# Preliminary results on the assessment of using Venetian blinds as a solar thermal collector in double skin facades in Mediterranean climates

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## Abstract

The global trend on energy integration and building efficiency is making both researchers and developers look for technical solutions to use façade surfaces for electricity and/or domestic hot water production. These applications improve the energy performance of the building, but the integration of solar photovoltaic panels or solar thermal collectors into the façade may block visibility to the exterior and may prevent natural light from entering the building, both important comfort factors for building users.

This paper presents the preliminary results on the assessment of the thermal performance of a double-skin facade (DSF) with a venetian blind-type of structure used as a solar thermal collector to heat up a circulating fluid by means of computational fluid dynamics (CFD). This type of heat exchange structure would allow for energy recovery and exterior views simultaneously, and can be easily integrated into the façade aesthetical design. For the purposes of this study, the modeled façade is set to be located in Barcelona (Spain), where large solar gains are a constant condition throughout the year, and such large semi-transparent areas as this type of façades can produce significant over-heating in buildings, even during the winter.

For the studied façade both the reductions in radiative heat gains entering the building and the heat recovery are evaluated for summer meteorological and solar radiation conditions and numerical results obtained are compared with previous results reported by our research group on a similar DSF model without a façade-integrated thermal system.

Keywords: Double skin facades; computational fluid dynamics; solar thermal collector; energy integration; thermal performance analysis; architectural integration.

## 1. Introduction

The efficient use of energy resources is one of the great challenges of our society. In recent years we have witnessed the increase in the study, construction and operation of renewable energy power plants all around Europe, and the implementation of specific energy efficiency regulation policies for different productive sectors and type of energy consumer at the state level, in order to meet the reduction in greenhouse effect gasses emissions agreed upon by the state member governments and the EU, and ratified in several international treaties.

In recent years there has been a growing interest in the academic and the construction sector about the functionalization of the building external surfaces in order to reduce the building's energy consumption. This has strengthened the desire to use the building facade for the local production of electricity or the accumulation of thermal energy [1]. The aim of this work is to assess the use double-skin facades (DSF) as solar thermal collectors. DSF are a building envelope typology of widespread use in singular/institutional buildings because of their particular aesthetics: their large glassed surfaces allow daylighting into the building, and the air cavity in between skins increase the thermal insulation and soundproofing. However, in Mediterranean latitudes these facades are proven to cause overheating in building interiors due to the moderate to high temperatures, high levels of solar radiation, and the greenhouse effect associated to glazed, enclosed spaces [2].

The purpose of this work is to assess the feasibility of converting the envelope of singular/institutional buildings into thermal energy recovery units, integrating radiative heat absorption/transfer capabilities into the architectural elements of a double-skin facade (e.g. shading structures as venetian blinds - VB), and use these elements to transfer the absorbed heat to a high thermal capacity fluid. The recovered heat could then be used to cover the building thermal energy requirements, thereby reducing its ecological footprint without compromising the aesthetic appeal, the daylighting conditions and the outdoors views offered by this type of facades.

## 2. Modeled case

The numerical setup used for this study was set to replicate the numerical setup used in previous work published by this research group [3] in order to establish a common reference frame for thermal performance comparisons.

Figure 1 shows the geometric configuration used in this study. The control volume for the selected DSF comprises (from outdoors to indoors) an external glazing, a flow cavity with a VB, an internal double glazing (65% of the internal façade area) and an internal wall (35% of the internal façade area). The flow cavity dimensions were set to 0.8 m wide, 4 m height and 6 m depth.

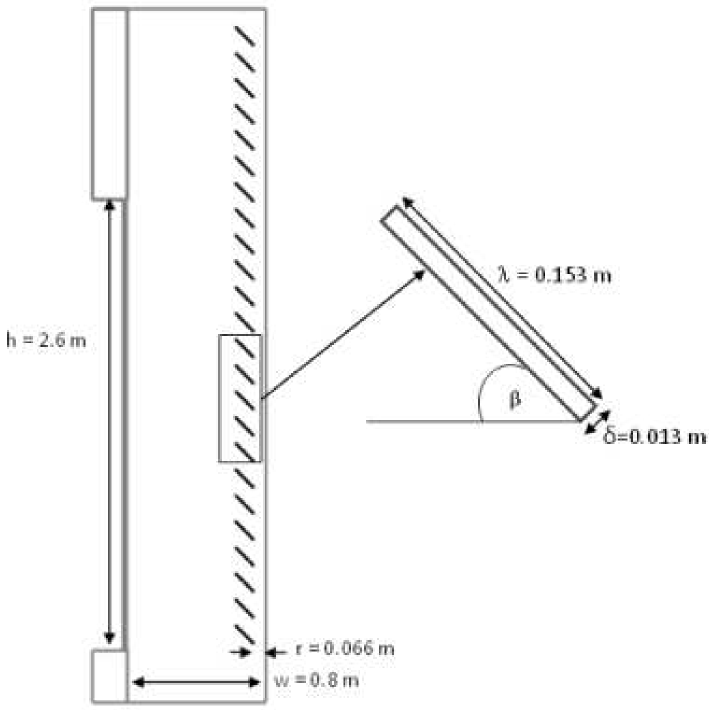


*Figure 1. Geometric model used*

Table 1 shows the thermos-physical and optical properties for all the construction materials used in the DSF. Thicknesses for the different layers were assigned following common practices in the construction industry.

It was assumed that the studied DSF was located in Barcelona, Spain (41.23° N–2.11° E) and facing sout h. Theoretical maximum values for solar irradiance (global and diffuse) and climatic data (for outdoors temperature) for a warm, sunny summer day (17th July) were taken from open-access databases [4].

| Facade element | Density (kg/m$^3$) | Heat capacity (J/kg·K) | Thermal conductivity (W/m·K) | Absorptivity | Transmissivity | Thickness (mm) |
|---|---|---|---|---|---|---|
| Glass | 2500 | 795 | 1,16 | 0,15 | 0,78 | 6 |
| Interior wall | 720 | 1,096 | 0,10 | 0,8 | - | 200 |
| Venetian blind | 2719 | 878 | 169 | 0,9 | - | 13 |

*Table 1: Thermo-physical and optical properties of the construction materials*

The fluids were taken to be incompressible, Newtonian and in turbulent flow regime. DSF cavity was set to be open to the outdoor atmospheric air by its upper and lower surfaces. The outdoor air temperature variation through the day was modeled and introduced as a dynamic boundary condition to the CFD solver via user defined functions. Water at 15 ºC, circulating through the VB louvers interior void space at 0,05 m/s, was used as thermal accumulating fluid.

All the numerical sub-models, discretization and simulation strategies used were previously validated against an experimental database [5]. A transient solver with a time step of 120 s was selected for performing the simulations. Numerical experiments were performed in a Hybrid Bull machine property of Consorci de Serveis Universitaris de Catalunya (CSUC). Numerical convergence of the model was checked based on the normalized numerical residuals of all computed variables. Heat fluxes and temperatures on all solid surfaces and the water flow streams were recorded for analysis and discussion purposes.

## 3. Results and discussion

The effect of a solar collector integrated into a VB (VB/SC) on the indoor solar heat gain was evaluated using a set of numerical simulations of the DSF under free convection operation regime (no ventilation, DSF cavity open to atmosphere by upper and lower surfaces) without VB, with VB and with VB/SC. Heat flux through the interior surfaces of a DSF were recorded for a 24-hour period for all studied cases. These heat fluxes were integrated and area-weighted averaged to compute the solar heat gains. Figures 2 and 3 show the heat fluxes recorded for the simulated period, and Table 2 presents the results obtained for this set.

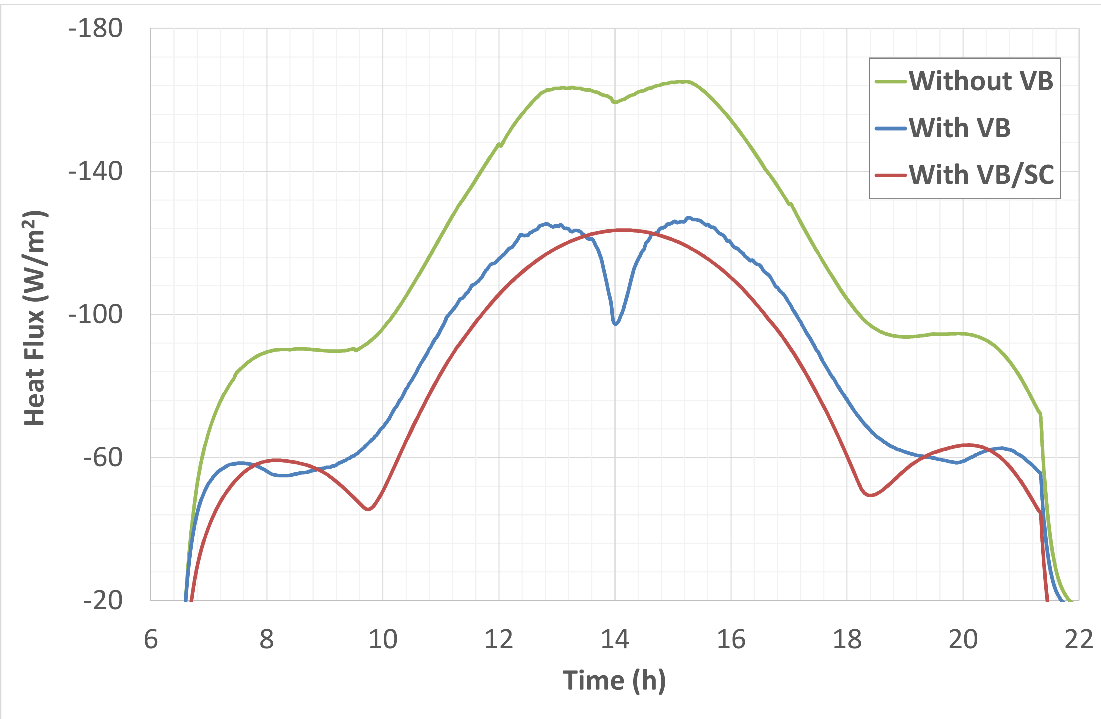


*Figure 2: Heat flux through the inner glass for the studied DSF*

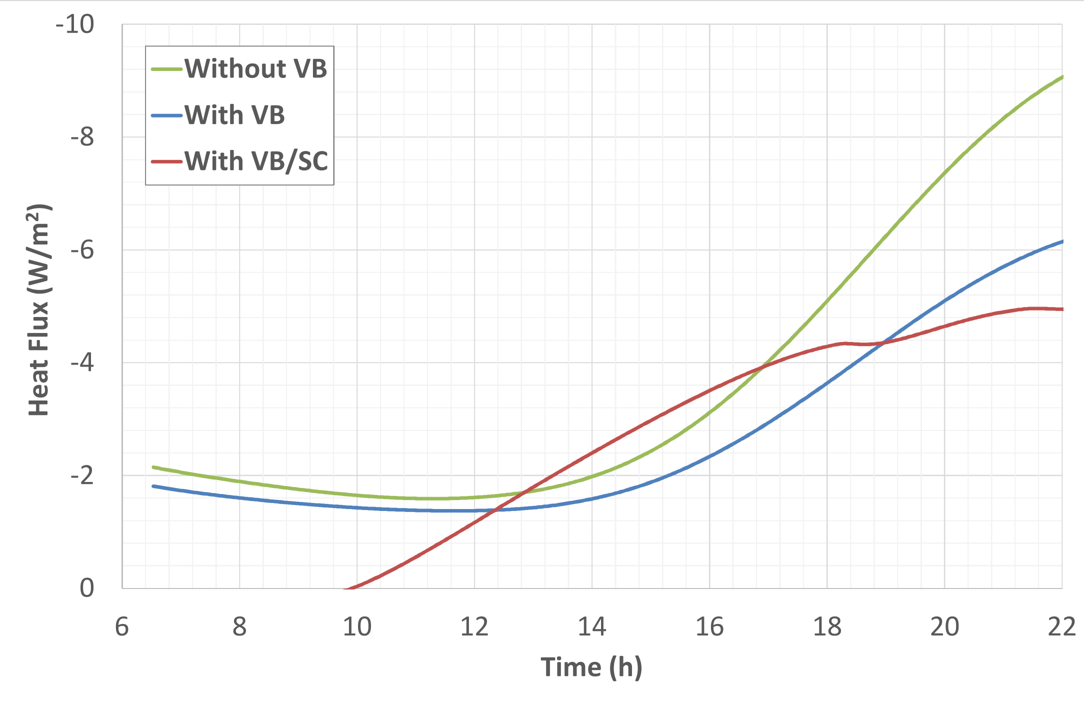


*Figure 3: Heat flux through the inner wall for the studied DSF*

| Solar Heat Gains (Wh/m$^2$-day) | Inner glass | Inner wall | Inner surface average | Reduction in solar heat gains |
|---|---|---|---|---|
| **DSF without VB** | 1768,5 | 59,9 | 1170,5 | |
| **DSF with VB** | 1296,5 | 44.1 | 858,15 | 27 % |
| **DFS With VB/SC** | 1181,1 | 39,5 | 781,58 | 33 % |

*Table 2: Solar heat gains for the studied cases*

Table 2 shows that the use of a VB/SC improves the thermal performance of the facade when compared with a DSF with VB. Using the VB structure as a heat exchanger by circulating a fluid in its interior void space reduces the solar heat gains by 33 % of the average gains of a DSF without VB or by 9 % of the average gains of a DSF with VB.

## 4. Conclusions and future work

CFD proves to be a useful tool when modeling conductive/convective/radiative heat transfer in ventilated DSF. Numerical simulations were run for several cases and heat fluxes through all surfaces were obtained for the studied scenarios. A previously validated modeling strategy was used to obtain the presented results, consolidating the idea that CFD can offer tailored solutions for DSF performance optimization.

Heat fluxes through the inner layer of a DSF were evaluated for a VB/SC DSF, and the results obtained compared with the heat fluxes recorded for a DSF with/without VB in free convection regime in order to assess the influence of VB/SC on DSF thermal performance. Results obtained show that a VB/SC can reduce solar heat gains up to 33%.

The numerical model presented in this work has to be tested for several operating/climatic/radiation conditions, geometry configurations and material optical properties for a better understanding of the heat transfer mechanisms present in the studied case. A parametric study should be performed in order to obtain the best possible configuration for the DSF in order to maximize the heat recovery in the VB louvers.

## 5. Acknowledgments

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