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Evaluación del rendimiento energético: impacto de las persianas y el sombreado en el rendimiento de las fachadas de doble piel

Energy Performance Assessment: Impact of Blind and Shading on Double Skin Facade Performance

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Resumen-- **La integración de persianas y voladizos en fachadas de doble piel (DSF) ofrece la oportunidad de mejorar significativamente el rendimiento energético de los edificios. Este estudio investiga el impacto de una persiana interior y un voladizo en el rendimiento de las DSF mediante simulaciones realizadas en un edificio de oficinas en Madrid y Copenhague utilizando el software DesignBuilder. El análisis compara escenarios con y sin estos elementos de control solar, teniendo en cuenta parámetros como las cargas de refrigeración y calefacción. Los resultados muestran que la integración de una persiana interna en la DSF redujo la carga de refrigeración anual hasta un 16,4 % en Copenhague y un 6,4 % en Madrid. Además, la combinación del voladizo en ángulos variables con la persiana da lugar a reducciones adicionales de la carga de refrigeración, siendo la configuración de 45° la estrategia más eficaz. Curiosamente, las estrategias de sombreado mostraron un impacto mínimo en las cargas de calefacción en climas moderados, con aumentos observados que oscilaron entre el 0,8 % y el 3,3 %. En general, los resultados ponen de relieve el potencial de los DSF con persianas internas y voladizos integrados para optimizar el rendimiento energético de los edificios, especialmente en climas moderados.**

Palabras clave— Fachada de doble piel; ahorro energético en edificios; evaluación del rendimiento energético de edificios; software DesignBuilder..

Abstract— **The integration of blinds and an overhang within double skin facades (DSFs) presents an opportunity to enhance building energy performance significantly. This study investigates the impact of an inside blind and an overhang on DSF performance through simulations conducted on an office building in Madrid and Copenhagen using DesignBuilder software. The analysis compares scenarios with and without these solar control elements, considering parameters such as cooling and heating loads. Results show that integrating an internal blind within the DSF reduced annual cooling load by up to 16.4% in Copenhagen and 6.4% in Madrid. Furthermore, combining the overhang at variable angles with the blind results in additional cooling load reductions, with the 45° configuration proving to be the most effective strategy. Interestingly, shading strategies showed minimal impact on heating loads in moderate climates, with observed increases ranging from 0.8% to 3.3%. Overall, the findings highlight the potential of DSFs with integrated internal blinds and overhangs for optimizing building energy performance, particularly in moderate climates.**

Index Terms— Double Skin Façade; building energy saving; building energy performance assessment; DesignBuilder Software.

I. INTRODUCTION

THE evolution of building design has witnessed a constant pursuit of architectural elements that marry form with function. In the quest for sustainability and energy-efficiency, architects and engineers have embraced innovative solutions like double skin facades (DSFs) (Ascione et al., 2021). These innovative systems, consisting of two enclosure layers separated by and a cavity between them, offer a plethora of environmental and practical benefits, making them a compelling choice for modern architectural design (Ziasistani & Fazelpour, 2019). Beyond the fundamental functionality of DSFs, the integration of blinds and shading devices offers even greater potential for architects and building engineers (Lee &

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Chang, 2015). These strategically positioned elements allow precise adjustment of building performance through the regulation of natural light penetration. Through this control, architects are able to address critical challenges like excessive solar heat gain and glare while simultaneously maximizing the amount of natural daylight available to occupants, leading to improved visual comfort and energy savings (Zheng et al., 2024). The exploration of DSFs with integrated blinds and shading devices necessitates a thorough understanding of their individual contributions to building performance. Numerous studies have documented the multifaceted benefits of DSFs. These benefits include improved thermal insulation (Ascione et al., 2021), reduced energy consumption for heating and cooling enhanced sound insulation. The integration of blinds and shading devices within the DSF cavity further expands upon these advantages by offering additional benefits. Studies have shown that these integrated elements can significantly reduce solar heat gain within the building (Zheng et al., 2024), leading to decreased cooling energy demands. This study investigates the multifaceted performance of DSFs, focusing on the added functions provided by integrating an internal blind and an overhang within the cavity.

II. Methodology

A. Base case study: DSF Building

To analyze the impact of an overhang and an internal blind on building energy performance, an office building located in Madrid (Spain) and Copenhagen (Denmark), was simulated using DesignBuilder software. This approach enables an assessment of how these elements influence energy efficiency in these two different climatic conditions. The 3D model of the building is presented in Fig. 1. Table 1 lists the properties of building components and their global thermal transmittances (U-values). In this study, the primary model was a simple office building with 150m^2 total floor area, using DesignBuilder version 7.0.2.006. The building utilizes a packaged terminal heat pump (PTHP) for heating and cooling purposes. This system consists of a single-speed direct expansion (DX) cooling coil, a single-speed DX heating coil, an electric supplemental heating coil, a constant volume supply air fan, and an outdoor air mixer.

Table I.
Construction material used in the building

Component	Layers	U[W/(m^2·K)]	Thickness(m)
External walls	Brickwork Outer XPS Extruded Polystyrene Concrete Block Gypsum Plastering	1.6	0.1 0.0795 0.1 0.013
Floor	Urea Formaldehyde Foam Cast Concrete Floor Screed Timber Flooring	0.9	0.0869 0.1 0.07 0.03
Roof	Asphalt MW Glass Wool Air Gap Plasterboard	1.1	0.01 0.1445 0.2 0.013

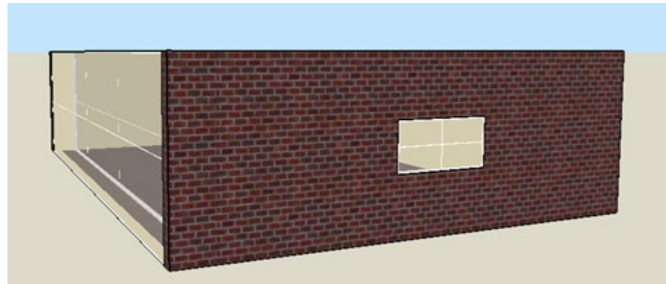

Fig. 1. 3D model.

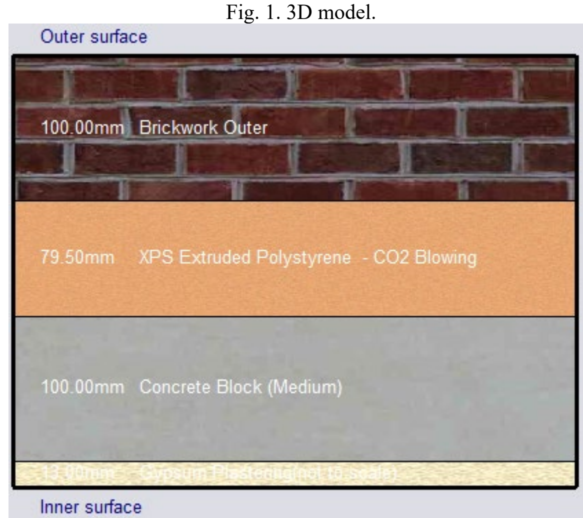

Fig. 2. Wall construction.

The model incorporates weather data, such as temperature and solar radiation, specific to the climate zones of Copenhagen and Madrid, to account for regional variations. Tables 2 and 3 provide location-specific details about Copenhagen and Madrid, respectively, relevant to the model's inputs.

Table II.
Copenhagen's geographical information

Location	Copenhagen - Denmark
Latitude (°)	55.62
Longitude	12.65
Elevation above sea level (m)	5

Table III.
Madrid's geographical information

Location	Madrid - Spain
Latitude (°)	40.45
Longitude (°)	-3.55
Elevation above sea level (m)	582

Following the input of all necessary data for the base case model, the simulation was executed using DesignBuilder software. Subsequently, the resulting data were analyzed to obtain insights into building performance.

A. Integration of an Internal Blind

Building upon the insights gained from the base model simulations, the study then focused on exploring the potential impact of integrated an internal blind within the double skin facade. Blind was strategically positioned within the facade's cavity to investigate their influence on the building's heating and cooling loads. The addition of an internal blind is expected to offer several potential benefits, such as reducing solar heat gain and enhancing insulation. The model incorporating blind was simulated using DesignBuilder software. The results were

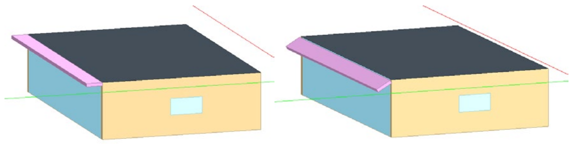

Fig. 3. 3D models of the building with an overhang at 0° and 45º.

then compared to the base case scenario to quantify the potential impact on heating and cooling loads in both Copenhagen and Madrid.

B. Integration of an Overhang

After analyzing the internal blind within the DSF, the study investigated the combined effect of the internal blind and an overhang. The overhang was modeled at tilt angles of 0° and 45° to evaluate its impact on energy efficiency.

III. Results and discussion

This analysis examines the cooling load implications of an internal blind and an overhang on a double skin facade in an office building. Figures 4 and 5 visually represent the impact of the internal blind and an overhang on cooling load in Copenhagen and Madrid respectively. The charts reveal a significant decrease in cooling load across the considered parameters compared to the unshaded case. This highlights the effectiveness of implementing shade in mitigating solar heat gain and reducing building cooling demand.

- Integrating an internal blind within the DSF cavity demonstrated a substantial reduction in annual cooling load, offering a 16.4% (386 kWh) decrease in Copenhagen and a 6.4% (494 kWh) decrease in Madrid, respectively.
- Implementing an overhang with 0° further enhances this effect, displaying a 22.7% (533 kWh) reduction in annual cooling load in Copenhagen and a 9.4% (725 kWh) reduction in Madrid compared to no shading.

The configuration with the overhang at 45° emerged as the most energy-efficient strategy, achieving a 24% (562 kWh) and a 10% (771 kWh) decrease in cooling load compared to the base case in Copenhagen and Madrid, respectively. This advantage stems from dynamic shading adjustment, which enhances solar control at times of peak solar gain.

Figures 6 and 7 illustrate the monthly heating load (kWh) for the internal blind and different overhang angles in Copenhagen and Madrid, respectively. Both figures showcase a similar trend, highlighting the minimal impact of shading on heating loads.

Data Breakdown:

- **Copenhagen:**
  - Internal blind: This scenario resulted in a 1% increase (120 kWh) in annual heating load.
  - Internal blind with overhang at 0°: This strategy led to a slightly higher increase of 2.4% (266 kWh) compared to internal blind alone.
  - Internal blind with overhang at 45°: This configuration demonstrated the highest, yet still minimal, increase of 2.7% (297 kWh).
- **Madrid:**
  - Internal blind: Integrating the internal blind alone resulted in a marginal increase of 0.8% (36 kWh) in annual heating load.
  - Internal blind with overhang at 0°: Like Copenhagen, this scenario resulted in a 2.7% increase (115 kWh) compared to the internal blind alone.
  - Internal blind with overhang at 45°: This approach led to a slightly higher increase of 3.3% (139 kWh) compared to the internal blind alone.

In moderate climates like Copenhagen and Madrid, the benefits of reduced cooling loads appear to substantially outweigh the slight increase in heating needs associated with shading implementation.

IV. Conclusions

This exploration of DSFs with integrated internal blind and overhang underscores their significant potential for optimizing building energy performance. Analyzing the impact in diverse climates like Copenhagen and Madrid revealed:

- Cooling Load Reduction: Shading strategies, including blind and overhang, substantially reduced cooling loads in both cities compared to unshaded scenarios. Overhang with 45° emerged as the most energy-efficient option, showcasing the highest reductions (24% in Copenhagen and 10% in Madrid).

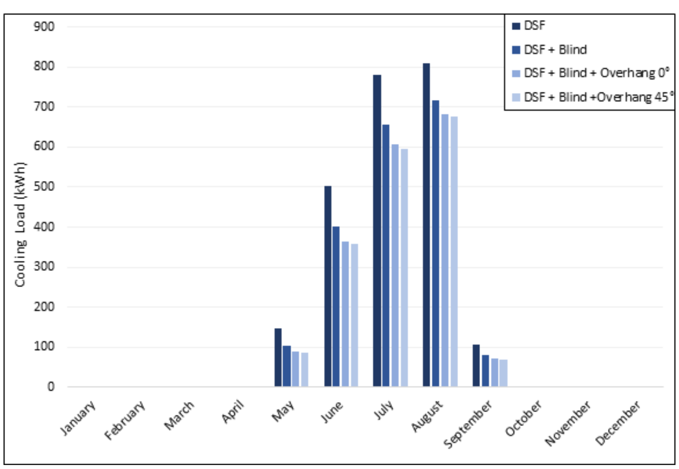

Fig. 4. Monthly cooling load in Copenhagen

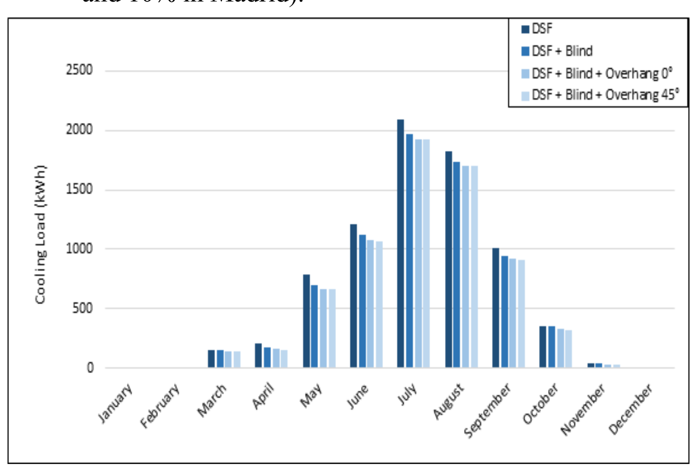

Fig. 5. Monthly cooling load in Madrid

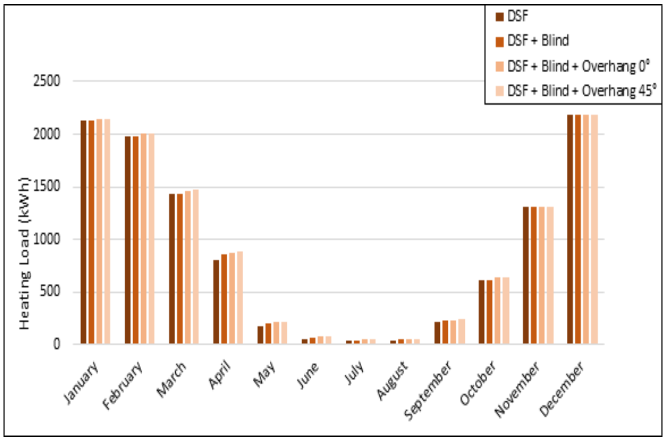

Fig. 6. Monthly heating load in Copenhagen

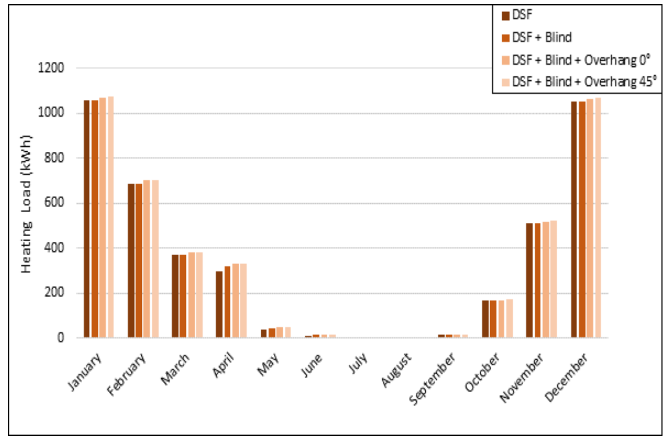

Fig. 7. Monthly heating load in Madrid

- Minimal Heating Load Impact: Interestingly, the implemented shading strategies had a minimal impact on heating loads in both locations. The observed increases (ranging from 0.8% to 3.3%) suggest that, in moderate climates, the benefits of reduced cooling loads outweigh the slight increase in heating needs.

These findings highlight the compelling advantages of DSFs with integrated shading for achieving sustainable and energy-efficient buildings in moderate climates.

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