Double-Skin Facade with Venetian Blind: Global Modelling and Assessment of Energy Performance

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ABSTRACT

In this past decade, glazed façades use in new buildings has soared. Some of these façades, called "double skin façades", are made of internal and external glazing. As indicated by its name, "double skin façades" are a special type of envelope which air space in between, called "the channel", can be rather important (up to 0.8 meter). Properly designed double skin façades allow for energy savings and for the increase of the indoor comfort. The majority of these facades are equipped with solar protections (such as venetian blinds) inside the channel in order to control the daylight and overheating due to the solar radiation. In general the channel is ventilated (naturally, mechanically, or using a hybrid system) in order to decrease the overheating problems in summer and to contribute to energy savings in winter. To reach these goals, the detailed behavior of double skin façade need to be better understood and a global model should be produced, the present work is dedicated to this issue. In fact, this model, implemented within dynamic thermal tool allows energy's simulations of buildings equipped with these facades.

KEYWORDS

Building, double skin façade, solar protection, global model, nodal approach, dynamic simulation.

INTRODUCTION

Double-skin façades (DSF), used in new architectural projects, are designed to fulfill several envelope functions, such as thermal and acoustic insulation, optimization of natural lighting and improvement of ventilation system. The aim of these facades is, on one hand to increase the internal comfort and on the other hand to decrease the energy consumption. DSF are highly technological building components and can also be called "intelligent façades" because of the sophisticated control system commanding solar protections and ventilation flows.

In this study a compact one floor double-skin façade is of interest. It is composed of two glazing separated by a 20 cm width ventilated air space, called channel. The facade is equipped with usual venetian blinds (25 mm slats) placed inside the channel. The channel is mechanically ventilated with the air inlet and the outlet situated respectively on the bottom and the top of the façade (cf. Fig. 1).

Energy performance of such a façade depends upon complex physical phenomena. Previous studies showed that short and long wave radiation and convection within the channel are the most important (Arons, 2000; Saelens, 2002; Hensen, 2002). Moreover both radiation and convection are highly influenced by the solar protection situated within the channel. In case of Venetian blinds transmitted solar radiation depends upon the slat tilt angle and optical properties of blind material. Convection air flow within the channel depends upon blind position (middle or side of the channel) but also on the slat tilt angle and on absorbed solar radiation (Safer, 2006; Safer et al, 2005). Global energy performance of the DSF is a combination of the thermal behavior of the façade element and of its integration within the building. Adapted numerical models, representing correctly physical phenomena, that can be integrated into whole building energy simulations are necessary to assess the energy performance. Such model, based on physical phenomena previously studied using CFD simulations and PIV measurements (Safer, 2006), is proposed in this paper.

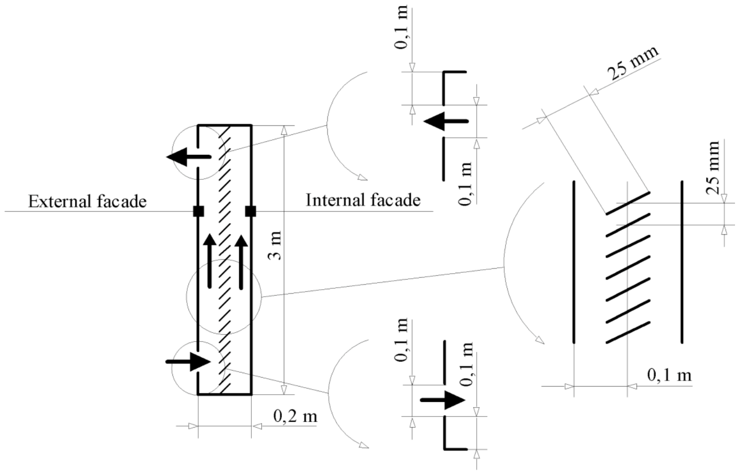

Figure 1: Double skin façade geometry.

DOUBLE SKIN FAÇADE MODEL

The façade is horizontally divided into several bands and each band is represented by six temperature nodes: the external glazing, the air in the outside part of the channel, the solar protection, the air in the inside part of the channel and two nodes for the internal double-glazing (cf. Fig. 2).

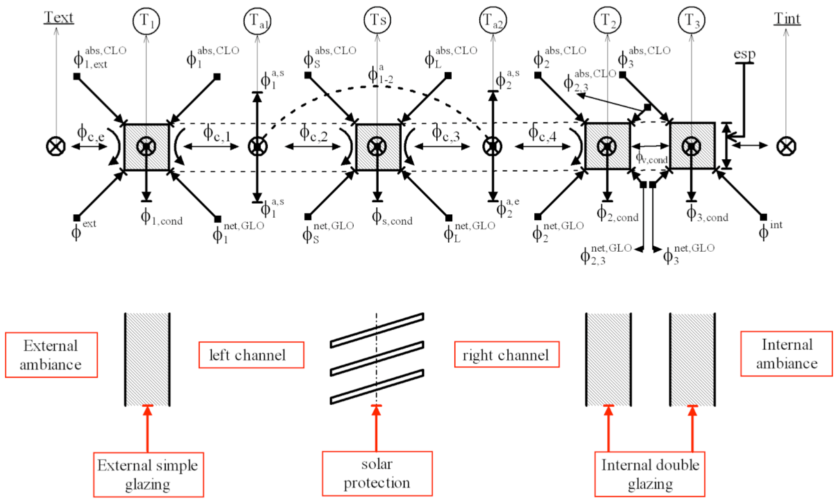

Figure 2: Double skin façade model.

Balance equations in each node include: a) convection exchanges (denoted Φ_c) between air of the channel and glazings (internal and external one): these exchanges are based on convective coefficients derived from CFD approach (Safer et al, 2005). b) Short and long wave radiation exchanges (denoted respectively $\Phi_{abs,CLO}$ and $\Phi_{net,GLO}$): the calculation of the short long wave radiation exchanges is based on the DSF geometry characteristics includes slat tilt angle of the solar protection and DSF orientation; the estimation of the long wave radiation exchanges is based on view factors calculation (Hottel method from Seigel, 2002). c) Enthalpy exchanges (denoted Φ_a) between the air of each band; theses exchanges are based on air flow distribution issued from CFD results (Safer, 2006).

The proposed global model have been compared with some experimental and numerical results and implemented in well known building simulation tool TRNSYS. In Figure 3, we present some comparison between our DSF model results and Campbell results (Campbell et al, 1997). Others comparisons are available in Safer (2006).

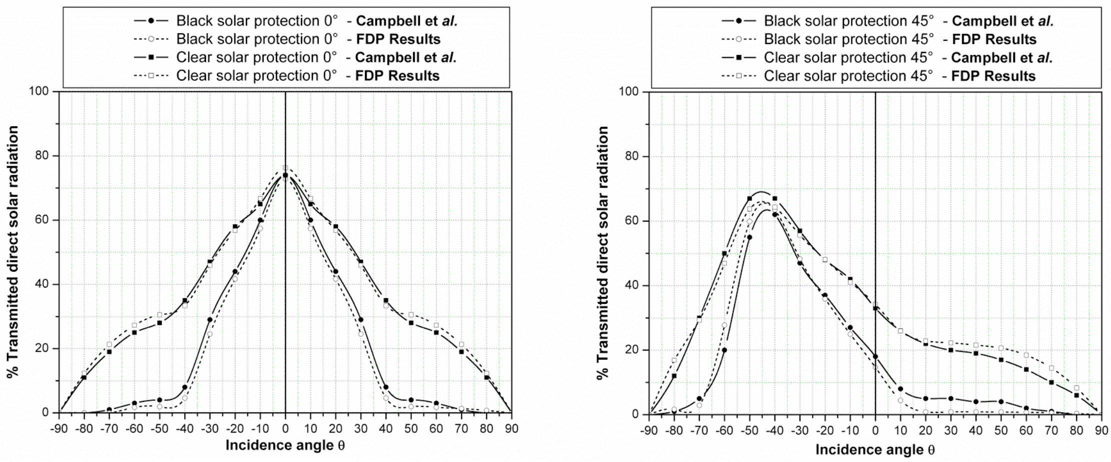

Figure 3: Percentage of transmitted direct solar radiation comparaison (FDP and Campbell et al. results)

CASE DESCRIPTION

When renewable energy is used in buildings, some additional difficulties emerge in order to manage correctly building's equipments. This situation occurs for solar gains in buildings with a DSF. Therefore the thermal behavior of a building equipped with DSF is of interest here and especially the impact of the DSF in terms of energy effectiveness and comfort on the interior environment. The investigations use TRNSYS a computer dynamic simulation tool of buildings and their components.

A standard office building of 2500 m² per floor is the support of the study. The room of 21.1m long, 13.1m wide and 3.3m height, situated on the top floor (exposed to summer overheating) of the building is represented in the simulation tool. Building material data are summarized in Table 1. The DSF is installed on the 21.1 m side long and the 3.3m height. The building is situated in Lyon, France (45°44' N, 5°05' E), where the extreme outdoor temperatures are around 32°C in summer and -8°C in winter.

In order to analyze clearly the impact of the DSF the simulations were performed without any HVAC or lighting equipment, internal loads or occupation patterns. Finally, the channel of the DSF is mechanically ventilated (airflow rate=150m^3/h) equipped with venetian blind (25mm).

TABLE 1

Building layers thermal characteristics

Element	Layer	Thickness [m]	Conductivity [W/mK]	Capacity [kJ/kgK]	Density [kg/m^3]	Uvalue [W/m^{2}K]
Exterior walls	Coatings	0.01	0.8	1	1600	0.23
	Mineral wool	0.15	0.035	0.1	1030	
	Concrete	0.15	2	1	2400	
Ceiling	Coatings	0.01	0.8	1	1600	0.19
	Polyurethane foam	0.12	0.024	1.4	1030	
	Concrete	0.3	2	1	2400	

DSF SIMULATION RESULTS

Reference case – fixed blinds

First simulations were performed with no regulation systems of the Venetian blinds. Two cases were investigated: a) solar blind completely open (slats at 0°) b) solar blind completely closed (slats at 90°). The simulations were run over one year and the results for a cold week in January and a hot week in July are presented respectively in figures 4 and 5. Naturally, the case with open blind performs better in winter conditions, because of the utilization of solar gains. Again, the solar gains should be avoided in summer by closing the blinds and evidently the corresponding case performs better in hot conditions. The difference between the two cases can be as much as 7 to 8°C in summer.

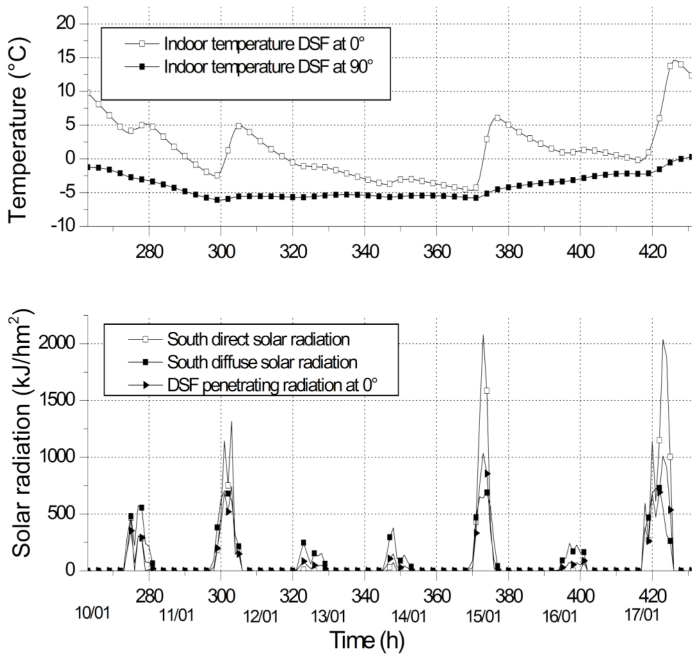

Figure 4: Indoor temperatures in winter period.

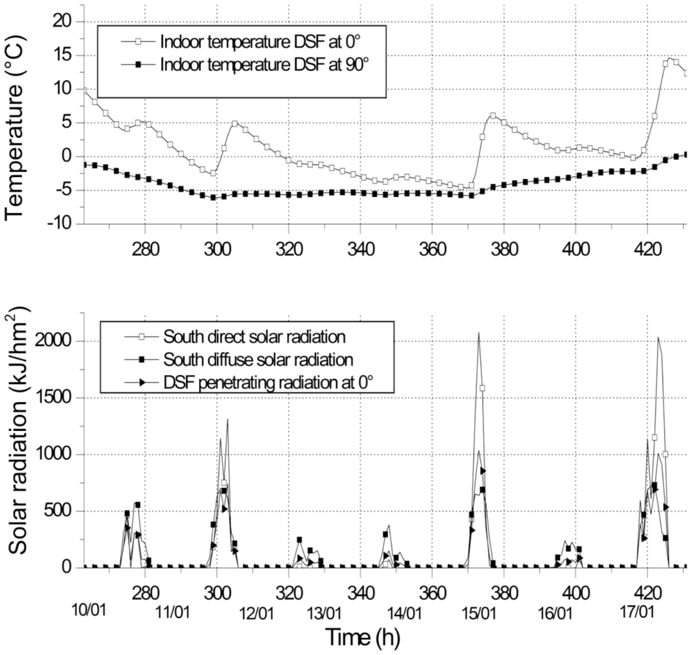

Figure 5: Indoor temperatures in summer period.

For the summer period, with the same strategies, we have compared the indoor air temperature with a classical building (the DSF have been replaced with regular double glazing windows). This comparison shown that it is possible to have a reduction about 7 to 8°C. Moreover, the indoor air temperature of building equipped with DSF is in the interval acceptance of thermal comfort particularly when the blinds are closed. This case is not recommended because the complete closing of the blinds will generate more energy consumption (the lighting system is switched on). In this case, the overall energy consumption will considerably decrease the building performances. Once more, a regulation strategy of the blinds according to the some parameters like the indoor temperature, the indoor light level or the incident solar radiation through the DSF must be adopted.

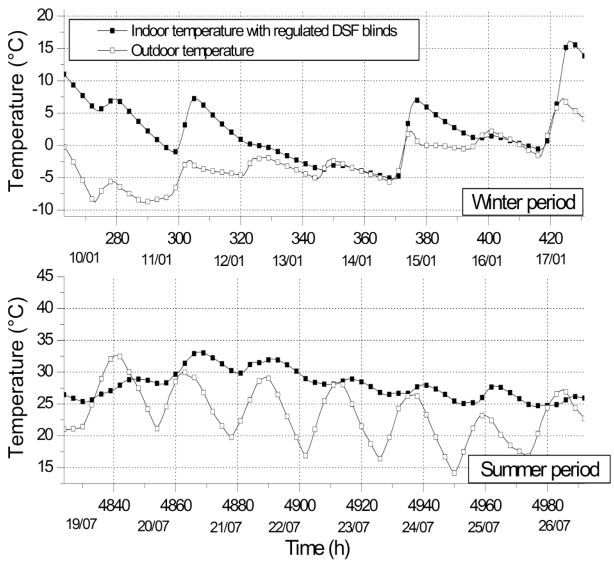

Figure 6: DSF – building system indoor temperature with a blind regulation system.

Figure 6 show the indoor air temperature resulting of the integration of the "blind regulation system" on the DSF. The blind regulation system is a proportional controller that allows the rotation of the slat tilt angle of the solar protection (between 0 and 90°). The decision of this system is taken according to the incident direct solar radiation and the indoor air temperature. For example, when the indoor temperature is lower than 26°C, the DSF allow a maximum solar gain. Finally, the regulation system is needed one time for the occupant comfort and the other time for a balance between the luminous and the thermal comfort.

CONCLUSIONS

A nodal model, representing thermal behavior of DSF, composed of 6 nodes in the horizontal direction and of n layers in vertical direction was proposed here. Energy balances in each node include the convection fluxes described by convective heat transfer coefficients. Results from detailed CFD model were used in order to compute these quantities as a function of the velocity and temperature fields inside the channel of the double-skin. Moreover, the proposed global model have been exhaustively compared with some experimental and numerical results and implemented in well known building simulation tool TRNSYS.

The results showed that in DSF configurations, the slat tilt angle effect on indoor air temperature and transmitted incident solar radiation through the DSF is very important, since it regulates the thermal human comfort and the light level describing the visual comfort inside the building equipped with DSF. In fact, the use of "blind regulation system" can personalize the luminous and thermal contributions, while playing full energy savings by the maximum use of the light in the winter period, and considerable reduction of greenhouse effect, during the summer. A regulation for a DSF system proves to be very gainful for the occupant comfort and especially for an energy economy.

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