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The Role of External Shading Devices and Thermal Insulation in Improving Energy Performance of Hotel Buildings in Cairo by using Computer Simulation

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Abstract: Sustainability can be achieved in the tourism sector by achieving a balance between guest satisfaction and taking into account environmental standards. Efforts made to achieve sustainability in the tourism sector can contribute to the preservation of natural resources. Reducing environmental impact, and decreasing energy consumption. Hotel rooms are among the spaces that consume a significant amount of energy due to guest requirements. External shading devices create a barrier between sunlight and windows, reducing heat transfer into the room. This helps maintain a more comfortable indoor temperature, especially during hot weather conditions, allowing guests to enjoy cooler and more pleasant spaces without relying heavily on air conditioning. The main objective of this research paper was to improve energy performance by using external shading devices on openings and thermal insulation for the exterior envelope of hotel rooms in Cairo. This was achieved through simulation using Design Builder v 7.0 software, followed by a comparison to assess energy savings for the model with external shading devices and the type of materials used in the hotel room's building envelope, compared to the baseline case. The results indicate that energy performance of hotel rooms in Cairo can be significantly improved by using external shading devices, 6 cm thick thermal insulation made of polystyrene, and low-emissivity (Low-E) glass, resulting in over 40% energy savings for cooling and heating compared to the base case.

***Keywords**: Energy savings, External Shading Devices, Thermal Insulation, Hotel Rooms.*

1. Introduction:

The concept of sustainability has become increasingly crucial in modern economies, with the primary threat to sustainability being the escalating demand for energy, which depletes natural resources and contributes to global climate change due to resulting emissions. Although tourism and its subsectors such as transportation, accommodation, and tourist attractions are becoming increasingly important in many economies, their energy use has not been adequately researched (1). Hotel rooms, in particular, consume a significant amount of energy due to guest requirements. Therefore, each component of the exterior envelope should be studied meticulously. External shading devices protect the building from solar radiation, reducing heat exchange between the interior and exterior and ensuring thermal comfort within these spaces throughout guests' stays, while also maintaining user comfort (2). As a result, hotel buildings should adhere to strict functional, architectural, and environmental standards and requirements that minimize energy depletion, reduce negative environmental impacts, optimize energy performance, and provide a high-quality indoor environment within hotel rooms that is free from environmental pollutants (3). External shading devices contribute to the sustainability efforts undertaken by hotels by helping to reduce the carbon footprint associated with cooling systems, promoting energy efficiency, and environmental responsibility (4). When designing hotel buildings, architects must consider the local climate, building orientation, and design requirements when selecting and installing external shading devices to maximize benefits and ensure optimal performance (5),(6). This study focuses on the use of external shading devices on openings and 6 cm thick thermal insulation to achieve optimal energy performance within hotel rooms in the hot climate of the Greater Cairo region.

2. Research Problem:

The problem addressed in this research is the high energy consumption rate in hotel rooms in Cairo, resulting from the lack of external shading devices, thermal insulation in the exterior envelope, and the absence of low-emissivity (low-e) glass. This leads to increased energy consumption within hotel rooms.

3. Research Objectives and Practical Study:

The objectives of this study are to determine the impact of using external shading devices on openings and thermal

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insulation in the exterior envelope of hotel rooms in the Greater Cairo region on improving energy efficiency. This will be achieved through simulation using Design Builder v 7.0 software.

4. Research Questions:

a) How can the energy performance of hotel rooms in the Greater Cairo region be improved through the use of external shading devices?

b) How can energy consumption efficiency be enhanced by using thermal insulation in the exterior envelope of hotel rooms in the Greater Cairo region?

c) What is the role of the properties and standards of low-emissivity glass in the openings in improving the thermal performance of the exterior envelope of hotel rooms in the Greater Cairo region?

5. Research Hypothesis:

The use of external shading devices on openings, 6 cm thick thermal insulation in the exterior envelope, and low-emissivity glass will improve the energy performance of hotel rooms in the Greater Cairo region.

6. Research Methodology:

To achieve the research objectives, a theoretical approach will be followed, which includes reviewing previous studies and their impact on the current study. The study will analyze the adopted concepts and develop a typical model. An analytical methodology will be employed to derive the typical model, followed by an applied approach using simulation through Design Builder v 7.0 software. The environmental aspects will be studied, considering the use of external shading devices, 6 cm thick thermal insulation in the exterior envelope, and the type of glass used. The simulation results for each case will be compared to achieve the research objectives, considering previous studies and their findings.

The main steps of the simulation were as follows:

1. Evaluating the environmental performance of the proposed model using the simulation program 7.0 Design Builder:

- Analysis of climate data. - Solar radiation analysis.

2. Identify energy consumption (thermal performance, cooling loads) based on the following patterns:

- External shading devices - Type of glass used - Occupancy rate - Building materials used.

- Thermal resistance R-value for different building materials, density, wall thickness.

7. The typical model of hotel rooms in the Greater Cairo region:

An analytical study was conducted on models of hotel rooms in the Greater Cairo region, from which the characteristics of the typical model were determined, which is the rectangular shape of hotel rooms, with the difference in the number of beds for hotel rooms, whether single or double, as shown in the following figures, taking into account the design requirements of hotel buildings.

8. Case Study: Semiramis Intercontinental Hotel – CAIRO

The Semiramis Intercontinental Hotel is considered one of the largest five-star hotels in Cairo in the world, as it directly overlooks the Nile River in Garden City. The area of the site on which it is built is 10,000 square meters, 30 floors high, and the built-up area is about 1,000 square meters.

https://structurae.net/en/structures/semiramis-intercontinental-hotel

- **Opening date**: 1987.

- **Architectural designer**: Benjamin Thompson (United States of America) and Sabbour Consulting Office (Egypt)

- **Management company**: Intercontinental International, USA.

- **Owner**: Semiramis Hotels Company.

The hotel contains 879 rooms. [(9), (10)]

- Accommodation units represent 45% of the hotel's built-up area

- Public spaces represent 29% of the hotel's built-up area.

- Services represent 26% of the hotel's built-up area.

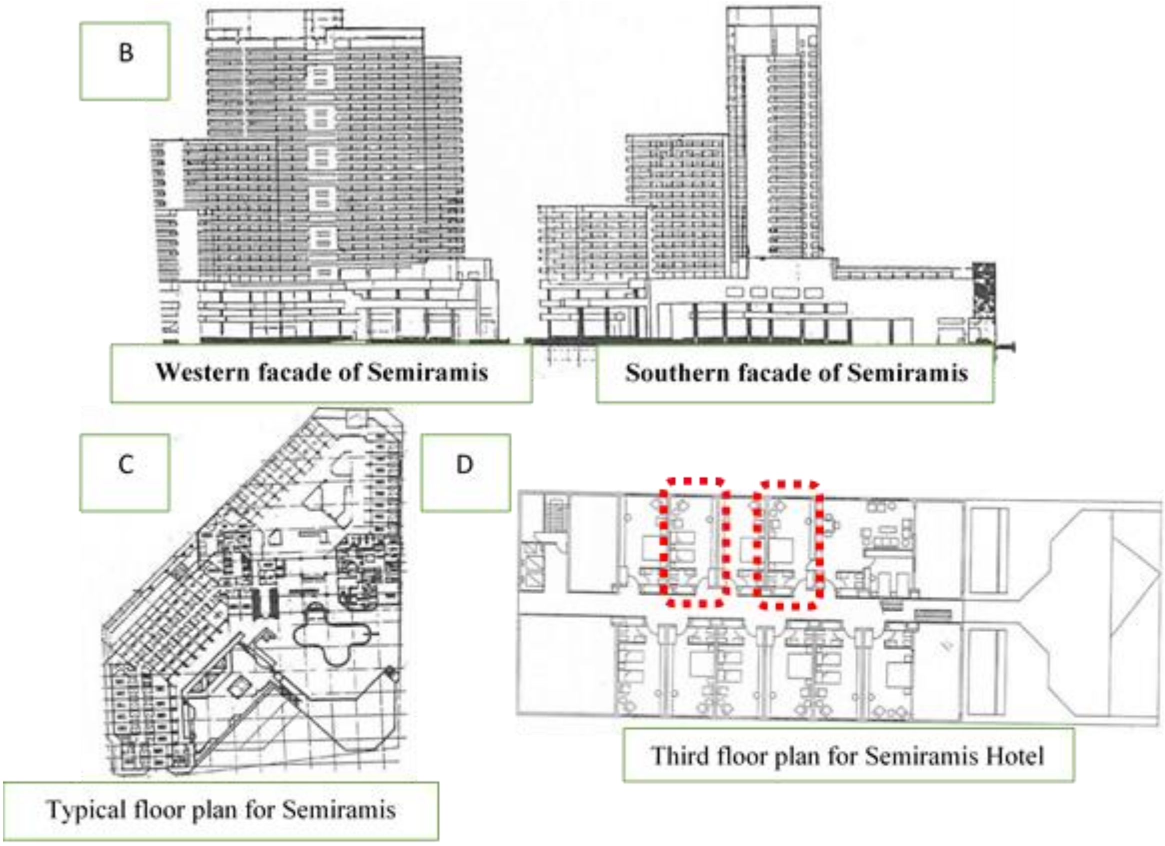


Figure (1) shows Semiramis Intercontinental Hotel plans and elevations

9. Evaluation of Thermal Performance for Case Studies:

The evaluation of thermal performance in hotel rooms in the Greater Cairo region serves as an indicator of the level of achieving thermal comfort, which is influenced by the selection of external shading devices and thermal insulation of 6 cm according to the energy code that the building envelope should meet. The choice of glass type is also considered. A comparison is made to assess the effectiveness of these treatments used in the external envelope to achieve thermal comfort in hotel rooms, with the aim of achieving energy efficiency in hotel room consumption in the Greater Cairo region.

10. Basis for Selecting Case Studies:

The Greater Cairo region is characterized by a hot and dry climate, and the lack of external shading devices in hotel rooms has resulted in a failure to achieve thermal comfort inside the spaces, negatively affecting guests. To achieve the study's objectives, the following factors need to be considered:

- The selected case studies should be within the same climatic region.

- The required information should be available to prepare for the simulation and evaluation phase.

- Projects that require studying the impact of building materials on achieving efficiency and environmental suitability should be chosen.

- These models require environmental design and a study of the materials used and their impact on thermal comfort.

- The Technical Method of Collecting and Documenting Data for the Selected Case Studies:

The researcher employed the following methods to gather information about the case studies:

- Field visits, photographic documentation, and researcher observations.

- Architectural and topographic maps of the case studies to develop a typical model.

- Previous research and studies related to the case studies.

- Personal interviews with technicians and experts in the engineering management of the projects under study.

- **Methodology of the Applied Study:**

1- Analysis of climatic data for the study area.

2- Analytical description of the hotel building under study, including architectural description, proposed building materials, occupancy rates, external shading devices, window-to-wall ratio, and orientation.

3- Evaluation of the base case using simulation, for the typical models of hotel rooms in the Greater Cairo region, using the Design Builder v7.0 simulation software, followed by evaluation.

4- Generating alternatives by testing the proposed methodology for the typical model using external shading devices, determining the most energy-consuming orientation, and adding 6 cm of thermal insulation in the external envelope, as well as using low-emissivity glass. This is done to obtain the best results by using simulation software to analyze the building's thermal performance and then produce the results.

5- Comparison and discussion of the results.

In this way, different alternatives can be evaluated in order to choose the best solutions that contribute to achieving comfort requirements and energy savings in hotel rooms in the Greater Cairo region.

- **The main objectives of this simulation were as follows:**

1- Studying the impact of external shading devices on thermal comfort inside hotel rooms in the Greater Cairo region.

2- Studying the effect of 6 cm thermal insulation on the windows in the external envelope of hotel rooms in the Greater Cairo region and its impact on energy performance.

3- Conducting a simulation of the cooling loads required for the typical model and proposing alternatives.

4- Estimating the energy savings achieved by using external shading devices, 6 cm of thermal insulation in the external envelope of hotel rooms in the Greater Cairo region, and the type of glass used.

11. Analysis of the Typical Model for Hotel Rooms in the Greater Cairo Region:

11-1 Analysis of the climatic data for the study area, the Greater Cairo region.

Climatic data for the Greater Cairo region was obtained using the Climate Consultant 6.0 software.

Psychometric Chart:

A psychometric chart illustrates the relationship between temperature and relative humidity on the horizontal and vertical axes, respectively. It provides insights into the climatic characteristics of the Greater Cairo region by identifying the thermal comfort zone in terms of temperature and humidity. It also considers factors such as occupancy rate, clothing type, and activity level. Figure (2) shows this.

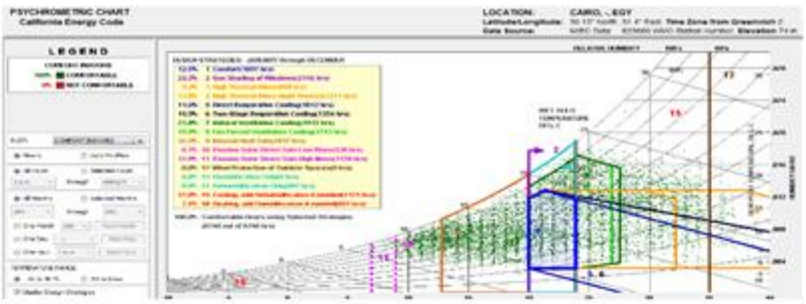


Figure (2) shows the psychometric map of thermal comfort for the study case using climate consultant 6.0 (7)

11-2 Data of the Typical Model:

1- Architectural Design Data:

The purpose of studying a model for hotel rooms in the Greater Cairo region before and after the modification of external shading devices is to assess the impact of these devices on thermal performance, orientation, and window-to-wall ratios based on different architectural dimensions of hotel rooms in the Greater Cairo region. A comparison will be made between the current state of hotel rooms in the Greater Cairo region and the modified state after implementing the alternatives. The comparison will cover important design elements such as horizontal sections, window-to-wall ratios, external shading devices, and building materials used in each element.

2- Evaluation of the typical model using simulation:

- **Methodology of simulation:**

The specifications and dimensions of the building are entered into the software to create a simulation model that accurately represents the building. This model simulates all aspects related to energy consumption in the building, as shown in the following model taken from the Design Builder v7.0 software. This software analyzes all input data in the case study.

- **Building operation data: Activities:**

Building operating period: 24 hours a day, year-round.

Occupancy density: 0.55.

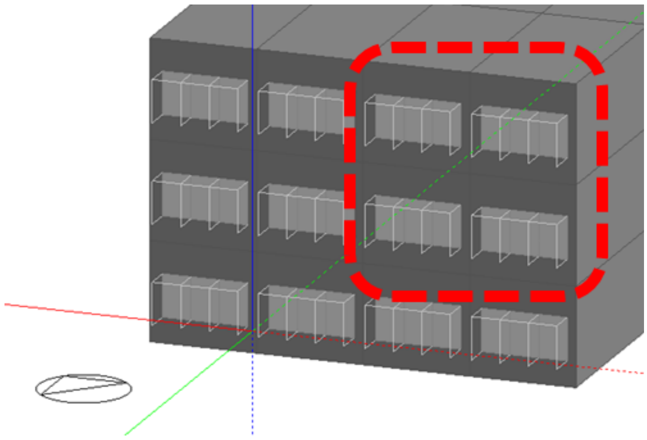
Clothing: In winter = 0.9 clo, in summer = 0.49 clo.

Metabolic rate for users (standing/walking) = 1.0.

Computer equipment.

Schedule setting: 24 hours a day, every day of the week

Figure (3) shows a model of the case study in the v 7.0 Design Builder program [8]

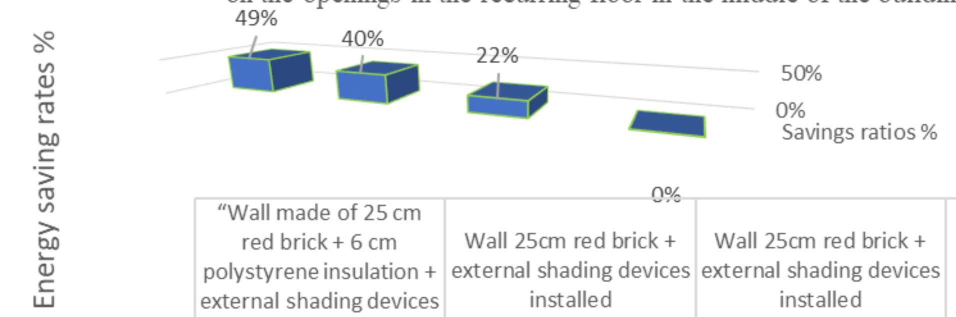


12. - Discussion of the results: Average energy savings by placing breakers in the openings for typical models (A, B):

First) Typical model (A):

- **A comparison of the energy** saving percentages for the base case of Model (A). As Figure (4) shows:

Figure (4) Comparison of the simulation results for the base case of Model (A) of individual hotel rooms with the simulation results of placing external shading devices on the openings in the recurring floor in the middle of the building.

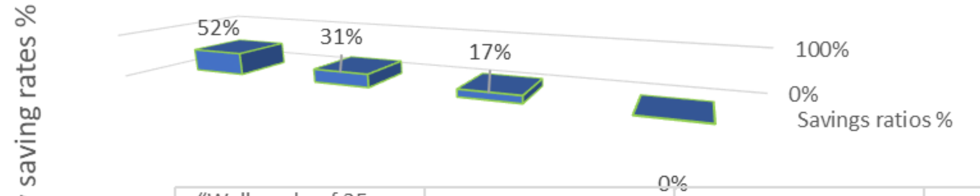


	"Wall made of 25 cm red brick + 6 cm polystyrene insulation + external shading devices installed	Wall 25cm red brick + external shading devices installed	Wall 25cm red brick + external shading devices installed	"Wall 25cm red brick without external shading devices
	6mm double low-e glass	6mm double low-e glass	6mm single clear glass	6mm single clear glass
Savings ratios %	49%	40%	22%	0%

The simulation was performed for the typical model (A) with the base case of south-west **orientation** and a window-to-wall ratio of 30%. The wall construction consisted of a 25 cm thick red brick wall. The results indicate that the energy consumption savings rate increases when using 6 mm clear glass with the following specifications: (SHGC = 0.82), (LT = 0.88), (UV = 5.70), along with external shading devices installed at a rate of 22% compared to the base case. It achieves a 40% increase in energy consumption savings when using low-emissivity double glazing with the following specifications: (SHGC = 0.23), (LT = 0.42), (U Value (UV) = 1.55). Furthermore, adding 6 cm of polystyrene insulation to the 25 cm thick red brick wall increases the savings rate by 49% for individual hotel rooms on the repeated floor in the middle of the building.

- **A comparison of the energy consumption savings ratios between the base case for the individual hotel rooms in model (A)** and the case with external shading devices installed on the windows on the corner of the repeated floor is shown in Figure (5).

Figure (5) Comparison of simulation results for the base case of Model (A) individual hotel rooms with the simulation results of placing external shading devices on the openings in the recurring floor at the corner of the building.

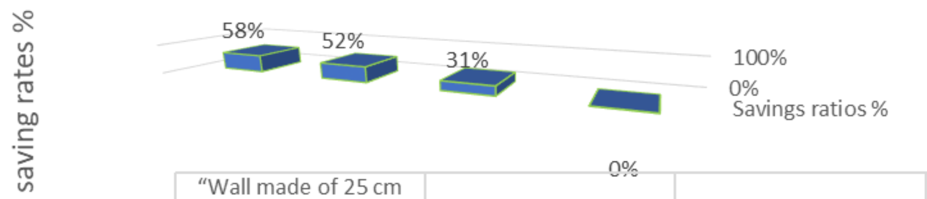


	"Wall made of 25 cm red brick + 6 cm polystyrene insulation + external shading devices installed	Wall 25cm red brick + external shading devices installed	Wall 25cm red brick + external shading devices installed	"Wall 25cm red brick without external shading devices
	6mm double low-e glass	6mm double low-e glass	6mm single clear glass	6mm single clear glass
Savings ratios %	52%	31%	17%	0%

The simulation was performed for the typical model (A) with the base case of south-west orientation and a window-to-wall ratio of 30%. The wall construction consisted of a 25 cm thick red brick wall. The results indicate that the energy consumption savings rate increases when using 6 mm clear glass with the following specifications: (SHGC = 0.82), (LT = 0.88), (UV = 5.70), along with external shading devices installed at a rate of 17% compared to the base case. It achieves a 31% increase in energy consumption savings when using low-emissivity double glazing with the following specifications: (SHGC = 0.23), (LT = 0.42), (U Value (UV) = 1.55). Furthermore, adding 6 cm of polystyrene insulation to the 25 cm thick red brick wall increases the savings rate by 52% for individual hotel rooms on the corner of the repeated floor.

- A comparison of the energy consumption savings ratios between the baseline case for the individual hotel rooms in model (A) and the case with external shading devices installed on the windows on the top floor with the roof in the middle of the building, according to the energy code, is shown in Figure (6).

Figure (6) Energy saving ratios for the base case for Model (A) individual hotel rooms with simulation results by applying the energy code and placing external shading devices on the openings. The last floor with the roof in the middle of the building.



	"Wall made of 25 cm red brick + 6 cm polystyrene insulation + external shading devices installed	Wall 25cm red brick + external shading devices installed	Wall 25cm red brick + external shading devices installed	"Wall 25cm red brick without external shading devices
	6mm double low-e glass	6mm double low-e glass	6mm single clear glass	6mm single clear glass
Savings ratios %	58%	52%	31%	0%

The simulation was performed for the typical model (A) with the base case of south-west orientation and a window-to-wall ratio of 30%. The wall construction consisted of a 25 cm thick red brick wall. The results indicate that the energy consumption savings rate increases when using 6 mm clear glass with the following specifications: (SHGC = 0.82), (LT = 0.88), (UV = 5.70), along with external shading devices installed at a rate of 31% compared to the base case. It achieves a 52% increase in energy consumption savings when using low-emissivity double glazing with the following specifications: (SHGC = 0.23), (LT = 0.42), (U Value (UV) = 1.55). Furthermore, adding 6 cm of polystyrene insulation to the 25 cm thick red brick wall increases the savings rate by 58% for individual hotel rooms on the top floor with the roof in the middle of the building.

- A comparison of the energy consumption savings ratios between the base case for the individual hotel rooms in model (A) and the case with external shading devices installed on the windows on the top floor with the roof in the middle of the building, according to the energy code, is shown in Figure (7).

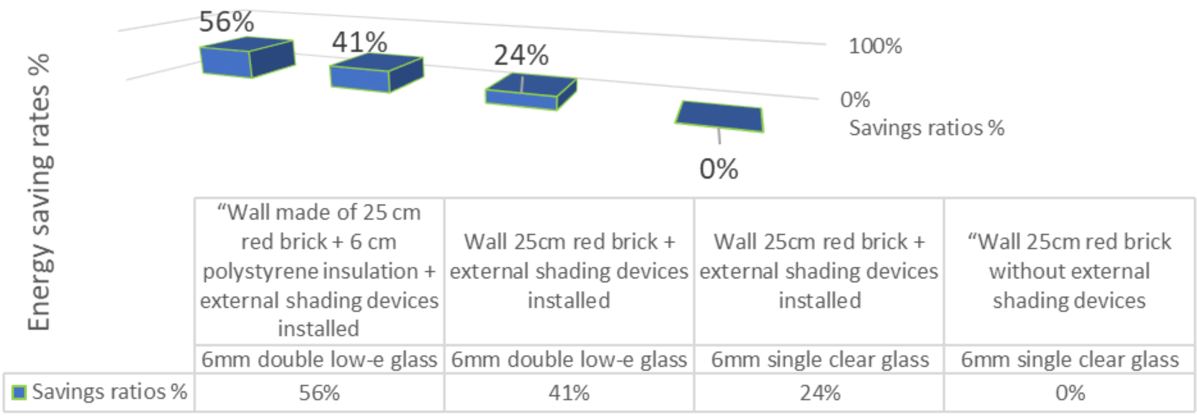


Figure (7) Energy saving ratios for the base case for Model (A) individual hotel rooms with simulation results by applying the energy code and placing external shading devices on the openings. The last floor with the roof at the corner of the building.

The simulation was performed for the typical model (A) with the base case of south-west orientation and a window-to-wall ratio of 30%. The wall construction consisted of a 25 cm thick red brick wall. The results indicate that the energy consumption savings rate increases when using 6 mm clear glass with the following specifications: (SHGC = 0.82), (LT = 0.88), (UV = 5.70), along with external shading devices installed at a rate of 24% compared to the base case. It achieves a 41% increase in energy consumption savings when using low-emissivity double glazing with the following specifications: (SHGC = 0.23), (LT = 0.42), (U Value (UV) = 1.55). Furthermore, adding 6 cm of polystyrene insulation to the 25 cm thick red brick wall increases the savings rate by 56% for individual hotel rooms on the top floor with the corner roof.

Second) Typical model (B):

- **A comparison of the energy consumption savings ratios between the base case for the double hotel rooms in model (B)** and the case with external shading devices installed on the windows on the repeated floor with the roof in the middle of the building is shown in Figure (8).

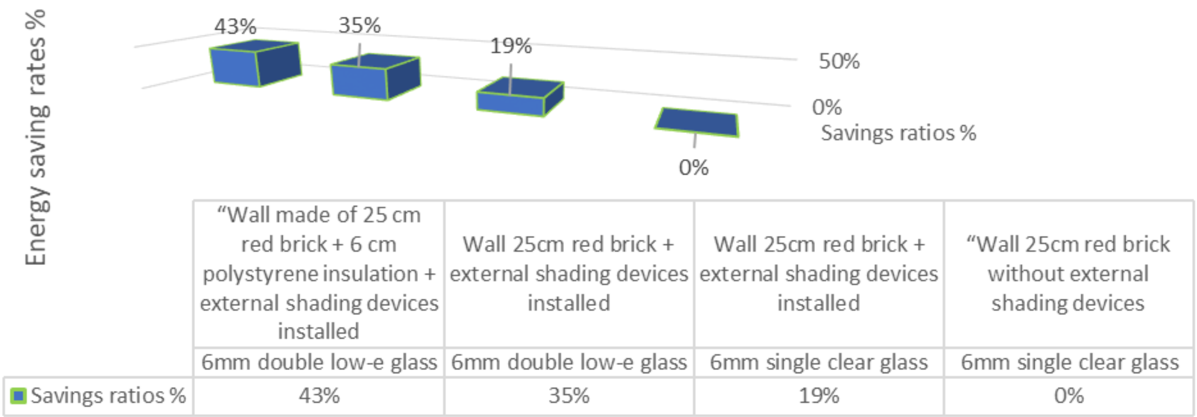
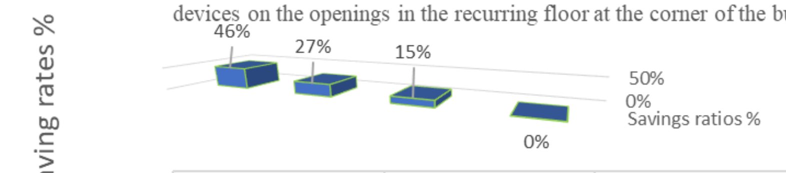


Figure (8) Comparison of energy consumption saving ratios for the base case of Model (B) double hotel rooms with energy consumption saving ratios by placing external shading devices on the openings in the recurring floor in the middle of the building.

The simulation was performed for the typical model (B) with the base case of south-west orientation and a window-to-wall ratio of 30%. The wall construction consisted of a 25 cm thick red brick wall. The results indicate that the energy consumption savings rate increases when using 6 mm clear glass with the following specifications: (SHGC = 0.82), (LT = 0.88), (UV = 5.70), along with external shading devices installed at a rate of 19% compared to the base case. It achieves a 35% increase in energy consumption savings when using low-emissivity double glazing with the following specifications: (SHGC = 0.23), (LT = 0.42), (U Value (UV) = 1.55). Furthermore, adding 6 cm of polystyrene insulation to the 25 cm thick red brick wall increases the savings rate by 43% for double hotel rooms on the repeated floor with the corner roof.

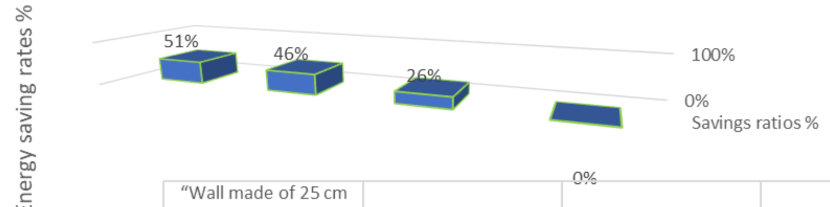
- A comparison of the energy consumption savings ratios between the base case for the double hotel rooms in model (B) and the case with solar breakers installed on the windows on the repeated floor with the corner of the building is shown in Figure (9).



	"Wall made of 25 cm red brick + 6 cm polystyrene insulation + external shading devices installed	Wall 25cm red brick + external shading devices installed	Wall 25cm red brick + external shading devices installed	"Wall 25cm red brick without external shading devices
	6mm double low-e glass	6mm double low-e glass	6mm single clear glass	6mm single clear glass
Savings ratios %	46%	27%	15%	0%

The simulation was conducted for the typical Model (B) with a base case of south-west orientation and a window-to-wall ratio of 30%. The wall construction comprised a 25 cm thick red brick wall. The results indicate that the energy consumption savings rate increases when using 6 mm clear glass with the following specifications: (SHGC = 0.82), (LT = 0.88), (UV = 5.70), along with external shading devices installed at a rate of 15% compared to the base case. It achieves a 27% increase in energy consumption savings when using low-emissivity double glazing with the following specifications: (SHGC = 0.23), (LT = 0.42), (U Value (UV) = 1.55). Moreover, adding 6 cm of polystyrene insulation to the 25 cm thick red brick wall results in a 46% increase in the savings rate for double hotel rooms on the repeated floor with the corner roof.

- A comparison of the energy consumption saving ratios for the base case of Model (B) double hotel rooms with the energy consumption saving ratios by applying the energy code and placing external shading devices on the openings. The last floor with the roof in the middle of the building. As Figure (10) shows:



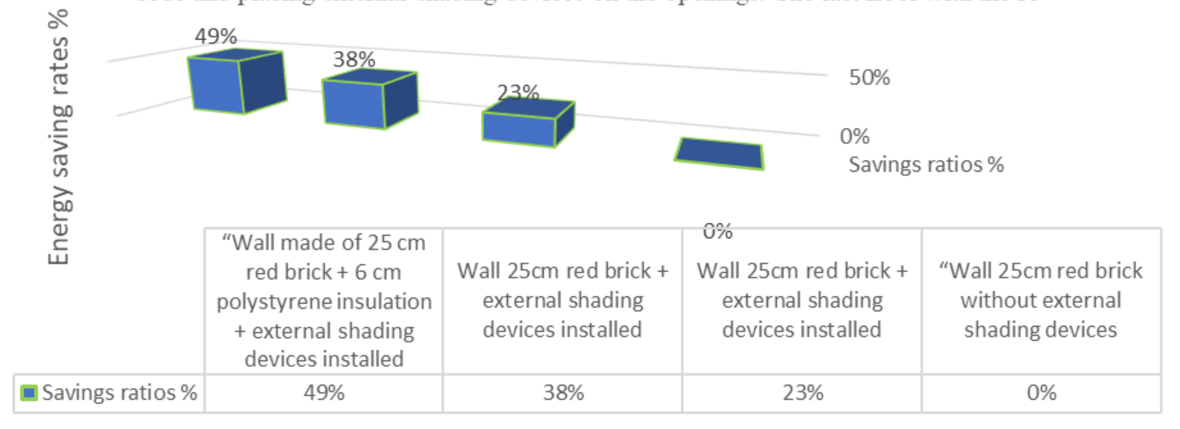
	"Wall made of 25 cm red brick + 6 cm polystyrene insulation + external shading devices installed	Wall 25cm red brick + external shading devices installed	Wall 25cm red brick + external shading devices installed	"Wall 25cm red brick without external shading devices
	6mm double low-e glass	6mm double low-e glass	6mm single clear glass	6mm single clear glass
Savings ratios %	51%	46%	26%	0%

Axis Title

Simulations were performed for the typical model (B) for the base case, orientation (south-west), opening ratios of 30%, and a red brick wall with a thickness of 25 cm. The results indicate that the rate of saving energy consumption increases in the case of 6 mm transparent glass with standards ((SHGC) = 0.82).), ((LT) = 0.88), ((UV) = 5.70)) using external shading devices installed at a rate of 26% over the base case. It achieves an increase in energy consumption by an average of 46% in the case of using double LOW-E low-emission glass with standards ((SHGC) = 0.23), ((LT) = 0.42), (U Value (UV) = 1.55). If 6 cm polystyrene insulation is added to a 25 cm thick red brick wall, the savings rate increases by 51% for double hotel rooms on the last floor with the roof in the middle of the building.

- A comparison of the energy consumption saving ratios for the base case of Model (B) double hotel rooms with the energy consumption saving ratios by applying the energy code and placing external shading devices on the openings. The last floor with the roof at the corner of the building. As Figure (11) shows:

Figure (11) Comparison of energy consumption saving ratios for the base case of Model (B) double hotel rooms with energy consumption saving ratios by applying the energy code and placing external shading devices on the openings. The last floor with the ro



Simulations were performed for the typical model (B) for the base case, orientation (south-west), opening ratios of 30%, and a red brick wall with a thickness of 25 cm. The results indicate that the rate of saving energy consumption increases in the case of 6 mm transparent glass with standards ((SHGC) = 0.82).), ((LT) = 0.88), ((UV) = 5.70)) using external shading devices installed at a rate of 23% over the base case. It achieves an increase in energy consumption by an average of 38% in the case of using double LOW-E low-emission glass with standards ((SHGC) = 0.23), ((LT) = 0.42), (U Value (UV) = 1.55). If 6 cm polystyrene insulation is added to a 25 cm thick red brick wall, the savings rate increases by 49% for double hotel rooms on the last floor with the roof at the corner of the building.

13. Recommendations of the applied study:

Use simulation during the design phase: Simulation can help understand the energy performance of hotel rooms in the Greater Cairo region. By simulating different scenarios, it becomes possible to identify the optimal alternative for energy-efficient systems that can enhance performance and function effectively.

Apply research findings to hotel room models: The results and simulations conducted in the study can be applied to hotel room models in the Greater Cairo region. The relevant authorities responsible for constructing these rooms can incorporate the research findings to achieve thermal comfort inside the hotel rooms and reduce energy consumption. It is evident that both architectural dimensions and the selection of external shading devices have a significant impact on energy consumption. If architects consider these dimensions during the design process, energy savings can be achieved.

Energy consumption is influenced by design decisions: The research focused on studying and analyzing the thermal insulation of the external envelope and the use of external shading devices. These dimensions were tested due to their importance and impact on addressing the external envelope and energy consumption of hotel rooms in the Greater Cairo region. The main focus was on using external shading devices on openings and 6 cm thickness of thermal insulation in the external envelope of hotel rooms. The optimal orientation was found to be north, northeast, northwest, while the least energy consumption occurred in the south and southwest orientations.

Wall thickness requirements: The required wall thickness for achieving the best thermal performance and user privacy in hotel rooms in the Greater Cairo region is determined to be 25 cm of red brick along with 6 cm of polystyrene insulation. This combination helps achieve better thermal performance, user comfort, and sound insulation.

Glass type and external shading devices: Using energy-efficient glass with external shading devices and thermal insulation can result in more than 50% energy savings compared to using single-pane transparent glass. The recommended glass type is double-glazed low-emissivity glass with specific standards such as (SHGC) = 0.23, (LT) = 0.42, and (U Value (UV) = 1.55). This outperforms single-pane transparent glass with standards of (SHGC = 0.82, LT = 0.88, UV = 5.70) in most of the studied cases.

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