors most studied about the cavity in DSFs is its depth, which may vary from 10 cm to more than 2 m according to different design concept such as the provision of enough space for the shading device, an adequate access to the cavity interior for maintenance and cleaning [36].

Evaluations of DSF's cavity depth on the amount of solar heat transferred through the cavity and the resulting temperature and ventilation rates produced have been evaluated by Rahmani et al. [37], Torres et al. [34] and Radhi et al. [15]. The results show that narrower cavities presented an accentuated stack effect and a stronger air movement which leads to a more effective extraction of the warmer air through the cavity. On the other hand, in larger cavity depths (more than 1 m) there is a reduction in the stack effect and the heat transfer towards the interior rooms increases. Thus, a cavity depth between 0.7 and 1.2 m was recommended by Radhi et al. [15] as it made a balance between air extraction and heat transmission to the user room.

In air-conditioned buildings the accentuated stack effect in the cavity resulted in less energy demand for cooling the building and thus, narrower cavities were preferred. However, in a naturally ventilated building the influence of the cavity airflow on the interior of the building still needs investigation due to the proximity of these openings to the user room. Similarly, the equilibrium between the ventilation rate to remove heat from the