

Daylight Optimization in Classrooms under Composite Climates: Simulation Insights

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ABSTRACT

One of the fundamental criteria architects consider when designing schools, colleges, or educational buildings is the daylight in the classrooms. It is desirable to provide more usable daylight in buildings, not only to conserve energy, but also to improve the performance and productivity of the occupants. Daylight systems can reduce the artificial lighting requirements of a building while achieving appropriate illumination levels inside the space. In this study, classroom models were designed as per Indian Standard: 8827-1978, considering the room size in the ratio 1:1.5, a window on one side of the wall with an opening equal to 20% of the floor area, and a work desk at 0.80 m above the floor level. The study was conducted to investigate the illumination performance in the composite climatic zone of Central India using a computer simulation tool for various combinations, such as window opening, shading devices, months, and timings. The design sky illumination was set at 12,000 lux under an overcast sky condition. The simulation results exhibited that the shading devices are very effective in restricting the excessive illumination levels in accordance with Indian Standard: 8827-1978. Shading for the south-facing windows reduced the illumination levels from 708 lux to 392 lux in April and from 5873 lux to 3645 lux in December, preventing the glare and overheating. Shading for the north-facing windows provided 310 to 351 lux in April and August, making them perfect for a classroom under daylight. These results highlight the importance of orientation-specific shading strategies for classrooms, which are relevant in the composite climate of Central India.

Keywords-daylight; illumination; classroom; simulation; composite climates and Indian Standard: 8827-1978

I. INTRODUCTION

Daylight reaching the Earth from the Sun, both directly and indirectly, varies with the time of day, season, and weather conditions [1]. Daylighting is defined as the process of bringing natural light into and around a building [2-4]. It improves the comfort and health of occupants living or working in such spaces [5, 6]. Daylighting in schools has gained significant attention because of its benefits for the occupants. It has been found that daylight increases the student academic performance [7, 8]. Exposure to natural light has been shown to reduce fatigue and stress among students and academic staff [9]. The introduction of daylighting makes schools and other learning spaces more sustainable, while also improving the health of the students and staff. [7, 10].

The exposure to natural sunlight can enhance students' cognitive function, improve concentration, and reduce absenteeism [11]. A well-designed daylighting system can function with minimal artificial lighting, enhance the appearance of classrooms, and significantly improve learning [12, 13]. Daylighting in classrooms should be planned by considering several factors at an early stage of the project. These factors include the site location, climate, orientation, and the functional requirements of the building [14]. In addition, it entails making decisions concerning the arrangement of window openings, shading systems, glazing materials, and artificial lighting systems [15]. Furthermore, it is important to maximize the amount of natural light entering the space while avoiding glare and heat gain.

Before creating learning spaces, it is essential to ensure the appropriate lighting conditions to support quality learning, even under inefficient daylight. This could be a complex challenge in certain geographical locations, especially where environmental factors further complicate the design of the daylighting system. Regions with composite climates have inconsistent weather throughout the year, making it difficult to fully utilize daylight [16]. The National Building Code of India 2016 categorizes five climatic zones: hot-dry, warm-humid, temperate, cold, and composite. A composite zone is a climate zone without a season for more than six months. The composite climate combines the features of hot-and-dry, warm-and-humid, and cold climates. The solar radiation intensity is constantly high throughout the year in a tropical composite climate.

Daylighting is a complex process, and several research organizations have developed computer simulation tools to study it [17-20]. The simulation tools help optimize parameters, such as building orientation, window size, glazing type, and daylight distribution to reduce the glare and heat gain [21, 22]. Simulations provide quantitative information to support evidence-based design decisions, making them an important tool in educational research and practical application [23]. With the help of simulation tools, designers can create lecture halls and classrooms that maximize the daylight and therefore, enhance the comfort and productivity of the students [24].

Radiance and DIALux programs can be used by researchers and designers to predict the daylight distribution, quantify the Daylight Factors (DF), and study the effects of different designs for buildings [25]. In addition, the interactive simulation tools provide an accurate understanding of how natural light interacts in classroom layouts at different times of the day and year for recognizing potential glare problems and insufficient light. These simulation tools help designers make informed decisions regarding the window placement, shading devices, and surface treatments to optimize the levels of natural lighting in educational spaces [25]. Indian Standard 7942-1976 [26] provides specific guidelines for the lighting conditions in school buildings, with a special focus on classrooms. It identifies the critical role lighting plays in a student's focus, visual interest, and overall academic performance.

Daylighting has been extensively studied across different climatic regions; however, simulation-based evaluations of classrooms in the composite climate of Central India remain relatively underexplored. The present study seeks to address this gap by employing detailed time-based simulations to examine orientation-specific shading strategies. The analysis was conducted on a standard classroom model developed in accordance with IS: 8827-1978, specifically designed for composite climatic conditions. The objectives of this research are twofold: (a) to identify and assess design strategies—such as building orientation, window configuration, and shading devices—that optimize the daylight availability while ensuring visual comfort, and (b) to evaluate the applicability of simulation tools in assessing the daylighting performance in classroom environments.

II. METHODOLOGY

A. Configurations of Window

The study was conducted in a classroom of size 6.0 m × 9.0 m, with a breadth-to-length ratio not exceeding 1:1.5. The window opening was 20% of the total floor area, located on one side of the classroom, as per IS 8827-1978. The classroom area is 54.00 m², with openings of 12.00 m² with four windows, each measuring 2.0 m × 1.5 m. The work desk was placed 0.8 m above floor level, with a 0.6 m wide shading device. Figures 1, 2, and 3 illustrate the floor plans of Room No. 1 and Room No. 2, and the sectional view of Room No.1, respectively.

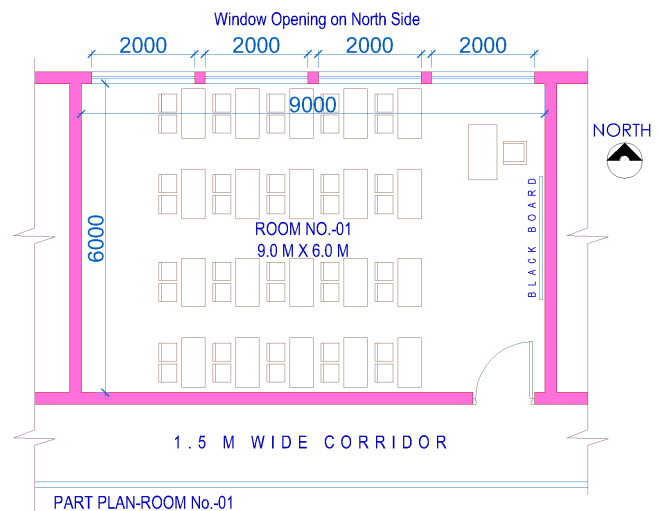


Fig. 1. Plan of Room No.1 with a north-oriented opening.

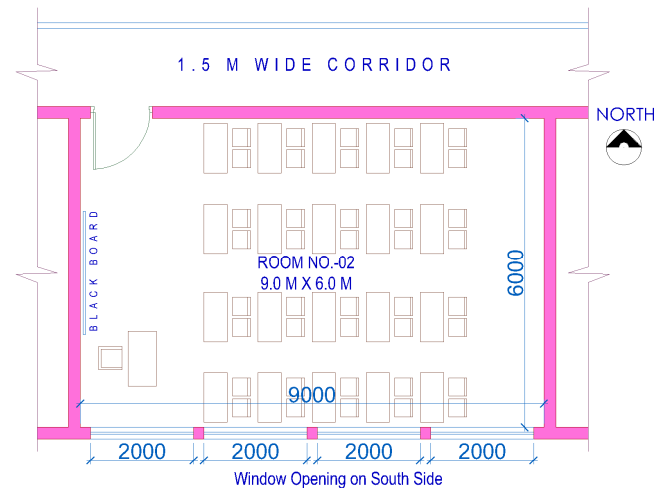


Fig. 2. Plan of Room No.2 with a south-oriented opening.

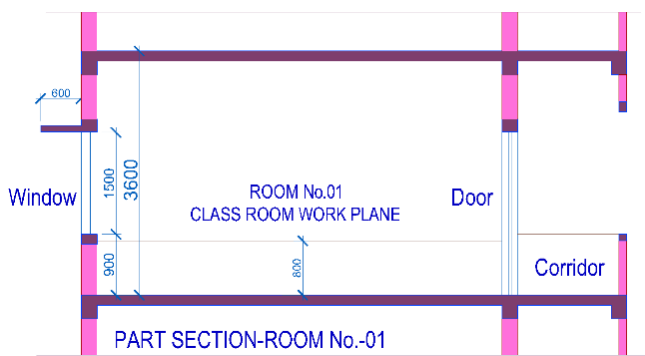


Fig. 3. Sectional view of Room No.1.

B. Simulation Setup and Parameters

The simulation was set up for Nagpur, Maharashtra, India (composite climatic zone of Central India), with latitudes 21° 08' 17.3" N and longitudes 79° 04' 14.3" E. As the study primarily focuses on the orientation and shading-specific strategies under Central Indian conditions, the design sky illumination was set at 12,000 lux under an overcast sky, representing a typical Central Indian climatic condition. DIALux evo 4.30 was the primary simulation tool used in this study, with standard default reflectance values (commonly used for classroom design) as follows: ceiling: 80%, walls: 55% (light-colored surface), and floor: 20%.

A typical classroom was modeled and analyzed under various parameters, including location and climatic conditions, model geometry and window orientation (North and South), as well as time and seasonal parameters. The classrooms with north-facing windows receive relatively even daylight and diffuse it with a minimum glare and solar heat gain, and are visually comfortable throughout the day. However, south-facing windows are preferred in classrooms due to the reduced solar radiation when combined with fixed or dynamic shading devices, specifically in a passive design. The study evaluated two shading strategies: classrooms with shading devices and classrooms without shading devices. The shading devices used in the simulation had a fixed overhang of 0.6 m depth. In Central India, August corresponds to the monsoon season, characterized by heavy clouds, diffused daylight, and high humidity, while December represents the winter season, with low solar altitude and cooler temperatures, and April represents the summer season, with high solar intensity and heat gain concerns. Together, these months effectively capture the extremes and variability of the daylight conditions of the study area. Simulations were conducted at three times of day: 9:00, 12:00, and 16:00.

III. SIMULATION

A. Analysis for North-Facing Window

Figures 4, 5, and 6 depict the effect of the shading devices on the north facade during April, August, and December, respectively. Windows on the north side of the classroom provide the maximum natural daylight but also cause a significant heat gain in April. In the monsoon season, schools are in session during the month of August, while they are also in session in December, during the winter season.

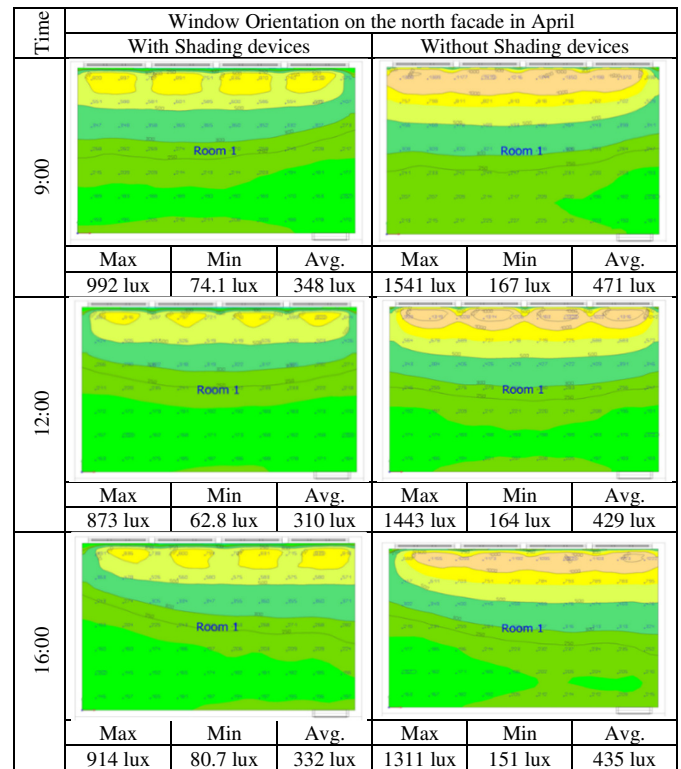


Fig. 4. Analysis of illumination levels on north-facing window openings, with and without shading devices, during April at 9:00, 12:00, and 16:00.

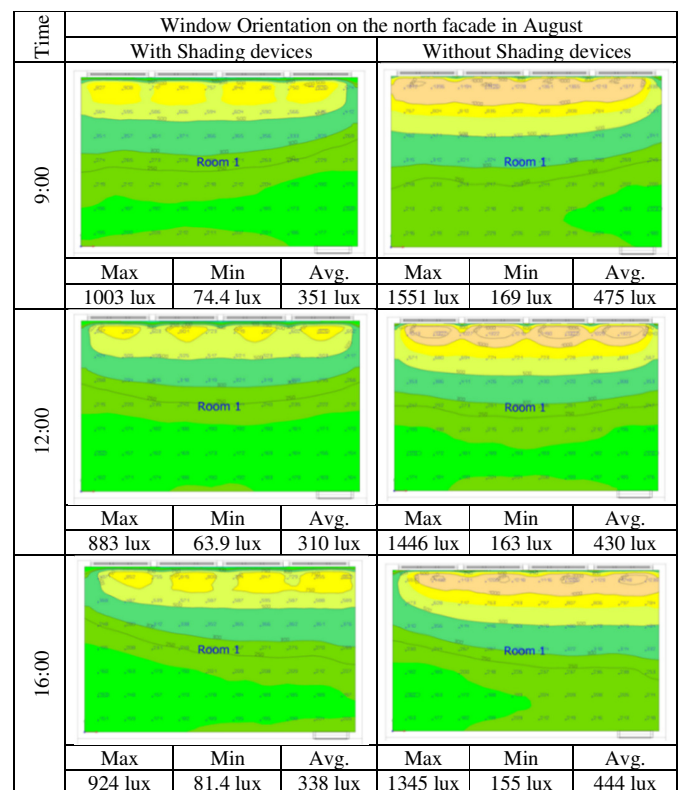


Fig. 5. Analysis of illumination levels on north-facing window openings, with and without shading devices, during August at 9:00, 12:00, and 16:00.

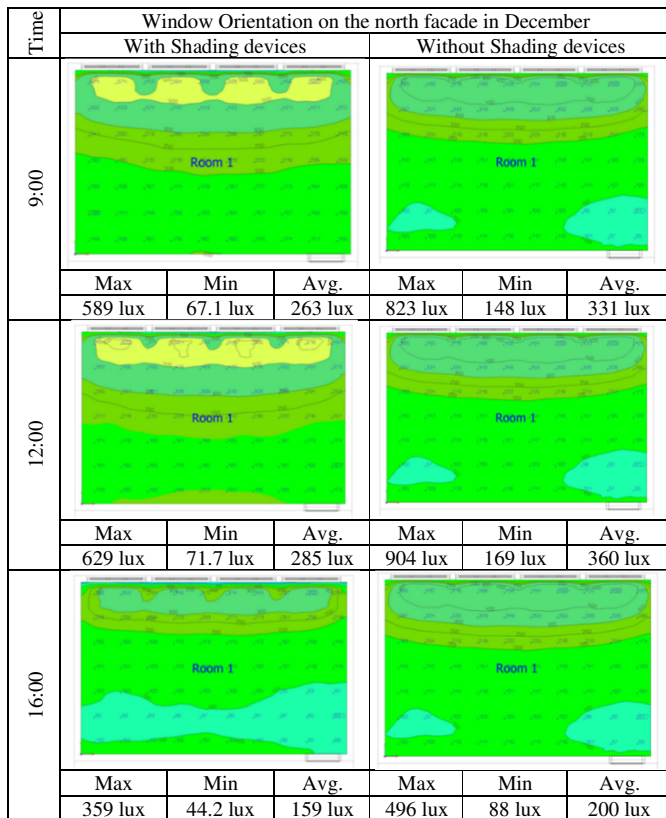


Fig. 6. Analysis of illumination levels on north-facing window openings, with and without shading devices, during December at 9:00, 12:00, and 16:00.

B. Analysis for South-Facing Window

Figures 7, 8, and 9 portray the effect of the shading devices on the south facade during April, August, and December, respectively. April has the maximum solar radiation when school is in session.

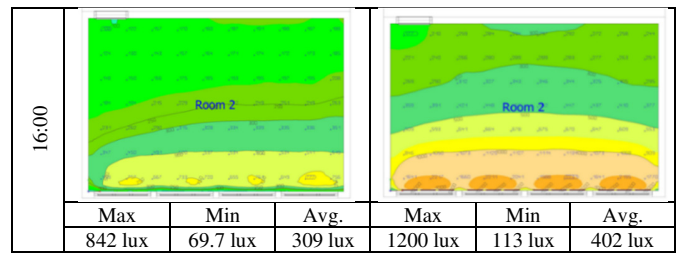
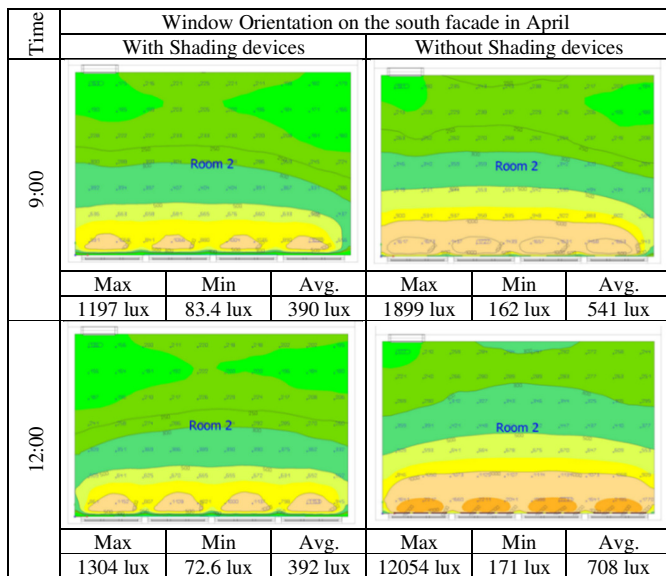


Fig. 7. Analysis of illumination levels on south-facing window openings, with and without shading devices, during April at 9:00, 12:00, and 16:00.

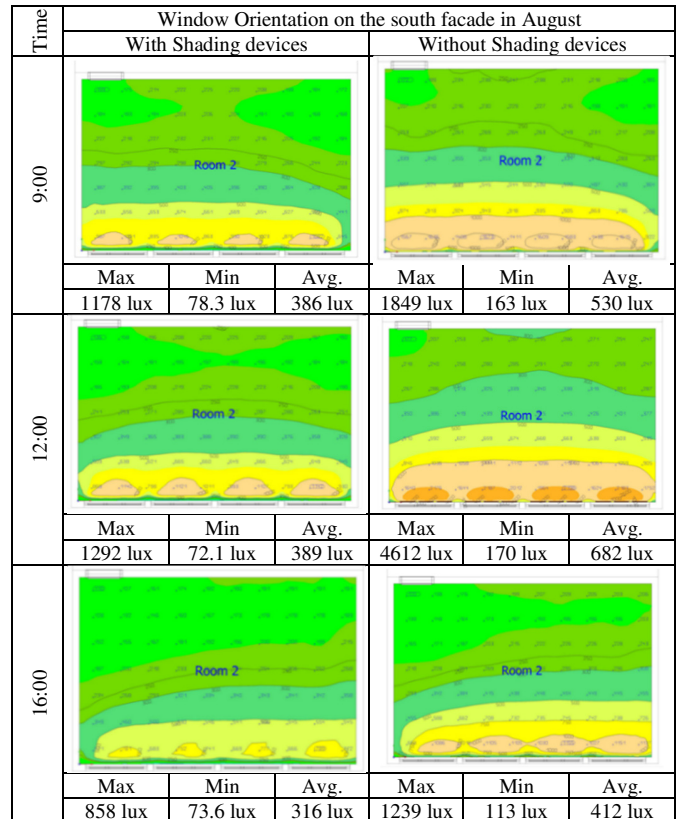


Fig. 8. Analysis of illumination levels on south-facing window openings, with and without shading devices, during August at 9:00, 12:00, and 16:00.

IV. RESULTS AND DISCUSSION

A. Results of Illumination Analysis for North-Facing Windows

North-facing windows were analyzed for April (summer), August (monsoon), and December (winter). In Central India, these orientations provide a uniform daylight, requiring some form of shading to reduce the glare and heat gain. During the month of April, the average levels of illumination with shading were 348 lux (9:00), 310 lux (12:00), and 332 lux (16:00), which are within the IS: 8827-1978 specified range of 300-500 lux. Without shading, the Illumination levels reached from 471 lux to 435 lux, indicating a possibility of glare. In August, shading maintained the illumination levels within the optimum range (310–351 lux). However, without shading, the illumination levels reached a maximum of 475 lux. In

December, with shading, the illumination fell short of the minimum standard (159-285 lux); however, shading in this case helped avoid the excessive illumination without shading (331-360 lux). Fixed shading works better in the summer and monsoon seasons; however, adjustable shading is advisable for winter to compensate for lower light levels.

Time	Window Orientation on the south facade in December					
	With Shading devices			Without Shading devices		
9:00						
	Max	Min	Avg.	Max	Min	Avg.
	26713 lux	297 lux	2745 lux	27699 lux	370 lux	3765 lux
12:00						
	Max	Min	Avg.	Max	Min	Avg.
	40575 lux	322 lux	3645 lux	41844 lux	410 lux	5873 lux
16:00						
	Max	Min	Avg.	Max	Min	Avg.
	5945 lux	109 lux	904 lux	6302 lux	125 lux	1084 lux

Fig. 9. Analysis of illumination levels on south-facing window openings, with and without shading devices, during December at 9:00, 12:00, and 16:00.

B. Results of Illumination Analysis for South-Facing Windows

During April, August, and December, the south-facing windows were subjected to significant solar radiation, requiring effective shading measures. The simulation results indicate that in April, shading maintained the illumination levels within the IS: 8827-1978 standards—390 lux at 9:00, 392 lux at 12:00, and 309 lux at 16:00. In contrast, the absence of shading led to an excessive level of 708 lux at noon, resulting in visual discomfort and glare. In August, the shaded conditions ensured values within acceptable limits, ranging from 386 to 316 lux, whereas without shading conditions, a peak of 682 lux was produced. December presented a more critical scenario: even with shading, the noon levels reached 3645 lux compared to 5873 lux without shading, with the morning and afternoon values also exceeding the proposed limits. These findings emphasize the need for adaptable shading solutions, where advanced louver systems may provide effective seasonal regulation without compromising the daylight quality or occupant comfort.

This study offers quantitative evidence of the interaction between orientation, shading strategies, and seasonal daylight performance, derived using DIALux evo simulations. The results demonstrate that both fixed and dynamic shading on north- and south-facing facades contribute significantly to enhancing the visual comfort while maintaining compliance with IS: 8827-1978.

V. CONCLUSION

The current study demonstrates that shading devices play a critical role in regulating the daylight in classrooms in composite climates. Fixed shading proved adequate for north-facing windows, consistently maintaining illuminance within the IS: 8827-1978 range, while south-facing windows required dynamic systems to mitigate the excessive solar gain and glare. Orientation-specific solutions—fixed devices for the north and adjustable louvers for the south—are, therefore, essential for achieving visual comfort and energy efficiency. Furthermore, the study contributes a replicable simulation-based methodology that can be applied to classroom designs in composite climatic regions across India, establishing its relevance as a reference framework for future educational building design.

REFERENCES

- [1] J. Mardaljevic, "Daylight, Indoor Illumination, and Human Behavior," in *Encyclopedia of Sustainability Science and Technology*, R. A. Meyers, Ed. New York, NY, USA: Springer New York, 2012, pp. 2804–2846.
- [2] C. Reinhart, *Daylighting Handbook I: Fundamentals designing with the sun*, Second edition. Cambridge, MA, USA: Building Technology Press, 2020.
- [3] I. L. Wong, "A Review of Daylighting Design and Implementation in Buildings," *Renewable and Sustainable Energy Reviews*, vol. 74, pp. 959–968, Jul. 2017, <https://doi.org/10.1016/j.rser.2017.03.061>.
- [4] L. Edwards and P. Torcellini, "Literature Review of the Effects of Natural Light on Building Occupants," NREL/TP-550-30769, 15000841, Jul. 2002. <https://doi.org/10.2172/15000841>.
- [5] J. L. Gómez Sirvent, D. Fernández-Sotos, R. Sánchez-Reolid, F. De La Rosa López, A. Fernández-Sotos, and A. Fernández-Caballero, "Pre-occupancy Evaluation of a Virtual Music School Classroom: Influence of Color and Type of Lighting on Music Performers," *Building and Environment*, vol. 246, Dec. 2023, Art. no. 110989, <https://doi.org/10.1016/j.buildenv.2023.110989>.
- [6] S. Roy, P. Satvaya, and S. Bhattacharya, "Effects of Indoor Lighting Conditions on Subjective Preferences of Task Lighting and Room Aesthetics in an Indian Tertiary Educational Institution," *Building and Environment*, vol. 249, Feb. 2024, Art. no. 111119, <https://doi.org/10.1016/j.buildenv.2023.111119>.
- [7] L. Heschong, R. L. Wright, and S. Okura, "Daylighting Impacts on Human Performance in School," *Journal of the Illuminating Engineering Society*, vol. 31, no. 2, pp. 101–114, Jul. 2002, <https://doi.org/10.1080/00994480.2002.10748396>.
- [8] R. Baloch et al., "Daylight and School Performance in European Schoolchildren," *International Journal of Environmental Research and Public Health*, vol. 18, no. 1, Dec. 2020, Art. no. 258, <https://doi.org/10.3390/ijerph18010258>.
- [9] M. G. Figueiro, B. Plitnick, and M. S. Rea, "Light Modulates Leptin and Ghrelin in Sleep-Restricted Adults," *International Journal of Endocrinology*, vol. 2012, pp. 1–6, 2012, <https://doi.org/10.1155/2012/530726>.
- [10] D. Baeza Moyano, M. San Juan Fernández, and R. A. González Lezcano, "Towards a Sustainable Indoor Lighting Design: Effects of Artificial Light on the Emotional State of Adolescents in the Classroom," *Sustainability*, vol. 12, no. 10, May 2020, Art. no. 4263, <https://doi.org/10.3390/su12104263>.

- [11] L. Mason, A. Ronconi, S. Scrimin, and F. Pazzaglia, "Short-Term Exposure to Nature and Benefits for Students' Cognitive Performance: a Review," *Educational Psychology Review*, vol. 34, no. 2, pp. 609–647, Jun. 2022, <https://doi.org/10.1007/s10648-021-09631-8>.
- [12] L. Heschong, *Daylighting in Schools An Investigation into the Relationship Between Daylighting and Human Performance Condensed Report*. CA, USA: The Pacific Gas and Electric Company, 1999.
- [13] S. Mirrahimi, N. L. N. Ibrahim, and M. Surat, *Effect of Daylighting on Student Health and Performance*. Houston, TX, USA: WSEAS Press, 2013.
- [14] A. Obralic and S. Jeghel, "The Case Study on Significance of Daylight in Classroom Setting at Sarajevo Campus," *European Scientific Journal, ESJ*, vol. 17, no. 1, Jan. 2021, Art. no. 19, <https://doi.org/10.19044/esj.2021.v17n1p19>.
- [15] G. D. Ander, "Daylighting," *Whole Building Design Guide*, 2016. <https://www.wbdg.org/resources/daylighting>.
- [16] A. Kaminska, "Impact of Building Orientation on Daylight Availability and Energy Savings Potential in an Academic Classroom," *Energies*, vol. 13, no. 18, Sep. 2020, Art. no. 4916, <https://doi.org/10.3390/en13184916>.
- [17] L. Heschong and J. McHugh, "Skylights: Calculating Illumination Levels and Energy Impacts," *Journal of the Illuminating Engineering Society*, vol. 29, no. 1, pp. 90–100, Jan. 2000, <https://doi.org/10.1080/00994480.2000.10748485>.
- [18] M. A. Lehar and L. R. Glicksman, "Rapid Algorithm for Modeling Daylight Distributions in Office Buildings," *Building and Environment*, vol. 42, no. 8, pp. 2908–2919, Aug. 2007, <https://doi.org/10.1016/j.buildenv.2005.02.010>.
- [19] T. W. Setiati and A. Budiarto, "Optimization of Lighting Design in Classroom for Visual Comfort (Case Study: Universitas Tridnanti Palembang Tower)," *IOP Conference Series: Earth and Environmental Science*, vol. 738, no. 1, Apr. 2021, Art. no. 012035, <https://doi.org/10.1088/1755-1315/738/1/012035>.
- [20] L. Udhwani and A. Soni, "Evaluation of Daylighting Performance in an Office Building: A Case Study," *Materials Today: Proceedings*, vol. 46, pp. 5626–5631, 2021, <https://doi.org/10.1016/j.matpr.2020.09.518>.
- [21] S. Attia, E. Gratia, A. De Herde, and J. L. M. Hensen, "Simulation-Based Decision Support Tool for Early Stages of Zero-Energy Building Design," *Energy and Buildings*, vol. 49, pp. 2–15, Jun. 2012, <https://doi.org/10.1016/j.enbuild.2012.01.028>.
- [22] A. K. Maurya, R. Kumar, and A. Kumar, "Assessing Window Design's Impact on Daylight Uniformity in Classrooms in Patna, India," *Engineering, Technology & Applied Science Research*, vol. 13, no. 5, pp. 11898–11903, Oct. 2023, <https://doi.org/10.48084/etasr.6212>.
- [23] R. Guglielmetti, D. Macumber, and N. Long, "OpenStudio: An Open Source Integrated Analysis Platform," presented at the Building Simulation, Nov. 2011.
- [24] A. Tzempelikos, A. K. Athienitis, and P. Karava, "Simulation of Façade and Envelope Design Options for a New Institutional Building," *Solar Energy*, vol. 81, no. 9, pp. 1088–1103, Sep. 2007, <https://doi.org/10.1016/j.solener.2007.02.006>.
- [25] C. F. Reinhart and M. Andersen, "Development and Validation of a Radiance Model for a Translucent Panel," *Energy and Buildings*, vol. 38, no. 7, pp. 890–904, Jul. 2006, <https://doi.org/10.1016/j.enbuild.2006.03.006>.
- [26] *Code of practice for daylighting of educational buildings*, IS 7942, Bureau of Indian Standards, New Delhi, Delhi, 1976.