Migration Letters

Volume: 20, No: S5(2023), pp. 360-376

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)
www.migrationletters.com

The Impact of Applying Shading Elements on the Thermal Comfortability in the University of Mosul's Buildings

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Abstract

This paper addresses the significance of natural lighting and solar control in building design, mainly focusing on housing buildings at the University of Mosul. The effective utilization of natural lighting is crucial for achieving optimal thermal performance and environmentally successful buildings. Various design and natural factors influence the lighting levels within interior spaces, necessitating the critical process of controlling natural lighting aspects and providing appropriate shading based on space requirements. Among the factors that pose environmental and thermal challenges for buildings are the direction, area, and shape of windows. Utilizing solar control and shading methods becomes imperative to mitigate these challenges and enhance energy efficiency. Shading plays a vital role in building cooling systems, as it helps reduce direct solar heat gain and prevents excessive solar radiation from entering the building during different seasons. Additionally, it offers the potential for harnessing natural light to achieve self-heating benefits during colder seasons. Hence, this research focuses on developing a simple and effective solar control mechanism using solar shades for university buildings within the University of Mosul. By employing qualitative analysis and simulations, the study explores the optimal design and physical characteristics of solar shades to ensure suitable thermal comfort and address the facade treatment of university buildings. The research findings highlight that models 1 and 2 of louvre designs demonstrate the most effective performance, providing comfortable thermal conditions and optimal lighting and significantly reducing energy consumption by 65%. This study underscores the importance of natural lighting and solar control strategies in building design and offers practical solutions for improving thermal comfort and energy efficiency.

Keywords: *Natural Lighting; Simulation; Heat Gain; Louvers; Shading Devices; University Housing.*

INTRODUCTION

Incorporating environmental elements, particularly natural daytime lighting, is essential for successful building designs that optimize user performance [1], [2]. Natural light significantly impacts the thermal comfort of buildings, influenced by factors such as the shape, area, and orientation of openings [3], [4]. However, designers often lack sufficient knowledge to effectively control the multitude of design and natural variables that affect the lighting levels within spaces [5], [6]. Additionally, considering appropriate shading techniques based on space type, orientation, and opening characteristics is often neglected during the design process [7], [8].

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Efficient utilization of solar control and shading methods is crucial for energy-efficient building design strategies [9], [10]. Proper shading is vital in the building's cooling systems, primarily by reducing direct solar heat gain during hot seasons. This preventive measure helps to minimize the entry of solar rays into the building [11]. However, it is equally important to allow for the entry of natural light, which can be harnessed for self-heating during colder seasons [12], [13]. Traditional approaches used to measure the efficiency of shading devices, such as louvres or inhibitors, often fail to simulate real-world situations comprehensively due to their reliance on a limited set of factors and variables [14], [15].

Therefore, this study aims to evaluate the efficiency of shading using louvres through the utilization of environmental simulation programs. By doing so, it seeks to provide a more accurate assessment of the effectiveness of these architectural elements in residential apartments in the city of Mosul. The research aims to identify a simple mechanism for controlling solar energy in buildings within the University of Mosul using solar circuit louvers, ensuring an optimal design considering both form and performance. The research questions addressed in this study are as follows: "What methods can be employed to control heat gain in university buildings using louvers effectively?" and "What are the optimal design principles and physical properties of louvers that provide appropriate thermal comfort as an efficient facade treatment at the University of Mosul?"

LITERATURE REVIEW

Louvers are designed elements that protect against the sun's rays. Their primary purpose is to prevent direct sunlight from falling on the building's outer shell or penetrating internal spaces when the outside air temperature exceeds the desired human comfort levels [16]. Louvers come in various types, including fixed and mobile, industrial and plant, permanent and seasonal. In general, louvers can be classified into three main types [17]:

1. Horizontal Louvers (Horizontal Types): These are commonly used on southern facades (frontispieces) and are designed based on vertical tangent angles (as the sun has a vertical angle).

2. Vertical Louvers (Vertical Types): These are typically employed on eastern and western facades (frontispieces) and can be tilted towards the north for increased sun protection. Vertical louvres use horizontal tangent angles.

3. Double Louvers (Egg-crate Types): These are utilized on southeastern and southwestern facades (frontispieces) and are designed based on both horizontal and vertical tangent angles.

Louvers create a shadow mask, representing the portion of the sky dome blocked by the louvers from direct entry into the inner space. This mask is a projection of the shadow on the solar path diagram. The shape of the shadow mask depends on the type of louver used [18]. Just like shading, the primary objective of louvers is to shield against direct solar rays and prevent the entry of solar heat into space. Interior shading devices such as strip blinds and hanging curtains can more efficiently reduce solar glare than external shading devices [19], as illustrated in Figure 1.

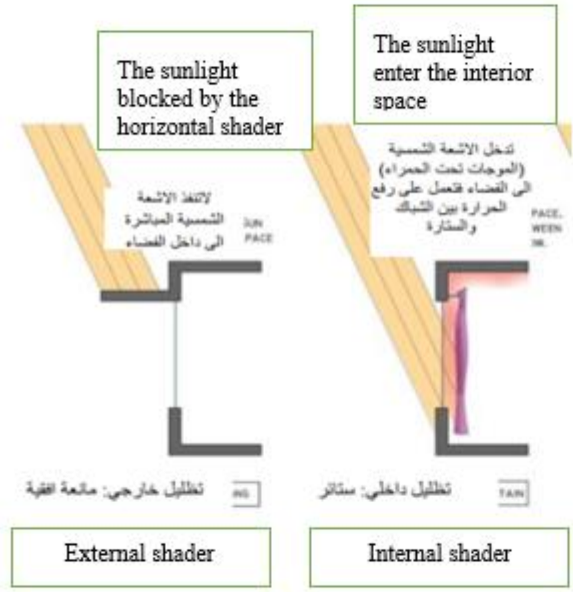
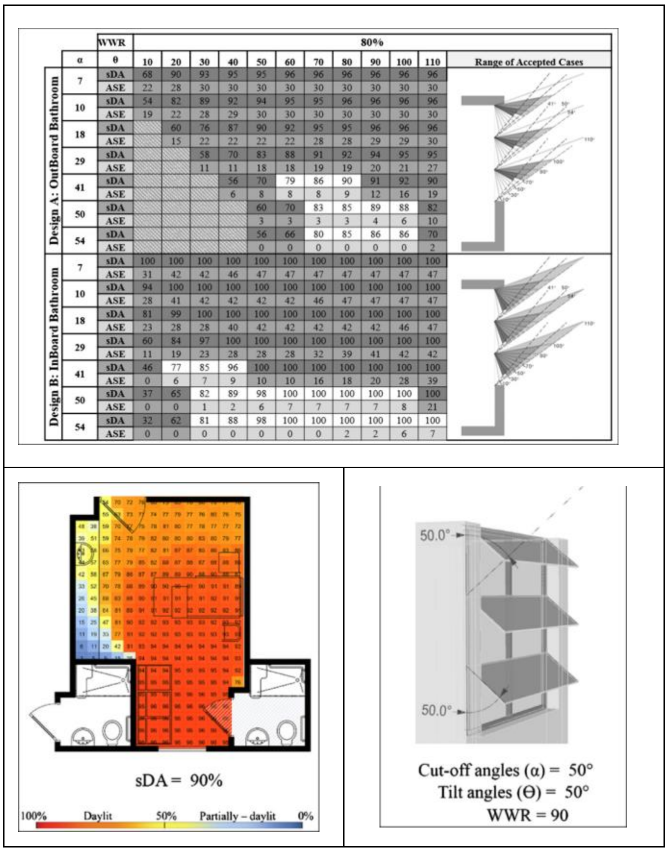


Figure 1 Difference between internal and external shading

Studies have consistently highlighted the benefits of using external louvers, including reducing air conditioning loads and saving energy by minimizing heat gain by blocking and hindering solar radiation before it reaches the interior space [20], [21]. Louvers effectively prevent solar penetration through windows and provide shading for the opaque non-insulated structural elements of the building, significantly reducing surface temperatures and minimizing heat transfer through the building envelope [22], [23]. Shading is crucial in reducing glare by reflecting light upwards towards the ceiling, resulting in a more even distribution of light within the space. This combination of darker areas with high-luminance spaces near the windows improves the uniformity of light distribution throughout the space [24].

In a study by Wagdy et al. (2017), the simulation of natural lighting through louvers on southern facades (frontispieces) of patient lobbies in desert hospitals demonstrated their positive impact on the health and well-being of patients and medical staff. The study examined two common patient room designs, incorporating externally mounted louvers in front of south-facing windows. The focus was on determining the optimal cutting angle of the sun barriers and the corresponding inclination angle to ensure effective shading and lighting. Parametric simulations were performed using Grasshopper, Diva-for-Rhino, and Speed Sim-for-Diva, with modelling software Rhinoceros interacting with Radiance simulation engines and Daysim software to simulate the thermal performance of both models [17], as depicted in Figure 2.



		WWR	80%										
	α	θ	10	20	30	40	50	60	70	80	90	100	110
Design A: OutBoard Bathroom	7	sDA	68	90	93	95	95	96	96	96	96	96	96
		ASE	22	28	30	30	30	30	30	30	30	30	30
	10	sDA	54	82	89	92	94	95	95	96	96	96	96
		ASE	19	22	28	29	30	30	30	30	30	30	30
	18	sDA		60	76	87	90	92	95	95	96	96	96
		ASE		15	22	22	22	22	28	28	29	29	30
	29	sDA			58	70	83	88	91	92	94	95	95
		ASE			11	11	18	18	19	19	20	21	27
	41	sDA				56	70	79	86	90	91	92	90
		ASE				6	8	8	8	9	12	16	19
	50	sDA					60	70	83	85	89	88	82
		ASE					3	3	3	3	4	6	10
	54	sDA					56	66	80	85	86	86	70
		ASE					0	0	0	0	0	0	2
Design B: InBoard Bathroom	7	sDA	100	100	100	100	100	100	100	100	100	100	100
		ASE	31	42	42	46	47	47	47	47	47	47	47
	10	sDA	94	100	100	100	100	100	100	100	100	100	100
		ASE	28	41	42	42	42	42	46	47	47	47	47
	18	sDA	81	99	100	100	100	100	100	100	100	100	100
		ASE	23	28	28	40	42	42	42	42	42	46	47
	29	sDA	60	84	97	100	100	100	100	100	100	100	100
		ASE	11	19	23	28	28	28	32	39	41	42	42
	41	sDA	46	77	85	96	100	100	100	100	100	100	100
		ASE	0	6	7	9	10	10	16	18	20	28	39
	50	sDA	37	65	82	89	98	100	100	100	100	100	100
		ASE	0	0	1	2	6	7	7	7	7	8	21
	54	sDA	32	62	81	88	98	100	100	100	100	100	100
		ASE	0	0	0	0	0	0	0	2	2	6	7

Figure 2 The effect of Louvers on the southern facades [17]

Their study found that for each patient room design, an increased number of louvers should be employed, especially when there are high window-to-wall ratios. Furthermore, the adequate performance of the models was achieved by projecting the windows at an oblique angle of approximately 45-50 degrees with the wall, and horizontal sun barriers yielded successful results in all tested cases [17].

A study by Skavara (2009) discussed the possibilities of employing neural networks as an artificial intelligence approach in determining the movement of moving louvers. The objective was to develop an efficient and adaptable building façade (frontispieces) that provides optimal shading conditions in the interior areas. Skavara's study utilized an artificial neural network to handle the system's complexity and generate preferential shading patterns based on inputs derived from the environment. The variables considered included the sun's position, angle of incidence, time, type and area of windows, and building orientation. Rules were formulated to determine the size and type of openings using lighting sensors on external windows, and simulation rules were implemented using the MATLAB program [18], as shown in Figure 3.

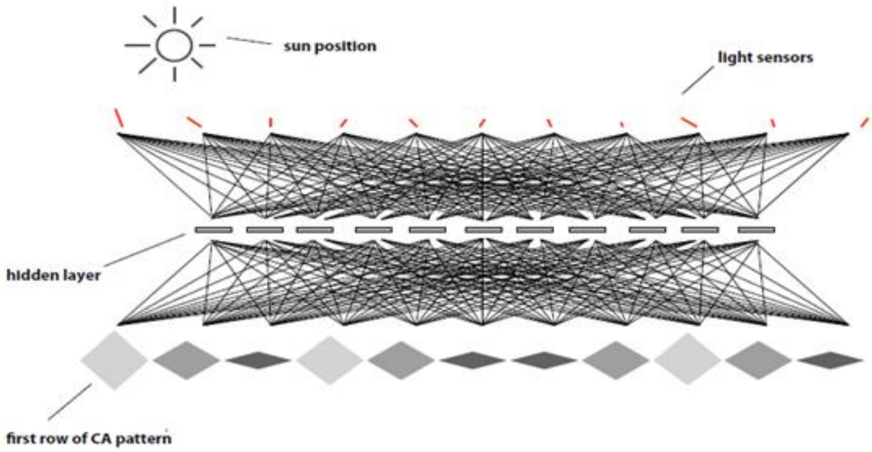


Figure 3 Structure of sensors arranged by louvers installed on the façade of the building [18].

Skavara's study revealed that dynamic louvers, responsive to the sun's movement, provide optimal shading conditions in hot weather while allowing for natural lighting and heating during cold conditions. These louvers rely on sensors that measure temperature and track the sun's position [18].

In a study by [16], the employment of louvers as architectural elements was discussed to reduce energy consumption in cooling and heating. The study highlighted the significant contribution of solar gain through windows and emphasized the importance of reducing energy consumption based on seasonal needs and achieving optimal thermal comfort within spaces [16]. Shading with louvers is considered an effective strategy within passive design approaches. While shading can reduce cooling loads, it may increase heating loads and vice versa. The study relied on the simulation methodology using the TRNSYS simulation program, which incorporated shading elements linked with simultaneous thermal information measurement [16].

Hernández et al. (2017) identified several energy-passive design concepts that enhance user satisfaction and productivity in spaces requiring concentration, such as offices with large glass areas, particularly in Mediterranean climates. The researcher highlighted the importance of louvers as an effective strategy for shading control, resulting in a reduction of heat gain by 20 to 40%, depending on the type of louvers and facades. Francisco utilized simulation tools, including Daysim for daylight analysis and TRNSYS for thermal analysis, and placed a network of lighting sensors at office height to assess glare. The study considered various variables such as the angle and tilt of louvers, louver length (L), the distance between vents (d), and tilt angle for horizontal louvers (α) [25].

Using neural network algorithms for designing sustainable building facades that comply with energy efficiency standards is essential for optimizing facades. [26] emphasized the efficiency of employing architectural additions such as louvers, shading devices, vertical and horizontal elements, and the type and number of glass layers to assess their impact on heat gain or loss, thermal comfort, and energy consumption efficiency. The goal of facade optimization was improved using a non-linear ENN model design. The importance of architectural elements, particularly louvers, in influencing the thermal and lighting performance of architectural spaces and reducing energy consumption through shading has been observed in previous studies. These studies have introduced diverse shapes and types of louvers based on climatic regions, treated facades, and openings. Furthermore, new concepts, such as smart covers with movable slices, have been introduced, which respond to external conditions [25], [26].

In recent research, there has been a shift towards digital simulation methods using engineering programs due to their accuracy, speed of analysis, cost-effectiveness, and the ability to examine and compare multiple models to determine the optimal case of study [27]–[30].

METHODOLOGY

The methodology of this study combines experimental and simulation approaches, as well as qualitative analysis, to achieve the research objectives. Evaluating the performance of louvers in shading architectural spaces requires analyzing various studies and theoretical criteria to determine the appropriate louver type for each geographical direction. However, these standards have not been extensively tested using current prevalent engineering programs.

To address this gap, the study selected one of the educational buildings at the University of Mosul, specifically the student apartments. These buildings were chosen because students occupy them throughout most of the year. The study applied methods and techniques derived from previous research and utilized simulation methods to assess the effect of louvers on shading and thermal performance. The aim was to develop a reliable design plan for improving the treatment of buildings at the University of Mosul. The selected building consists of seven apartments with similar designs, but the windows project in different geographical directions. This setup allows for evaluating their thermal performance while keeping architectural characteristics consistent. The study aims to determine the impact of louvers on shading and quantify the resulting reduction in energy consumption.

The shading simulation in the case study will be conducted using the DesignBuilder program, known for its high accuracy. The program also provides access to climatic data specific to Mosul City, which is essential for the study. Furthermore, the program enables calculating energy consumption and assessing energy reduction in each case [31], [32]. By employing this methodology, the study intends to provide valuable insights into the effectiveness of louvers in shading and their impact on energy consumption reduction in the context of the University of Mosul.

The design of louvers plays a crucial role in achieving effective shading for architectural spaces. In Iraq, specific design standards for louvers have been established based on the direction of the openings. Two main types of louvers are defined in Iraqi design standards.

1. Horizontal louvers are designed for southern openings, considering the vertical tangent angle apex (Figure 4). These louvers are specifically tailored to block and control sunlight from the southern direction, typically associated with higher solar angles.

2. Vertical louvers are employed for eastern, western, and northern facades, with a slight slope determined by the horizontal tangent angle (Figure 5). These louvers are designed to provide shading for openings facing these directions, where the sun's position and angle of incidence differ from the southern orientation.

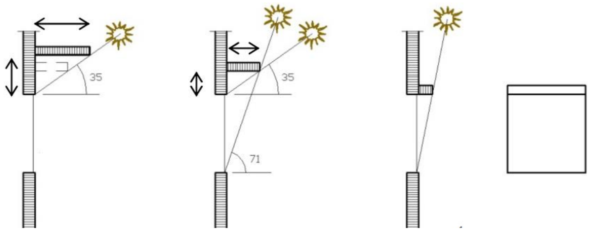


Figure 4 Design of Louvers for South Openings

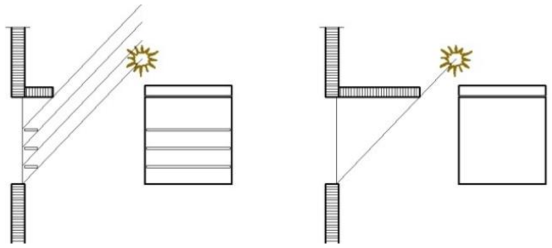


Figure 5 Design of Louvers for East, West and North Openings

The research focuses on a specific case study involving an apartment complex designated for university housing. This complex is notable for its distinctive characteristic of having housing units that share a remarkable similarity in their design, despite being positioned in different geographical directions. The apartments within the complex feature windows that face all four cardinal directions, presenting an excellent opportunity to examine the performance of louvers in a controlled environment where various factors remain constant. These factors include the proportions of the windows, the materials used, the architectural dimensions, and the spatial arrangements connected to the windows.

By isolating the facade as the variable of interest, the study aims to select and evaluate the specific type of louvers that can effectively provide optimal shading. The main objective is to assess how these louvers reduce heat gain and minimize energy consumption associated with cooling loads. Through a comprehensive analysis of the performance of these louvers, valuable insights can be gained into their effectiveness in creating a comfortable and energy-efficient indoor environment.

The schematic layout of the apartment block is depicted in Figure 6, illustrating the overall arrangement of the housing units within the complex. This visual representation helps to provide a clear understanding of the spatial configuration and the distribution of the windows facing different directions.

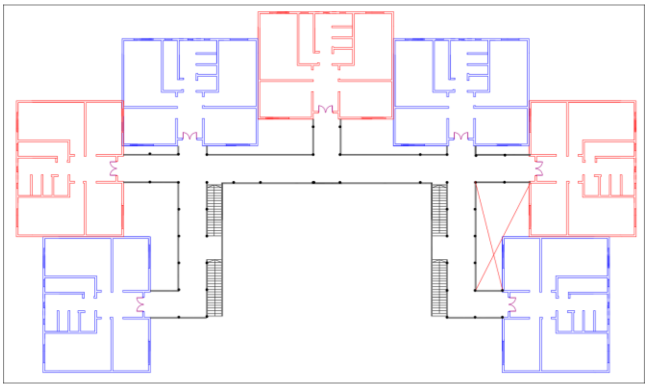


Figure 6 Schematic layout of the apartment block at the University of Mosul

To further understand the layout and design of the apartments within the housing complex, Figure 7 presents a detailed plan for a single apartment. This plan showcases the internal arrangement of rooms, including bedrooms, kitchen, and bathrooms. The windows' location and respective orientations can be observed, providing insights into the space's natural lighting and ventilation potential.

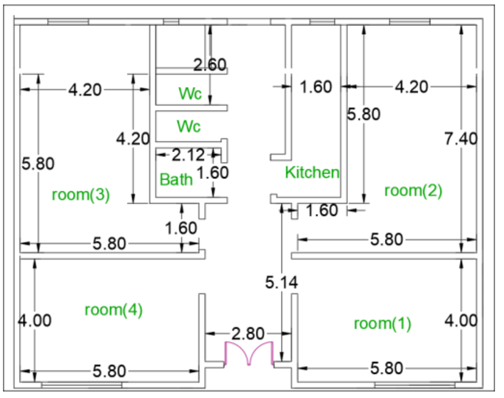


Figure 7 Single apartment plan

Model setup

The initial phase of the research involves configuring the simulation program to ensure compatibility with the specific climatic conditions of Mosul, the location where the building under investigation is situated. Local climate data were obtained from the Climate.OneBuilding.Org website, providing comprehensive climate information for regions worldwide. This data serves as a crucial input for accurately modelling the digital simulation.

To create a three-dimensional representation of the building, the simulation model incorporates the precise positions of windows and the ceiling height (refer to Figure 8). Furthermore, the model considers the specific activities within the building, as these activities can significantly influence temperature calculations and energy loads. Additionally, the model incorporates occupancy schedules tailored to the housing unit being studied.

Other architectural characteristics of the model, such as dimensions, materials, and window types, are also incorporated to reflect the real-world scenario accurately. It is important to note that these variables remain constant throughout the case study, enabling a focused examination of the impact of incorporating louvers on shading and subsequent cooling loads during the summer. By employing this comprehensive simulation approach, the study aims to obtain precise and reliable insights into the effectiveness of louvers in achieving shading and reducing cooling demands in the investigated context.

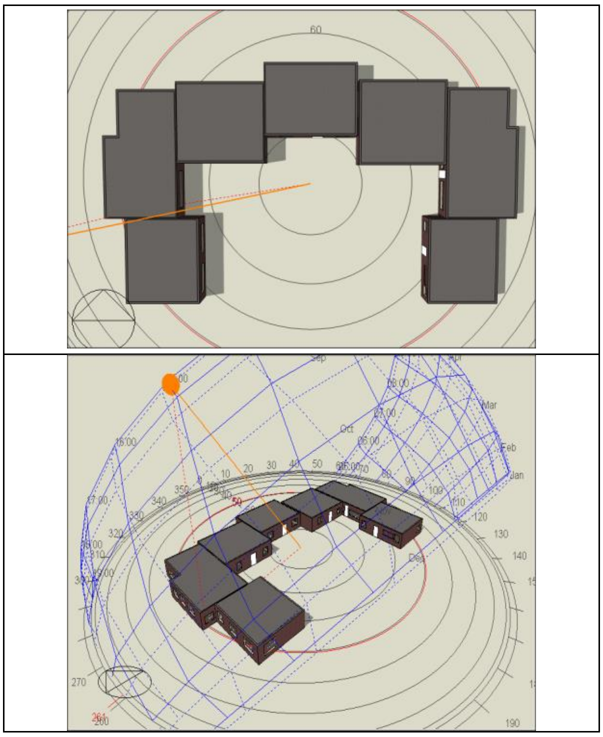


Figure 8 Different views of the case study building model

RESULTS ANALYSIS

The simulation phase encompasses two stages, each focusing on different aspects of the model for all four facade orientations. Before any modifications, the simulation process was initiated in the first stage to analyze the heat gain through the building's openings, evaluate the energy consumption associated with cooling loads, and examine the incoming lighting conditions. This initial stage provides a baseline understanding of the performance of the building in its original state.

The second stage involves the implementation of the louvers as architectural elements. Following the integration of louvers into the model, the simulation is conducted again to assess the impact of these elements. Specifically, the analysis focuses on determining the heat gain through the windows after adding louvers and calculating the resulting energy loads for cooling. Additionally, the simulation considers the effect of louvers on the lighting conditions within the building.

By conducting simulations at these two stages, the study aims to compare the performance of the building before and after the inclusion of louvers. This approach enables the evaluation of the effectiveness of louvers in reducing heat gain, optimizing cooling loads, and influencing lighting conditions. Through these simulations, the research seeks to provide valuable insights into the benefits and potential energy-saving capabilities of incorporating louvers into building design.

Table 1 comprehensively summarises the simulation results, encompassing heat gain through windows, annual cooling load, and lighting energy consumption for each façade orientation. The subsequent subsections will present a detailed analysis for each specific orientation, allowing for a more in-depth understanding of the findings.

Table 1 Simulation results before and after incorporating louvers into the facades

Façade Orientation	Heat gain through windows (Watt)			Cooling loads (kWh)			Lighting Energy Consumption (kWh)		
	Without Louvers	With Louvers	Difference	Without Louvers	With Louvers	Difference	Without Louvers	With Louvers	Difference
South	946	467	-51.5%	1424	1275	-10.5%	386	390	+1.01%
East	694	467	-32.7%	1559	1460	-6.3%	370	377	+1.20%
West	404	294	-27.8%	1602	1536	-4.1%	402	450	+11.9%
North	216	163	-24.5	1350	1333	-1.3%	453	466	+2.7%

South Façade

First, a simulation was conducted on the south-facing façade without louvres. This simulation aimed to determine the maximum heat gain of the windows at 1 pm on July 21, representing both peak temperature and a vertical sun angle. Additionally, cooling loads were calculated for the entire year to assess the building's energy requirements.

Figure 9 presents a 3D view of the simulated building before and after incorporating the louvres to provide a visual representation of the changes resulting from the addition of louvres. This visual comparison helps illustrate the modifications and enhancements by introducing the shading elements, offering a comprehensive view of the building's transformation.

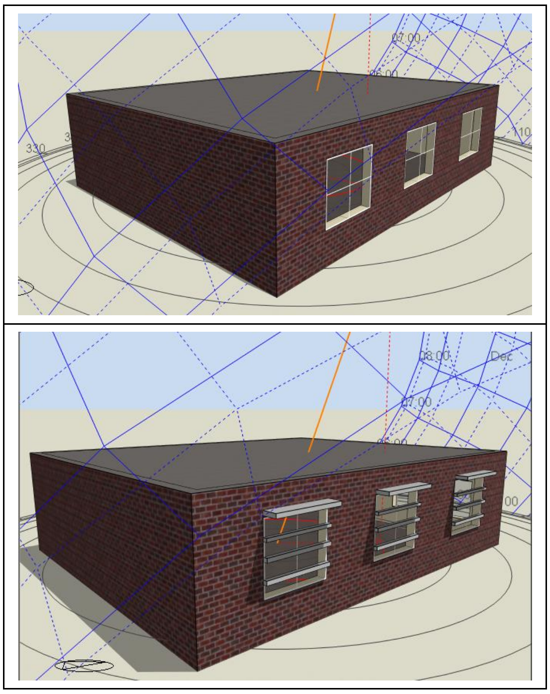


Figure 9 3D views of incorporating louvers on the southern façade

The simulation results on the southern façade can be summarized as follows: The heat gain through the windows at 1 pm on July 21 exhibited a noticeable reduction after adding louvres. Before processing, the heat gain was measured at 964 W, whereas post-processing yielded a significantly lower value of 467 W. This reduction in heat gain through louver shading amounted to approximately 51.55%. Furthermore, the assessment of cooling loads during the year (from May 1 to October 1) revealed a decrease in energy consumption after incorporating louvres. Before processing, the cooling loads were calculated to be 1423.95 kWh, whereas, after processing, the value decreased to 1275 kWh. This reduction corresponded to a 10.46% decrease in energy consumption due to the implementation of louver shading.

Regarding lighting requirements, the analysis of energy consumption throughout the year (365 days) indicated a slight increase following the addition of louvres. The energy consumption for lighting stood at 386 kWh before processing, and after processing, it rose slightly to 390 kWh. This change represented a marginal 1.01% increase in energy consumption attributed to shading with louvres.

East Façade

The simulation conducted on the eastern façade of the building has provided substantial insights into the effectiveness of louvres in addressing heat gain, cooling loads, and lighting distribution within the architectural spaces. Figure 10 visually depicts the eastern façade before and after incorporating louvres, clearly comparing the architectural transformation. Now, let us delve into the specific results obtained from the simulation:

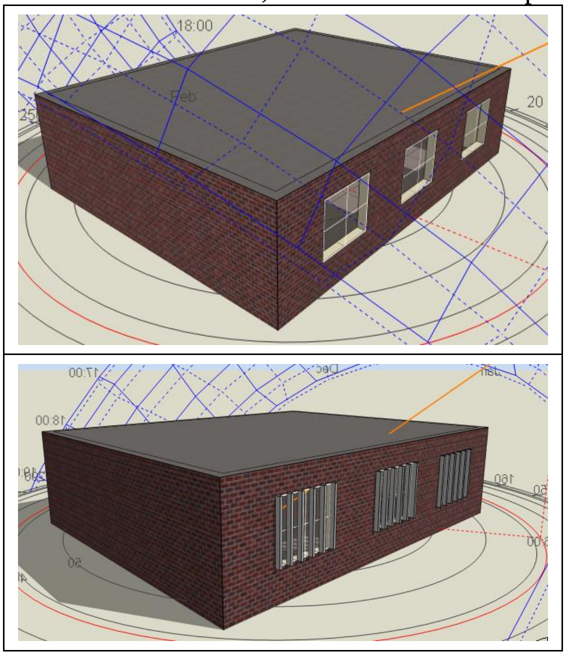


Figure 10 3D views of incorporating louvers on the eastern façade

Firstly, the assessment of heat gain through the window on July 21 at nine o'clock in the morning revealed notable improvements. Prior to the implementation of louvres, the heat gain was measured at 694 W, whereas after incorporating the louvres, the heat gain reduced to 467 W. This signifies a considerable reduction in heat gain by 32.71%, highlighting the efficacy of louvres in shading and minimizing heat transfer.

Furthermore, the analysis of cooling loads throughout the year, from May 1 to October 1, demonstrated promising outcomes. Before any processing or intervention, the cooling loads were calculated to be 1559 kWh. However, after incorporating the louvres, the cooling loads decreased to 1460 kWh. This represents a reduction in energy consumption for cooling purposes by 6.3%, indicating the potential energy-saving benefits associated with using louvres on the eastern façade. Additionally, the evaluation of energy consumption for lighting over a year yielded exciting observations. Before the introduction of louvres, the energy consumption for lighting was measured at 370 kWh. Following the implementation of louvres, the energy consumption slightly increased to 377 kWh. This indicates a marginal increase of 1.2% in energy consumption for lighting, which can be attributed to the impact of the louvres on the distribution of natural light within the space.

West Façade

The simulation conducted on the western façade of the building has provided valuable insights into the impact of louvres on heat gain, cooling loads, and lighting distribution within the architectural spaces. These findings contribute to a comprehensive understanding of the effectiveness of louvres on the western façade. Figure 11 visually presents the western façade before and after incorporating louvres, clearly comparing the architectural transformation.

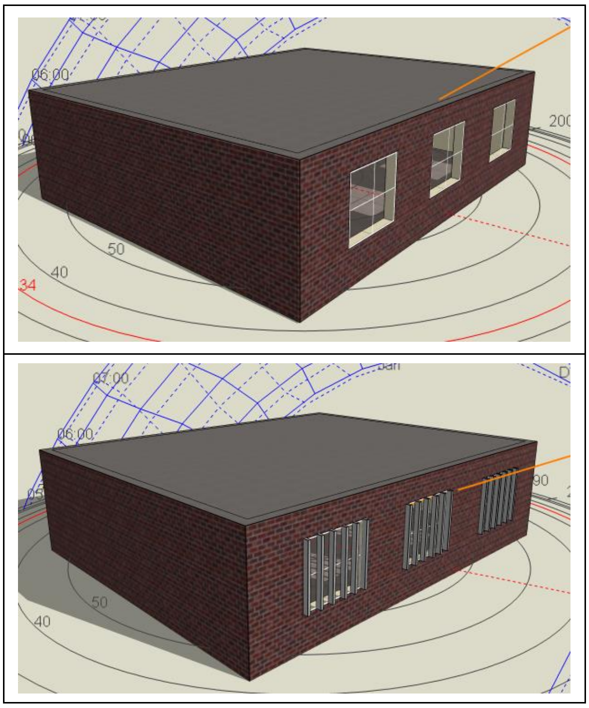


Figure 11 3D views of incorporating louvers on the western façade

Analyzing the specific results obtained from the simulation reveals the following:

Heat gain through the window on July 21 at 6 pm was significantly reduced after incorporating the louvres. The pre-processing measurement indicated a heat gain of 404W, whereas the post-processing measurement showed a reduced heat gain of 294W. This represents a substantial reduction of 27.77% in heat gain, highlighting the effective shading provided by the louvres. Examining the cooling loads during the year, which spanned from May 1 to October 1, revealed a notable decrease in energy consumption after incorporating louvres. Before the processing stage, the cooling loads were calculated at 1602 kWh. However, after incorporating the louvres, the cooling loads were reduced to 1536.2 kWh, indicating a 4.1% reduction in energy consumption for cooling purposes.

Evaluating energy consumption for lighting throughout the year also provided valuable insights. Initially, the energy consumption for lighting was measured at 402 kWh. With the inclusion of louvres, the energy consumption slightly increased to 450 kWh, resulting in an 11.9% increase in energy consumption for lighting. This can be attributed to the influence of the louvres on the distribution of natural light within the space.

North Façade

The simulation carried out on the north façade of the building has yielded insightful results regarding the effectiveness of louvres in mitigating heat gain, reducing cooling loads, and influencing lighting distribution within the architectural spaces. These findings contribute to a comprehensive understanding of the impact of louvres on the north-facing façade. Figure 11 visually presents the north façade before and after the modification with louvres, providing a clear representation of the architectural transformation and the effectiveness of the shading solution on this particular façade.

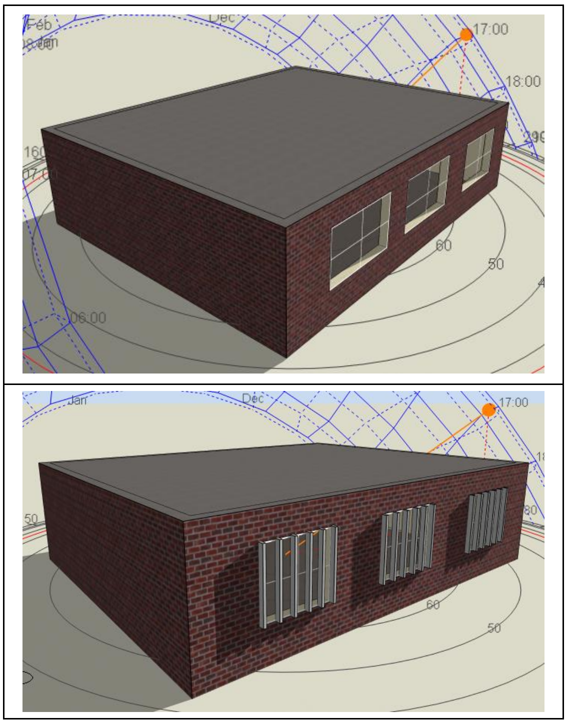


Figure 12 3D views of incorporating louvers on the northern façade

The heat gain through the window on July 21 at 6 pm was significantly reduced after incorporating the louvres. The pre-processing measurement recorded a heat gain of 216W, while the post-processing measurement indicated a reduced heat gain of 163W. This reduction represents a substantial decrease of 24.5% in heat gain through the louver shading solution.

Considering the cooling loads during the year, encompassing the period from May 1 to October 1, a notable decrease in energy consumption was observed after incorporating the louvres. The cooling loads were calculated at 1350 kWh before the processing stage, and after incorporating the louvres, the cooling loads were reduced to 1333 kWh. This reduction indicates a modest decrease of 1.25% in energy consumption for cooling purposes through the utilization of louver shading.

Furthermore, the evaluation of energy consumption for lighting throughout the year revealed an increase after incorporating the louvres. Initially, the energy consumption for lighting was measured at 453 kWh. However, after incorporating the louver shading solution, the energy consumption slightly increased to 466 kWh, resulting in a 2.7% increase in energy consumption for lighting. This can be attributed to the impact of the louvres on the distribution of natural light within the architectural spaces.

DISCUSSION

It is evident from the programming simulation of the building that the use of louvres has significant effects on various aspects. According to previous studies [33]–[35], horizontal louvres in the southern facades effectively reduce heat gain through windows by providing shading. This reduction in heat gain subsequently leads to decreased cooling loads and overall energy consumption. Notably, the incidence angles of solar rays in these orientations are generally more vertical, allowing them to penetrate architectural spaces without being intercepted by horizontal louvres. In terms of lighting, the horizontal louvres demonstrate a positive impact by reducing glare and improving lighting distribution. However, it is important to note that they may reflect a small amount of light, slightly increasing artificial lighting loads by approximately 1% [36].

On the other hand, vertical louvres, as indicated by the simulation results and supported by studies such as Han et al. (2020), prove to be effective in the eastern and western facades. These louvres provide shading during specific times of the day when the incidence angles of solar rays are more inclined. Consequently, they reduce energy consumption for cooling in the morning (in the eastern facades) and afternoon (in the western facades). However, regarding heating loads, the angles of falling rays in winter for both orientations are minimal, suggesting that the vertical louvres have negligible effects on heating loads. Nevertheless, these louvres impact the lighting entering architectural spaces by obstructing direct sunlight, resulting in a moderate increase in artificial lighting loads [36].

In the case of the northern facades, the influence of vertical louvres is relatively limited. Studies have shown that their effectiveness is more pronounced during the early morning hours and at the end of the day, particularly in the summer months of July and June [35]. The reduction of thermal gain through windows in this period is relatively small compared to other orientations, and the impact on lighting is also minimal. Thus, while using louvres on northern facades may provide some benefits, their impact on energy consumption and lighting distribution is not as significant as in other orientations.

By incorporating findings from previous studies, the simulation results confirm the effectiveness of louvres in reducing heat gain and cooling loads and influencing lighting distribution in the different orientations of the building [33]–[37]. These findings provide valuable insights for architects and designers in optimizing energy efficiency and occupant comfort by strategically implementing louvres in building designs.

CONCLUSION

In conclusion, this study aimed to evaluate the performance of louvres in shading architectural spaces and their impact on reducing heat gain, cooling loads, and lighting distribution. Through a comprehensive simulation-based methodology, the effects of different types of louvres on four facades of a university housing complex in Mosul were examined.

The simulation findings revealed that horizontal louvres installed on the southern facades effectively reduced heat gain through the windows by providing shading, significantly reducing cooling loads and energy consumption. However, it was observed that horizontal louvres had minimal impact on heating loads, as the solar rays' angles of incidence were inclined, allowing them to penetrate architectural spaces without an interception. Furthermore, the horizontal louvres positively influenced lighting conditions by reducing glare, although they reflected a small amount of light, leading to a slight increase in artificial lighting loads. Vertical louvres, on the other hand, proved to be effective for the eastern and western facades. Shading the windows during specific times when the solar rays' angles were inclined significantly reduced energy consumption for cooling. Although vertical louvres did not significantly affect heating loads due to the limited angles of falling rays in winter, they obstructed direct lighting, resulting in a higher demand for artificial lighting. Regarding the northern facades, the impact of vertical louvres was relatively limited. While they provided some shading during the early morning and late afternoon, particularly in July and June, the reduction in thermal gain through the windows was relatively modest compared to other types of louvres. The effect on lighting was also minimal in this orientation.

These findings contribute to the knowledge of using louvres for shading and thermal performance in architectural design. The study underscores the importance of considering geographical orientation and specific louvre types to optimize energy efficiency and improve occupants' comfort. Future research could explore additional variables such as louvre designs, materials, and configurations further to enhance the understanding of their impact on building performance. Overall, this study provides valuable insights into using louvres as an effective design strategy for shading and thermal management in architectural spaces. By implementing appropriate louvre configurations, architects and designers can optimize energy consumption, improve indoor comfort, and contribute to sustainable building practices.

ACKNOWLEDGMENTS

The researchers acknowledged the University of Mosul, College of Engineering, Department of Architectural Engineering, for registering the article under the research plan (2022-2023), which was approved by the scientific committee and allowed the researchers to use the software and instruments provided by the College of Engineering.

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