Jurnal Impresi Indonesia (JII)
p-ISSN: 2828-1284 e-ISSN: 2810-062x
Vol. 5. No. 6. 2026

Sensitivity of Louvers in Opening Angle and Profile on Daylighting and Natural Ventilation in Tropical Vertical Housing

Anggun Puspita Jahja, Asri Dinapradipta*, F.X. Teddy Badai Samodra
Institut Teknologi Sepuluh Nopember, Indonesia
Email: asri_dinapradipta@its.ac.id*

Keywords:
Louvers;
Daylighting;
natural ventilation;
vertical housing;
tropical climate.

Abstract

Vertical housing in warm humid tropics requires façade strategies that balance daylight and natural ventilation. External louvers are commonly used, yet empirical evidence on the sensitivity of design variables especially opening angle and profile remains limited. This research aims to evaluate the sensitivity of trapezoidal louvre configurations in balancing daylighting and ventilation performance in the critical west-facing orientation of tropical vertical housing. A paired physical experiment was conducted using two identical mock-up rooms at Eco House ITS, Surabaya: one untreated base case and one equipped with louvers. Three louver profiles and three opening angles (45°, 60°, and 90°) were tested. Indoor illuminance, air velocity, and air temperature were recorded at multiple interior points and an outdoor reference at 10-minute intervals. The analysis applied paired comparisons against the base case and two-way ANOVA to quantify the sensitivity of design variables. The results show that all louver configurations reduced indoor illuminance by 61.0–77.1%. Model 2 at 45° retained the highest proportion of useful daylight (42.7% above 300 lux), while Model 2 at 60° achieved the highest daylight factor (4.36%). In terms of ventilation, only Model 1 at 45° slightly increased indoor air velocity (+0.016 m/s), whereas all configurations reduced indoor temperature (0.432–0.663°C). Sensitivity analysis indicates that the opening angle is the dominant factor influencing daylight (78.1%), air velocity (54.7%), and temperature (50.4%). The study concludes that louver design should prioritize opening angle selection before refining profile geometry, providing empirical evidence for façade strategies that balance daylight control and natural ventilation in tropical vertical housing.

INTRODUCTION

Vertical housing in warm humid tropical climates must accommodate two essential environmental requirements: the admission of sufficient daylight and the maintenance of adequate air movement through relatively compact, often single sided facades. In such conditions, facade design plays a critical role in mediating solar exposure while ensuring indoor. environmental quality. External louvers have emerged as a promising passive strategy, as they can simultaneously provide shading, redirect daylight, and modulate airflow within a single façade layer (Dinapradipta et al., 2019, 2024; Suryo, 2022; Zheng et al., 2025)

Previous studies have demonstrated that louver geometry and façade configuration significantly influence daylighting performance (Dinapradipta et al., 2024; Ibrahim et al., 2024; Lee et al., 2017). For instance, bent horizontal louvers have been shown to improve daylight distribution in walk up apartment buildings (Dinapradipta et al., 2024), while variations in apartment layout can affect illuminance depth and spatial distribution (Suryo, 2022). In office environments, different shading types and opening configurations have also been found to impact visual comfort and glare conditions (Suryo, 2022; Zheng et al., 2025). These findings highlight the importance of geometric parameters in shaping indoor lighting quality.

In terms of ventilation, recent studies indicate that louver geometry, inclination, and configuration can influence indoor air movement, air change rate, and overall airflow performance in both single sided and double skin façade systems (Aalami et al., 2024; O'Sullivan & Kolokotroni, 2017; Zhao et al., 2025). Such studies emphasize that louvers not only function as shading devices but also play a role in passive ventilation strategies, particularly in warm humid climates where mechanical cooling should be minimized.

Despite these advances, most existing studies tend to focus on either daylighting or ventilation separately, often relying on simulation-based approaches or non-residential case studies. Measured, empirical studies that simultaneously evaluate both daylight and ventilation performance, particularly in the context of tropical vertical housing remain limited. Furthermore, the relative sensitivity of key louver design variables, such as opening angle and cross-sectional profile, has not been systematically examined.

To address this gap, this study employs a paired physical experiment to investigate the performance of trapezoidal louvers in a west facing tropical vertical housing scenario. Specifically, it aims to answer two research questions: (1) how do variations in louver profile and opening angle affect daylighting and ventilation performance relative to a base case, and (2) which design variable exhibits greater sensitivity in influencing these environmental responses? The findings of this study will provide practical benefits for architects and façade designers by offering empirical evidence on the sensitivity hierarchy of louver design parameters, enabling them to prioritize opening angle selection before refining profile geometry. Theoretically, this study contributes to the body of knowledge on passive façade strategies in tropical climates, particularly by quantifying the relative contribution of design variables to daylight and ventilation performance, which has been lacking in previous simulation-based studies. By providing empirical evidence on the sensitivity hierarchy of louver design parameters, this study contributes to the development of more effective façade design strategies for tropical vertical housing.

RESEARCH METHOD

The experiment was conducted at Eco House ITS, Surabaya, using two parallel was facing mock up rooms on the third floor of the laboratory building (Fig. 1a). One room was kept as an untreated base case, while the other received the louver treatment. The west facade was selected because it represents critical exposure condition in tropical climates, where east west façade is more susceptible to overheating due to high solar radiation and long sunshine duration, and west facing façade in particularly receive intense afternoon solar gains. This makes the west orientation especially relevant for assessing the effectiveness of façade strategies for daylight admission and solar heat control in tropical housing (Mangkuto et al., 2021). The overall experimental setting (Fig. 1a), is accompanied by the plan section of the mock up, including the arrangement of the measurement points (Fig. 1b).

(a)

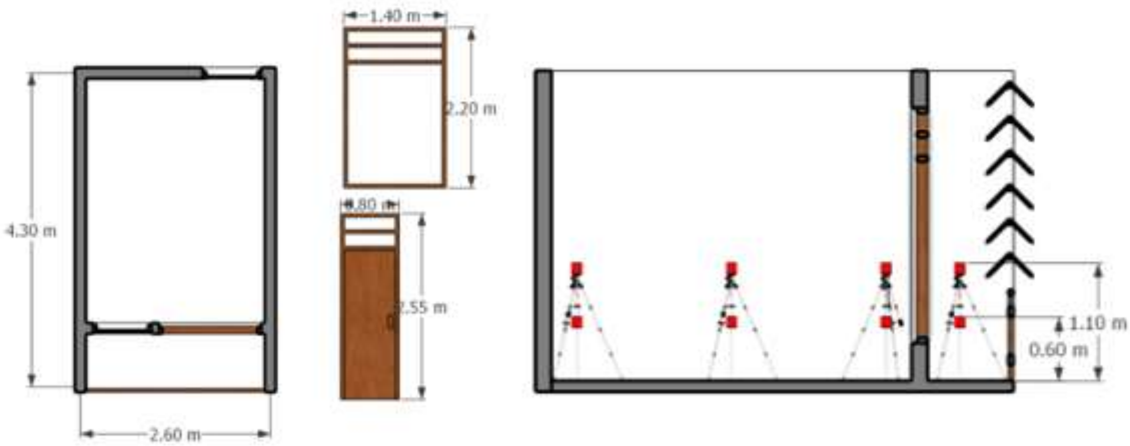


Figure 1. Eco House ITS (a) mock up room and measurement point (b).
Source: Author's documentation and primary data from field experiment, 2026

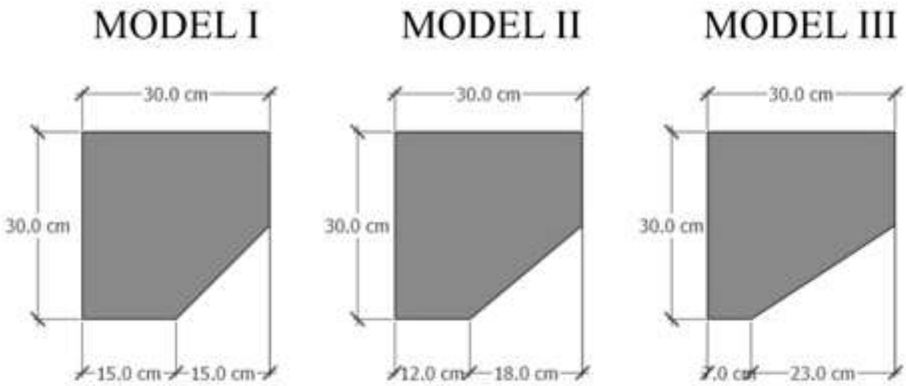
The treatment opening consisted of two dense louver panels, each comprising six horizontal trapezoid slats. The installed louver assembly and the indoor measurement setup (Fig. 2a). Three slat cross sections were tested according to the thesis prototype: Model 1 (15-15), Model 2 (18-12), and Model 3 (23-7), (Fig. 2b). These profiles were rotated to 45°, 60°, and 90°, resulting in nine experimental configurations in total.

Each configuration was measured for three days. Indoor illuminance, air velocity, and air temperature were recorded at four interior points and one outdoor reference point every 10 minutes from 08:00 to 17:00. After data cleaning, the three-day measurements for each configuration were averaged by time step and point, producing 1,980 paired observations (9 configurations x 55-time steps x 4 points).

The analysis was intentionally comparative rather than compliance-based. For each time step and point, the louvered value was matched to the simultaneous base case value. Daylight response was represented by indoor illuminance, daylight factor (DF = E_in/E_out x 100), and the share of observations above 300 lux as a practical daylight availability indicator.

Ventilation sensitivity was interpreted through changes in indoor air velocity and indoor air temperature relative to the untreated opening. Because wind direction, tracer gas exchange, and full flow rate measurements were outside the present experiment, no Q or ACH was derived here; those remain future work. Sensitivity was quantified with two-way ANOVA using louver model and opening angle as factors and paired deltas as responses.

(a)



(b)

Figure 2. Experimental setup in the west facing mock up room (a) and the three trapezoidal louver profiles used in the experiment (b).

Source: Author's documentation and primary data from field experiment, 2026

RESULTS AND DISCUSSION

Daylight response

From table 1, the result show that across all nine configurations, the louvers clearly moderated the daylight oversupply recorded in the base case. The average indoor illuminance decreased significancy from 1122.4 lux to 323.1 lux, with reductions of 61.0% to 77.1%. This demonstrates that external louvers effectively act as solar control devices by limiting excessive direct solar penetration, especially on west facing facades where afternoon radiation is most intense. Similar result has been noted in previous studies where louver systems ware shown to considerably cut indoor illuminance levels while improving visual comfort conditions (Abdollahi Rizi et al., 2023; Iqbal et al., 2025).

However, beyond the extent of reduction, the main issue is identifying configuration that maintain effective daylight. Among all cases, model 2-45° showed the highest proportion of observations above 300 lux (42.7%), followed by model 2-60° (41.4%). Additionally, model

2-60° achieved the highest average daylight factor (4.36%), indicating a more efficient transfer of outdoor daylight into the interior space. This suggests that moderate opening angles (45°-60°) offer a batter balance between daylight entry and shading. Previous parametric studies have similarly indicated that louver angle significantly influences daylight penetration and distribution, with certain tilt angles capable of maximizing illuminance while reducing glare (Eltaweel & Yuehong, 2017; Khidmat et al., 2022).

Despite these improvements, daylight distribution remained uneven, showing a strong front-loaded pattern. The ratio between minimum and maximum illuminance values (0.22-0.26) suggests that areas near the opening received significantly more light than deeper zones. This reflects a common limitation in single sided daylighting systems, where light penetration is limited by façade geometry and internal reflectance. While louvers can reduce excessive brightness near the façade, their capacity to spread light further into the space remains limited without additional reflective or light redirecting solutions. Studies on advanced louver systems indicate that adding reflective surfaces or using parametric angle adjustments can greatly enhance daylight uniformity and allow light to reach deeper zones (Konis & Lee, 2015).

From a sensitivity perspective, the findings clearly indicate that the opening angle has a greater influence on daylight performance that the cross-sectional profile. While variations in profile (Models 1, 2, and 3) affected the level of obstruction, the angle primarily determined the balance between reducing daylight and permitting it in. this supports the idea that louver angle is a key design factor that controls daylight entry, as it directly influences the incident angle of sunlight and the amount of light entering the interior space (Alsukkar et al., 2022).

Table 1. Summary of paired daylight, air velocity, and temperature responses for all louver configurations.

Conflg	Base case (lux)	Treatment (lux)	ΔLux (%)	DF (%)	>300 lux (%)	ΔAir (m/s)	ΔTemp (°C)
M1-45°	1082.4	336.8	-66.2	3.03	36.8	+0.016	-0.480
M1-60°	1072.3	337.9	-66.4	3.04	26.4	-0.014	-0.434
M1-90°	1225.0	249.1	-77.1	1.93	22.7	-0.022	-0.536
M2-45°	1145.8	369.3	-64.8	3.90	42.7	-0.017	-0.624
M2-60°	1168.5	355.2	-65.1	4.36	41.4	-0.013	-0.501
M2-90°	1150.6	236.4	-76.6	2.67	21.4	-0.037	-0.663
M3-45°	947.9	339.5	-61.0	3.23	38.2	-0.016	-0.432
M3-60°	1013.6	348.1	-63.8	3.39	37.7	-0.012	-0.479
M3-90°	1295.8	335.8	-72.4	2.24	37.7	-0.033	-0.641

Source: Primary data from field experiment (paired measurements), 2026

Ventilation and thermal response

From table 1 as well, the results show that the ventilation response exhibited greater variability that the daylight response, reflecting the complex interaction between louver geometry, airflow patterns, and pressure differences across the façade. As summarized in table 1, the mean indoor air velocity under louvered conditions ranged from 0,102 to 0,222 m/s. model 1-45° and model 1-60° produced the highest indoor air velocities (0.220 and 0.222 m/s), indicating that this profile offers relatively lower resistance to incoming airflow. In contrast, model 2 and model 3 generally resulting in lower air velocities, suggesting increased aerodynamic obstruction due to their steeper or more compact geometries. This implies that while certain louver profiles may offer superior solar control, they can simultaneously impede natural ventilation, thereby requiring a careful balance during the design phase to optimize both thermal and visual comfort (Tai et al., 2022).

When compared to the untreated base case through paired deltas, only model 1-45° produced a positive airflow response (+0.016 m/s), while all other configurations reduced indoor air velocity. The greatest reduction was observed in model 2-90° (-0.037 m/s), indicating that large opening angles do not necessarily enhance ventilation performance but may instead disrupt airflow paths depending on louver orientation and geometry. This finding aligns with previous experimental and simulation studies showing that louver inclination and geometry significantly influence airflow patterns and can either enhance or obstruct ventilation depending on their configuration (Aalami et al., 2024; O'Sullivan & Kolokotroni, 2017; Zhao et al., 2025). For instance, O'Sullivan and Kolokotroni (2017) demonstrated that narrow slotted louver systems can alter wind-driven airflow behaviour in single-sided ventilation, while Zhao et al. (2025) highlighted that inclined louvers in double-skin façades can either facilitate or restrict airflow depending on their angle and spacing.

Unlike airflow behaviour, all louver configurations consistently lowered indoor air temperature compared to the base case, with reductions ranging from 0.432°C to 0.663°C. the largest temperature drop was seen in model 2-90°, while the smallest was in model 3-45°. This shows that configurations with greater obstruction levels are more effective at reducing solar heat gain, especially on west facing façade studies where shading devices lessen solar radiation entry, resulting in noticeable decreases in indoor air temperature and cooling loads (Karava et al., 2004; Tzempelikos & Athienitis, 2007).

Together, the air flow and temperature responses show a clear trade-off between maintaining ventilation and reducing heat. Configurations with higher obstruction levels (e.g., 90°) are more effective at lowering solar heat gain but tent to restrict airflow. On the other hand, configurations within the 45°-60° range sustain better airflow while still offering moderate thermal improvements. This trade off highlights the dual function of louvers as both solar shading and airflow control elements, requiring careful adjustment in tropical design.

From a design perspective, model 1-45° stands out as the most balance configuration in this experiment. It is the only case that slightly enhances indoor air velocity while still reducing indoor temperature by about 0.45°C and maintaining acceptable daylight conditions. This finding underscores the importance of optimising louver geometry not for a single performance parameter, but for a balanced environmental response.

Is should be noted that this study assesses ventilation performance using air velocity as a proxy indicator, without including airflow direction, pressure distribution, or air change rate (ACH). Therefore, the results should be viewed as relative measures of airflow obstruction or flow preservation (Zavrl et al., 2018). Future studies should incorporate tracer gas techniques or computational fluid dynamics (CFD) simulations to more accurately capture volumetric airflow and directional patterns in louvered façade system.

Sensitivity of design variables

Figure 2 and Table 2 show that opening angle was the dominant design factor in all three responses. For dLux, angle contributed 78.1% of the explained design-factor sensitivity, whereas model and interaction contributed 10.5% and 11.5%. Only the angle effect on dLux was statistically significant ($p < 0.001$), indicating that daylight sensitivity in this dataset was governed mainly by how far the louvers opened.

The ventilation, related responses were more distributed. Angle still accounted for the largest share of dAir (54.7%) and dTemp (50.4%), but model and model-angle interaction also became meaningful, especially for air velocity where the interaction explained 22.0% of the design-factor contribution. All model, angle, and interaction terms were significant for dAir and dTemp ($p < 0.001$).

These results imply a practical hierarchy for louver design in tropical vertical housing. Angle should be selected first because it carries the strongest overall sensitivity across daylight, air movement, and temperature. After that, the cross-section can be refined according to the desired emphasis: Model 2 better preserved useful daylight, while Model 1 better preserved indoor air motion. This measured hierarchy extends the work of Dinapradipta et al. [1, 3, 4] by showing that, under a west-facing field condition, profile variation matters but angle dominates the combined environmental response.

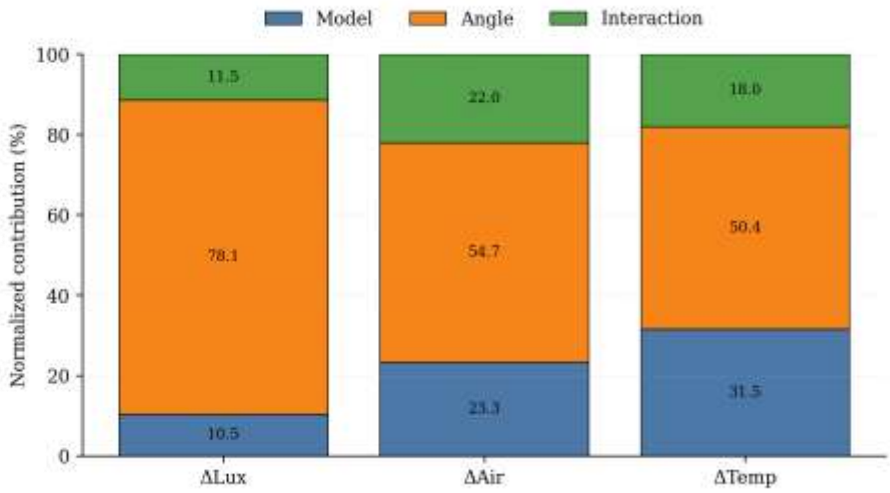


Figure 3. Normalized contribution of louver model, opening angle, and model-angle interaction to the paired daylight, air-velocity, and temperature responses.

Source: Author's analysis based on two-way ANOVA of experimental data, 2026

Table 2. Two-way ANOVA summary for the paired deltas. Contribution values are normalized among the tested design factors, excluding residual variation.

Response	Term	DF	f	p	Contribution (%)
ΔLux	Model	2	2.48	0.085	10.5
ΔLux	Angle	2	18.42	<0.001	78.1
ΔLux	Interaction	4	1.35	0.249	11.5
ΔAir	Model	2	14.25	<0.001	23.3
ΔAir	Angle	2	33.49	<0.001	54.7
ΔAir	Interaction	4	6.74	<0.001	22.0
ΔTemp	Model	2	17.71	<0.001	31.5
ΔTemp	Angle	2	28.32	<0.001	50.4
ΔTemp	Interaction	4	5.06	<0.001	18.0

Source: Author's statistical analysis using SPSS (primary experimental data), 2026

CONCLUSION

This paper reported a paired physical comparison of three trapezoidal louver profiles and three opening angles in a west-facing tropical vertical-housing mock-up. All louvered conditions reduced indoor illuminance relative to the untreated opening, but not equally. Model 2-45° retained the largest share of practical daylight availability, Model 2-60° produced the highest daylight factor, and Model 1-45° offered the best daylight-ventilation compromise because it was the only configuration that slightly increased indoor air speed while still lowering indoor temperature. Two-way ANOVA confirms that opening angle is the main sensitivity driver for daylight, air velocity, and indoor temperature. Accordingly, louver design for tropical vertical housing should prioritize angle selection before fine-tuning profile geometry. The present results are useful as a measured sensitivity map rather than a full ventilation or energy model. Future work should therefore incorporate wind direction, Q/ACH estimation, and operational-energy calculations to extend the findings from relative facade sensitivity to whole-building performance. Acknowledgments. The authors acknowledge Eco House ITS and the Laboratory of Architectural Science and Technology, Institut Teknologi Sepuluh Nopember, for supporting the experimental set-up and measurement process. Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

REFERENCES

Aalami, N., Maqsood, T., Bhuiyan, M. A., & Zhang, G. (2024). Development of operable modular louvers Sited in a single-sided ventilated room through 3D parametric optimization. *Building and Environment*, *266*, 112134.

Abdollahi Rizi, R., Sangin, H., Haghighatnejad Chobari, K., Eltaweel, A., & Phipps, R. (2023). Optimising daylight and ventilation performance: A building envelope design methodology. *Buildings*, *13*(11), 2840.

Alsukkar, M., Hu, M., Gadi, M., & Su, Y. (2022). A study on daylighting performance of split louver with simplified parametric control. *Buildings*, *12*(5), 594.

Dinapradipta, A., Sudarma, E., Defiana, I., & Erwindi, C. (2019). Glare from Windows Assessment at Offices with Three Types of Internal Solar Shadings. *IOP Conference Series: Materials Science and Engineering*, *676*(1), 12037.

Dinapradipta, A., Sudarma, E., Indrawan, I. A., Krisdianto, J., Arifin, M. F., & Hasya, A. H. (2024). The Efficacy of Horizontal Adjustable Bent Louver Shading for Enhancing Daylighting Performance in Walk-Up Apartment Buildings. *IOP Conference Series: Earth and Environmental Science*, *1351*(1), 12027.

Eltaweel, A., & Yuehong, S. U. (2017). Parametric design and daylighting: A literature review. *Renewable and Sustainable Energy Reviews*, *73*, 1086–1103.

Ibrahim, A., Alsukkar, M., Dong, Y., & Hu, P. (2024). Improvements in energy savings and daylighting using trapezoid profile louver shading devices. *Energy and Buildings*, *321*, 114649.

Iqbal, W., Ullah, I., Hussain, A., Cho, M., Park, J., Lee, K., & Shin, S. (2025). Optimizing energy efficiency: Louver systems for sustainable building design. *Buildings*, *15*(7), 1183.

Karava, P., Stathopoulos, T., & Athienitis, A. K. (2004). Wind driven flow through openings–a review of discharge coefficients. *International Journal of Ventilation*, *3*(3), 255–266.

Khidmat, R. P., Fukuda, H., Paramita, B., & Koerniawan, M. D. (2022). The optimization of louvers shading devices and room orientation under three different sky conditions.

Journal of Daylighting, *9*(2), 137–149.
Konis, K., & Lee, E. S. (2015). Measured daylighting potential of a static optical louver system under real sun and sky conditions. *Building and Environment*, *92*, 347–359.
Lee, K. S., Han, K. J., & Lee, J. W. (2017). The impact of shading type and azimuth orientation on the daylighting in a classroom–focusing on effectiveness of façade shading, comparing the results of DA and UDI. *Energies*, *10*(5), 635.
Mangkuto, R. A., Koerniawan, M. D., Apriliyanthi, S. R., Lubis, I. H., Atthaillah, Hensen, J. L. M., & Paramita, B. (2021). Design optimisation of fixed and adaptive shading devices on four façade orientations of a high-rise office building in the tropics. *Buildings*, *12*(1), 25.
O'Sullivan, P. D., & Kolokotroni, M. (2017). A field study of wind dominant single sided ventilation through a narrow slotted architectural louvre system. *Energy and Buildings*, *138*, 733–747.
Suryo, M. S. (2022). Study on Daylight Performance and Spatial Configuration of Low-cost Apartment Building in Indonesia through Computational Simulation. *IOP Conference Series: Earth and Environmental Science*, *1058*(1), 12014.
Tai, V. C., Kai-Seun, J. W., Mathew, P. R., Moey, L. K., Cheng, X., & Baglee, D. (2022). Investigation of varying louver angles and positions on cross ventilation in a generic isolated building using CFD simulation. *Journal of Wind Engineering and Industrial Aerodynamics*, *229*, 105172.
Tzempelikos, A., & Athienitis, A. K. (2007). The impact of shading design and control on building cooling and lighting demand. *Solar Energy*, *81*(3), 369–382.
Zavrl, E., Bivolarova, M. P., Melikov, A. K., Kierat, W., & Popiolek, Z. (2018). Effect of airflow interaction on temperature and velocity at the breathing zone of seated person. *Roomvent & Ventilation 2018*, 169–174.
Zhao, X., Song, Y., Huang, L., Song, Z., Dong, Q., Qi, J., & Shi, L. (2025). Controlling double-skin façades with inclined louvers for natural ventilation: An experimental and theoretical study. *Applied Energy*, *377*, 124560.
Zheng, Y., Wu, J., Zhang, H., Lin, C., Li, Y., Cui, X., & Shen, P. (2025). A novel sun-shading design for indoor visual comfort and energy saving in typical office space in Shenzhen. *Energy and Buildings*, *328*, 115083.