Using Dynamic Solar Shading Devices on the Building Envelope of Government Schools to increase Thermal Performance and Improve Energy Consumption

Mohamed Hedek Ibrahim[1,2]

[1] *Teaching assistant, Architecture Department,* October High Institute for Engineering and Technology, Egypt. *Email:* mohamedhedek@gmail.com

[2] *Ph.D. Student, Architecture Department, Faculty of Engineering, Cairo University, Giza, Egypt, 12613.*

ABSTRACT

The Egyptian state seeks to develop the educational system and overcome many of the challenges it faces, according to an ambitious plan to apply to existing educational buildings, rehabilitate them and raise their efficiency, and to improve the quality of the internal environment for students, and for better education in government schools, and achieving thermal comfort for students inside classrooms is also considered. Study is one of the most important requirements for the quality of the educational process that is achieved through good design of the external envelope of the educational building, as it is the main focus of all thermal control processes and the link between the internal and external environment [1]. The research aims to show the role of Dynamic solar shading devices on the building envelope of Educational research aims to achieve thermal comfort and reduce energy consumption in school classrooms in the Greater Cairo region, as a result of the inefficiency of the existing outer shell of these schools. An applied study was conducted on a government school in the Greater Cairo region using computer simulation in the Design Builder 6.1 program to measure the effect of using Dynamic solar shading devices. In raising the thermal performance and improving energy consumption on the openings in the outer shell of the southern school classrooms, and also measuring the effect of using Dynamic solar shading devices and smart materials together on the outer shell of the southern school classrooms. The results show through application that the use of horizontal moving solar refractors and glass treated with Nano technology (Double Low-E Elec Reflective Colored glass) with a thickness of 6 mm and 13 mm air (SHGC = 0.119), (LT = 0.12), (UV = 1.616), on The outer shell of the southern school classrooms works to save energy better than using Dynamic solar shading devices only on the Building Envelope of the southern classrooms, as the energy consumption changes with the angle of the breaker, in addition to increasing the percentage of energy savings as a result of using glass treated with Dynamic solar shading.

Keywords: Educational buildings - Building Envelope - Dynamic solar shading - smart materials - thermal comfort.

1. Introduction:

School buildings are among the most widespread structures in the world. They are the foundation for building future generations. The number of schools in the Greater Cairo region has reached 12,314 schools with a total of 138,342 classrooms [2]. This necessitates the importance of designing school buildings and achieving thermal comfort for students inside the classrooms while protecting them from solar radiation during study hours. Students spend long hours in their classrooms, and therefore, a good indoor environment can help improve conditions for their performance. The thermal performance of school classrooms not only affects the health and comfort of students but also affects the efficiency of the entire educational process [3]. The building envelope is considered the most effective component in energy consumption, as it is responsible for more than 50% of the total energy consumption in the building [4]. Therefore, it is necessary to ensure the effectiveness of the existing school classroom envelopes and the materials used in achieving thermal comfort and improving energy performance in the building.

2. Research Problem:

The research problem is the increased energy consumption and the lack of thermal performance efficiency in the traditional, untreated building envelope of south-facing classrooms in the Greater Cairo region.

3. Research Objective:

The objective of the research is to improve thermal efficiency and energy performance by integrating solar shading devices and smart materials into the building envelope of south-facing classrooms in the Greater Cairo region.

4. Research Methodology:

A simulation was conducted for an existing government school (Sheikh Zayed Secondary School for Girls), and an analytical study was carried out to analyze the heating and cooling loads of the south-facing classrooms. The simulation was performed using the Design Builder 6.1 software to compare the results of modifying the building envelope of the south-facing classrooms using movable solar shading devices and smart materials with the results of the traditional envelope used. The effectiveness of the modifications in improving the thermal performance of the south-facing classrooms and reducing energy consumption was measured, taking the following into consideration:

- Consideration of the climatic data for the Greater Cairo region during the simulation.
- Simulation of one south-facing classroom on the top floor of the school, considering it as the most exposed to heat loads.
- Building orientation, number of students inside the classroom, opening ratios, and the floor on which the classroom is located.
- Simulation of the U-VALUE heat transfer coefficients for both the baseline and modified building envelope and calculation of the required cooling loads.
- Fixed classroom area of 60 m2.
- Working hours from 7 am to 3 pm daily, except for Fridays and Saturdays.

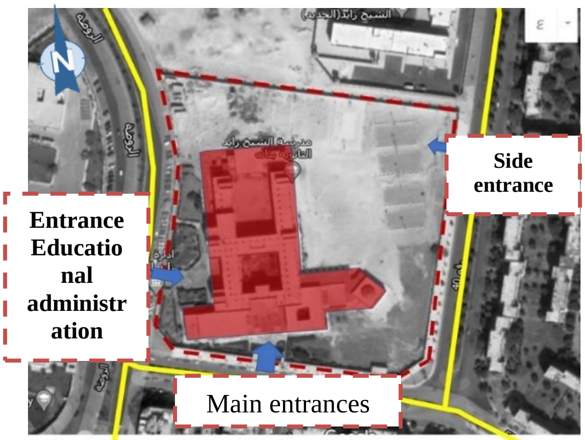


Figure (1): shows the lay out and main entrances to the school. Source: researcher

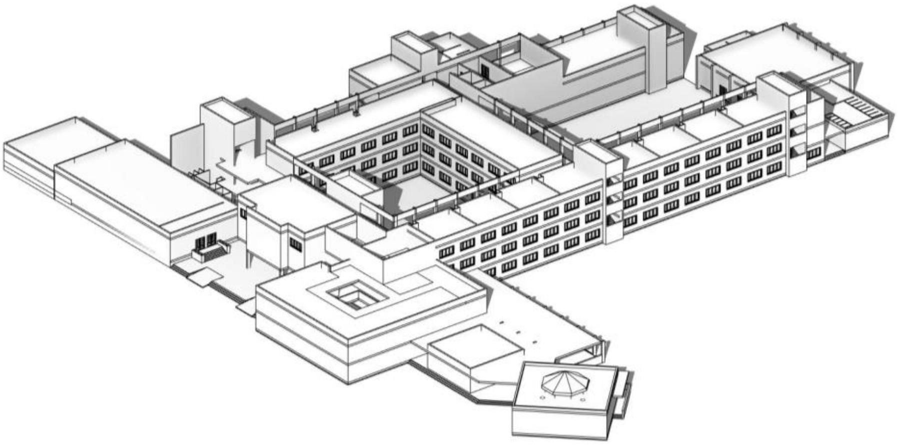


Figure (2): A perspective showing the mass of the building. Source: researcher

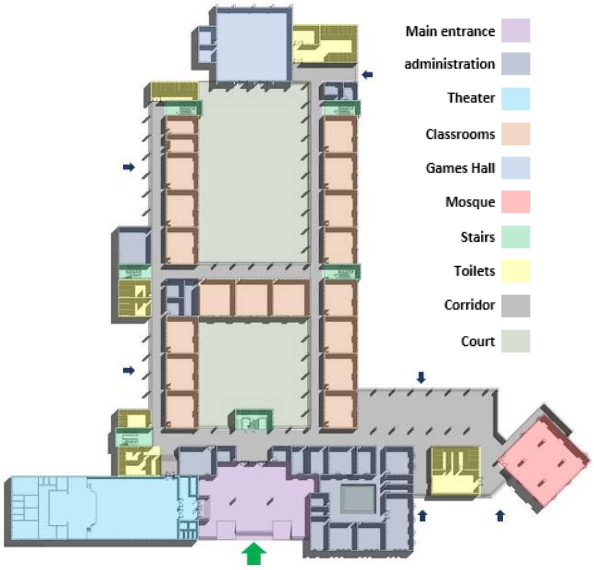


Figure (3): showing plan for the ground floor of the school.

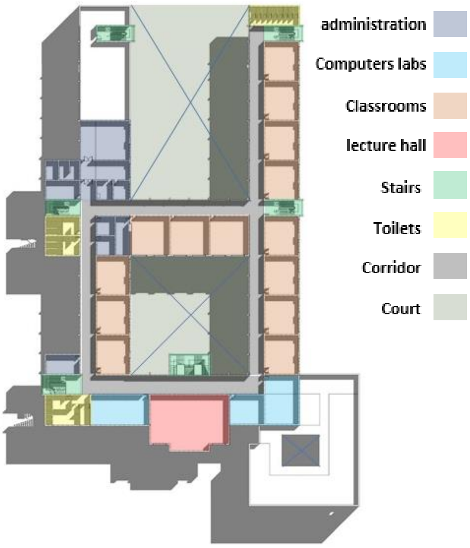


Figure (4) shows the plan for the typical floor of the school.

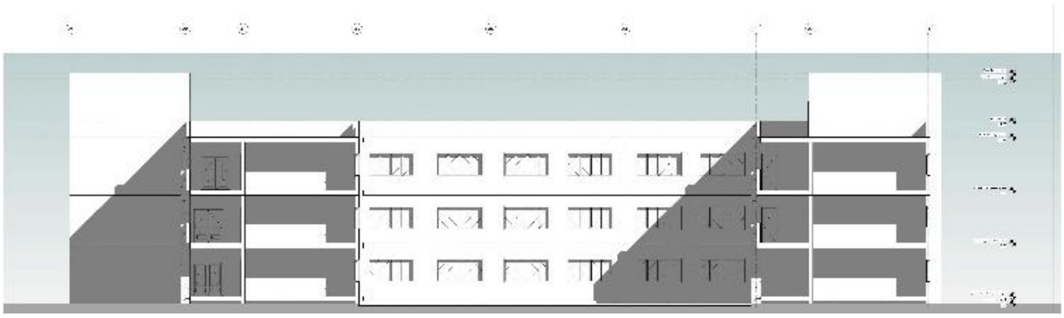


Figure (5): A vertical section of the school's inner courtyard showing the school's southern classrooms.

5. Building Envelope and Thermal Performance:

The design of the building envelope relies on using external and internal walls between classrooms with a thickness of 25 cm, in addition to finishing layers. However, thermal insulation materials or treatments to improve the building's performance are not utilized. The classrooms are equipped with windows that have a width of 2.80 m and a height of 1.60 m, and the corridors have upper window openings. However, these windows are insufficient to provide an adequate amount of natural lighting. Moreover, the glass used in the windows is single-pane glass, 3 mm thick, without any treatment. This allows the passage of radiation, heat, and glare into the classrooms, making the students uncomfortable. As a result, students often resort to placing barriers on the windows to reduce glare [5], as shown in Figure (6)

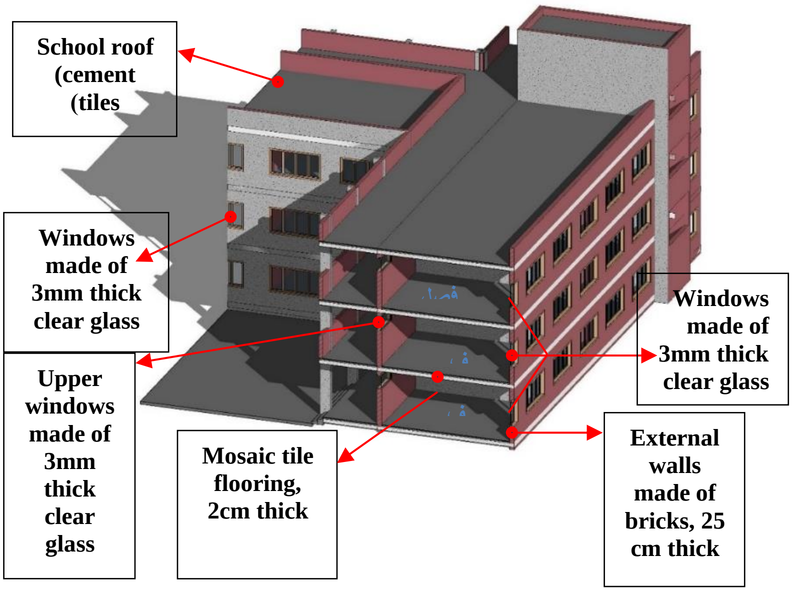
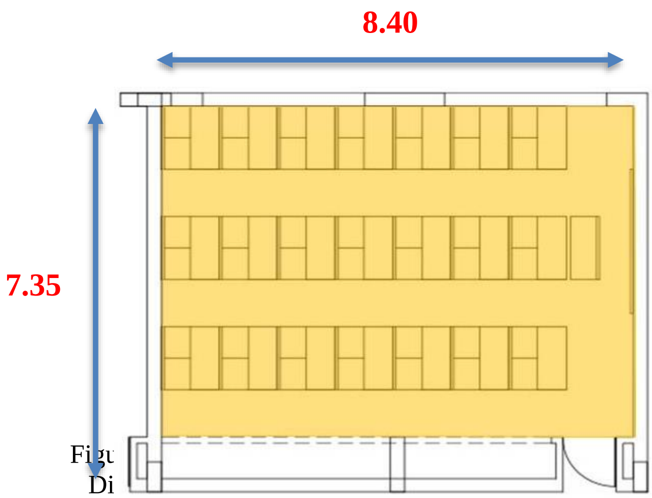


Figure (7): A three-dimensional section of the classrooms showing the exterior envelope used for the building. **Source**: researcher

Figure (6): shows the students' use of screens and curtains on the windows to protect against glare and solar radiation inside the classroom, which blocks natural lighting inside the space. **Source**: researcher

6. Designing the southern educational classrooms in the school:

The southern educational classrooms were designed with a size of 8.40 x 7.35 m, so that the class can accommodate 35 to 40 female students in a classroom area of about 60 square meters, meaning that the student's share is about 1.5 square meters [5].



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Sheikh Zayed. Source: Researcher

Figure (8): shows the educational classrooms from the inside at the First District Secondary School for Girls. Source: researcher

7. Analyzing the climate data for the study sample:

7-1 Location of the study case:

A- Analysis of temperature and relative humidity:

An analysis of the climate of the Greater Cairo region in which the study case is located was conducted using the climate analysis program And obtain these results as in Figure (10): (Climate Advisory 6.0)

We find from the analysis that the thermal comfort zone is between (20°C and 24°C), and that the months of discomfort are from March until November.

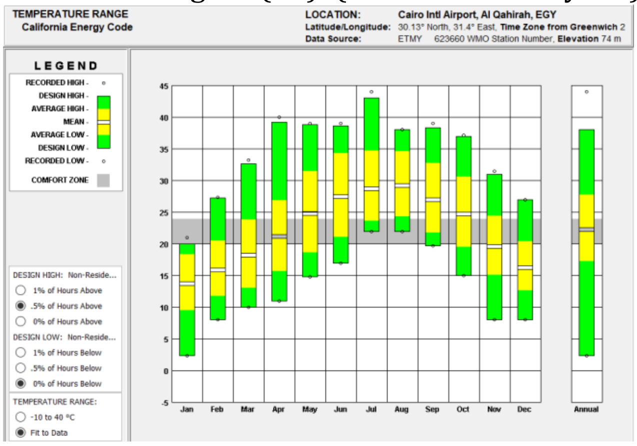


Figure (10): shows the average temperatures throughout the year for the region. Source: Climate consultant.

8. Simulation results of energy consumption in the southern classrooms of Sheikh Zayed Secondary School for Girls using the (Design Builder v6.1) program:

The study proposes to evaluate a model of one of the school classrooms in the Greater Cairo region at Sheikh Zayed Secondary School for Girls on the simulation program (Design Builder 6.1) by measuring the cooling and heating loads in one of the southern classrooms of the school with an area of about 60 square meters. The classroom on the last floor was chosen because it is the most exposed to thermal loads, with Set the height of the partition at 3.0 meters from the finish, the height of the window at 1.60 meters, and the height of the front window session at 0.90 meters [6].

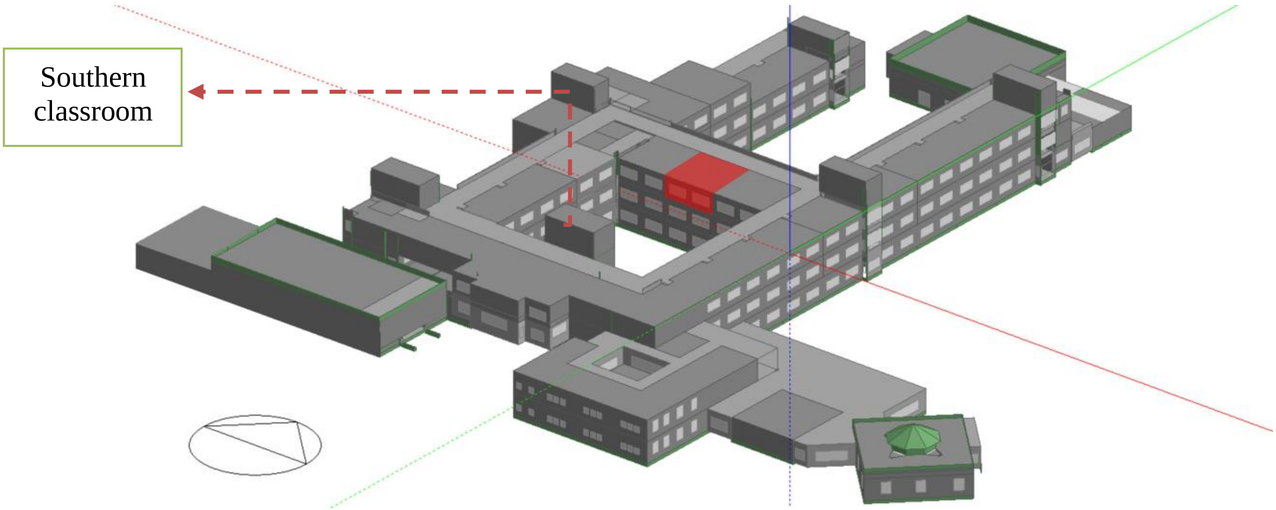


Figure (11): It shows the final model of the case study on the program. **Source**: Design Builder 6.1

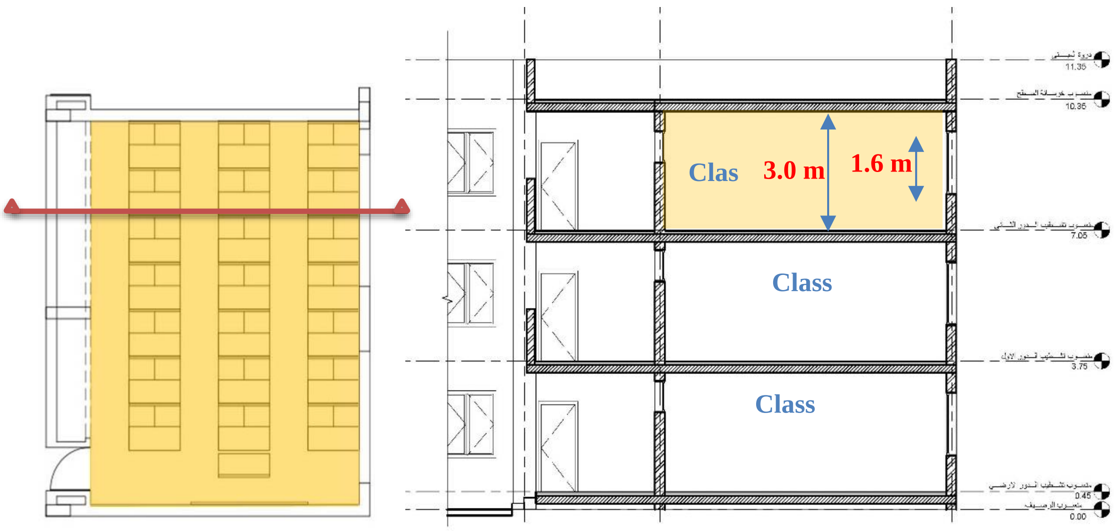
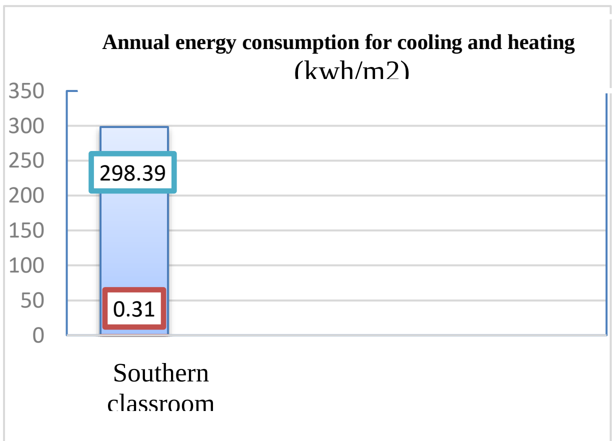


Figure (12): shows a vertical section and plan of one of the classrooms on the last floor
Of the First District Girls Secondary School building in Sheikh Zayed.

9. Simulation results for energy consumption in the southern classrooms:

We find from the results of analysis and simulation that the months of discomfort are from March until November, in accordance with the temperatures recommended in the Egyptian code to improve the efficiency of energy use in buildings. Also, the simulation results of energy consumption in the case of using the existing model with a 25 cm thick wall, red brick, and 3 mm single untreated transparent glass (SHGC = 0.861), (LT = 0.898), (UV = 5.894) reach (298.39 Kwh/m2) annually, which This means the need for environmental treatments to raise the efficiency of thermal performance and improve the energy performance of the building



Energy consumption	Southern classroom
Cooling loads	298.39
Heating loads	0.31

Figure (14): shows the simulation results of energy consumption in the southern classrooms without any .environmental treatments

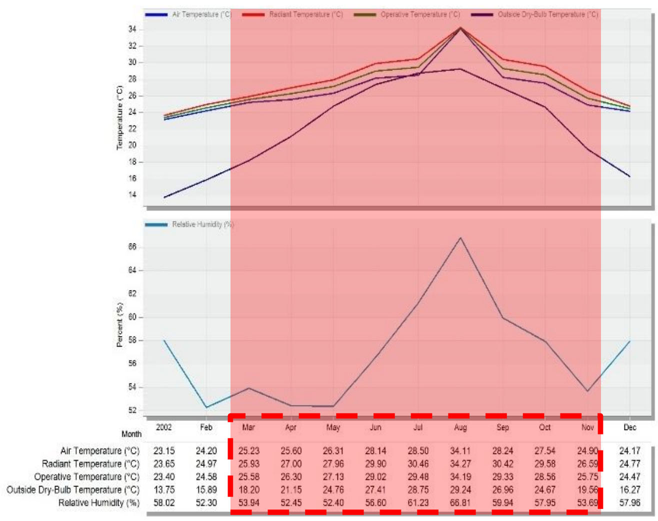


Figure (13): shows the actual temperatures, relative humidity, .and months of discomfort for the southern classrooms

10. Modifying the Building Envelope of the southern classrooms using dynamic solar shading:

A- Proposed modifications to the building:

Adding mobile solar shutters to the openings of the southern façade that close and open automatically to avoid solar glare and adapt to the external climate through electrical and mechanical techniques. The solar shading relies on the folding method. The unit consists of two panels touching on the largest side, and the angle between them increases and decreases according to the surrounding external conditions. The solar shading is made of polytetrafluoroethylene (PTFE) and is characterized by strength, durability and high flexibility. It has a high ability to withstand bending and folding, allows 40% light to pass through, and is also distinguished by its resistance to ultraviolet rays [7].

Specifications for proposed solar shading use			
Material used	Polytetrafluoroethylene (PTFE)		
solar shading dimensions	The width of the solar shade is 2.80 m, the width of the window opening, and the height of the solar shade is approximately 1.60 m, covering the window opening, and the .thickness of the solar shade is 1 cm		
U Valua	4.6 w/m^2-k	**Solar heat gain coefficient SHGC**	0.18
Density	2200 kg/m^3	**Thermal conductivity**	0.25 w/m-k
Control systems technology	Central control individually	**Engine technology**	Linear actuators
Sensor technology	Light sensor - central control	**The structural system on the facade**	Aluminum beams and partitions on the facade

Table (1): shows the proposed solar shading specifications and their application to the building envelope for the southern classrooms [7]

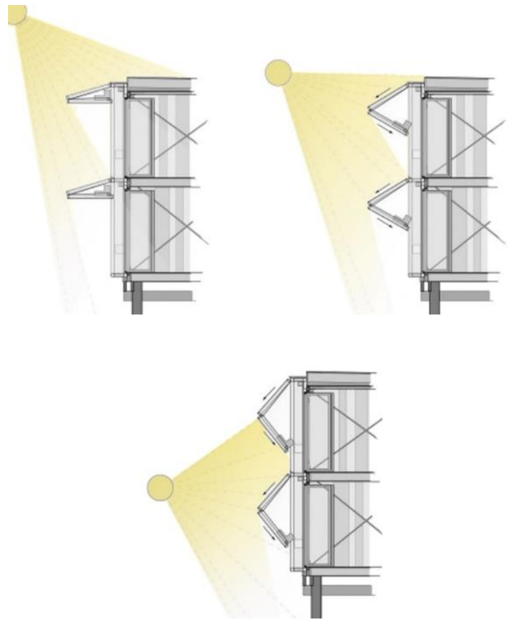


Figure (15): illustrates the working idea of the proposed solar shading https://cutt.us/7JKMf

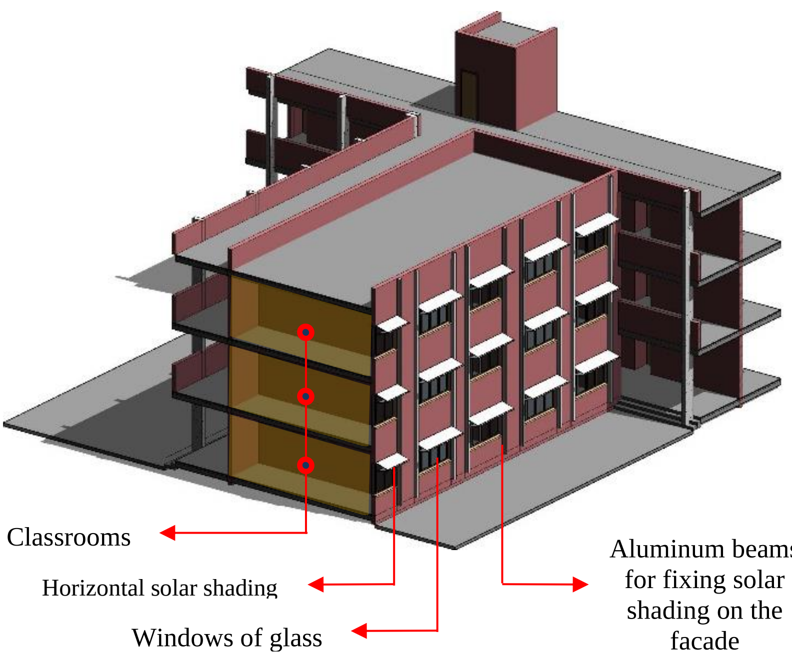


Figure (16): shows the dynamic solar shading on the southern facade of the .building's classrooms

The movement of solar shading on the southern façade of the classrooms of the First District Girls Secondary School building in Sheikh Zayed will be studied within the simulation program (Design Builder 6.1) at more than one angle, and the cooling and heating loads [6] will be calculated during working hours as shown in Table (2).

A vertical section in the building envelope of the southern chapter showing the different angles of dynamic solar shading				
Angle 75/150°	Angle 60/120°	Angle 45/90°	Angle 30/60°	Angle 15/30°

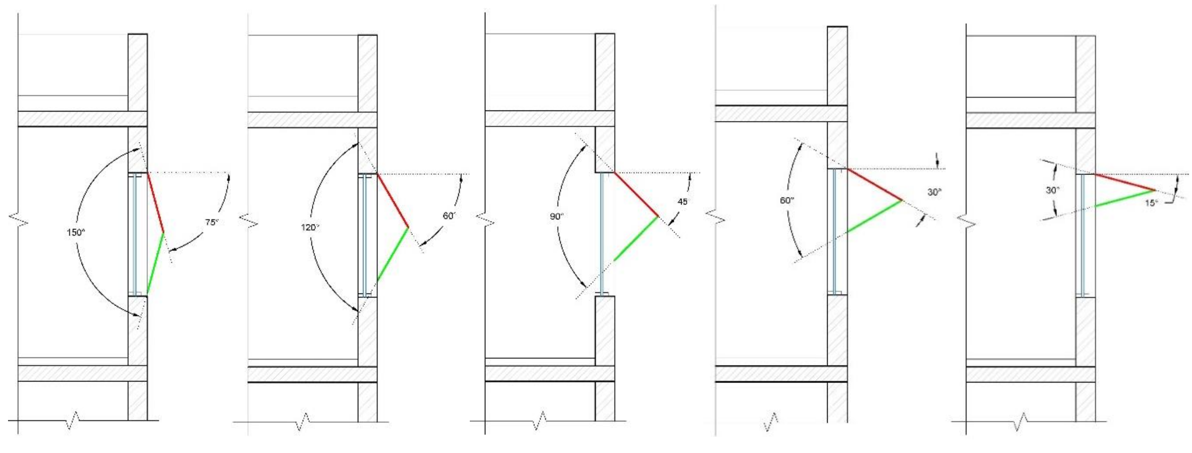
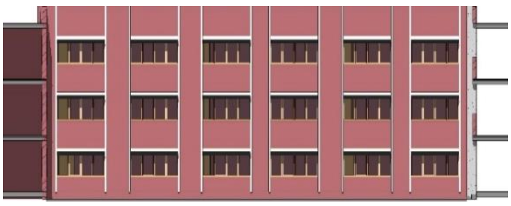
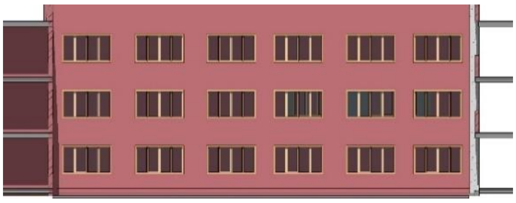


Table (2): Shows the different angles of dynamic solar shading used on the southern classrooms



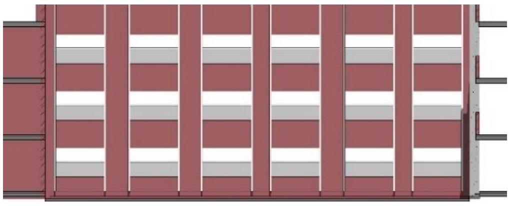
South facade with dynamic solar shading added (15/30) angle



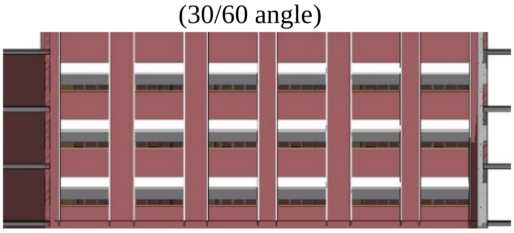
The southern facade without solar shading

South facade with dynamic solar shading added (45/90 angle)

South facade with dynamic solar shading added (30/60 angle)



South facade with dynamic solar shading added (75/150 angle)

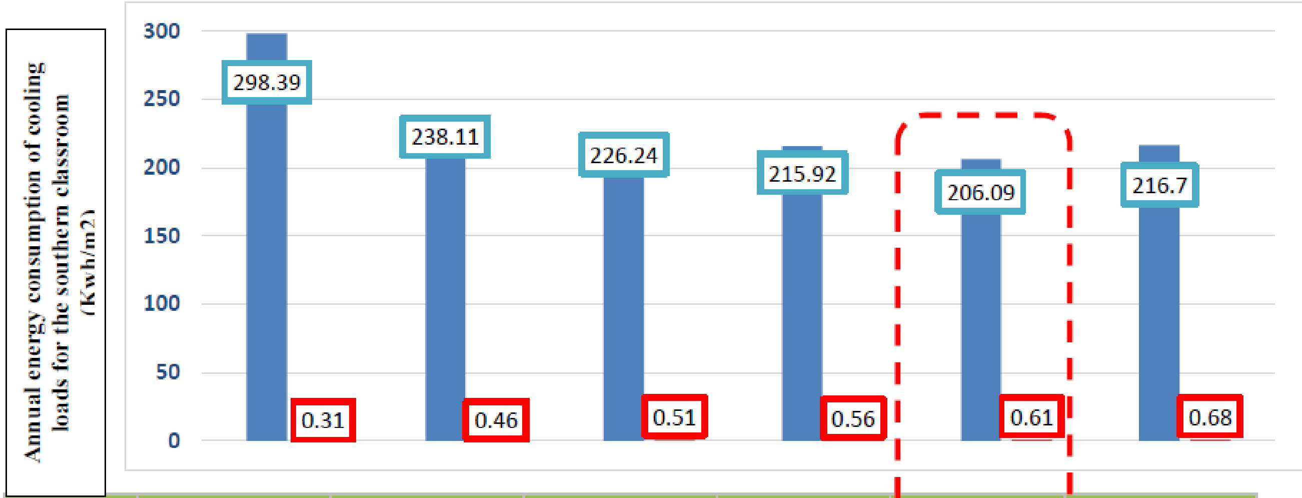


South facade with dynamic solar shading added (60/120 angle)

Figure (17): shows the different dynamic solar shading angle on the southern facade of the building's classrooms.

B- Simulation results of energy consumption in the southern season after treatment using dynamic solar shading:

We find that energy consumption in the southern season is in the case of using dynamic horizontal solar shading on the facade with a 25 cm thick wall, red brick, and 3 mm single untreated transparent glass (SHGC = 0.861), (LT = 0.898), (UV = 5.894). It reached 209.09 kW/m2, with a saving rate of more than 30% compared to the traditional cover without solar shading



Annual energy consumption of cooling loads Kwh/m2	BASE CASE	FIRST CASE	SECOND CASE	THIRD CASE	FOURTH CASE	FIFTH CASE
	Without solar shading	solar shading an angle of (15°/30°)	solar shading an angle of (30°/60°)	solar shading an angle of (45°/90°)	solar shading an angle of (60°/120°)	solar shading an angle of (75°/150°)
Cooling loads	289.39	238.11	226.24	215.92	206.09	216.7
Heating loads	0.31	0.46	0.51	0.56	0.61	0.68
Energy saving rate		%20.13	%24.08	%27.52	%30.80	%27.22

Figure (18): shows a comparison of energy consumption results in the case of using dynamic solar shading on the southern facade.

The consumption of cooling and heating energy also changes with changing solar shading angles, as the lowest energy savings are achieved by solar shading at an angle of (15°/30°) by 20.13%, and the highest energy savings are achieved by the breaker at an angle of (60°/120°) by 30.80. %, and we conclude from this that the greater the internal angle of solar shading, the greater the percentage of .savings in energy consumption

11. Simulation results of energy consumption in the southern classroom by combining dynamic solar shading with the use of glass treated with nanotechnology:

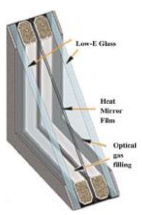
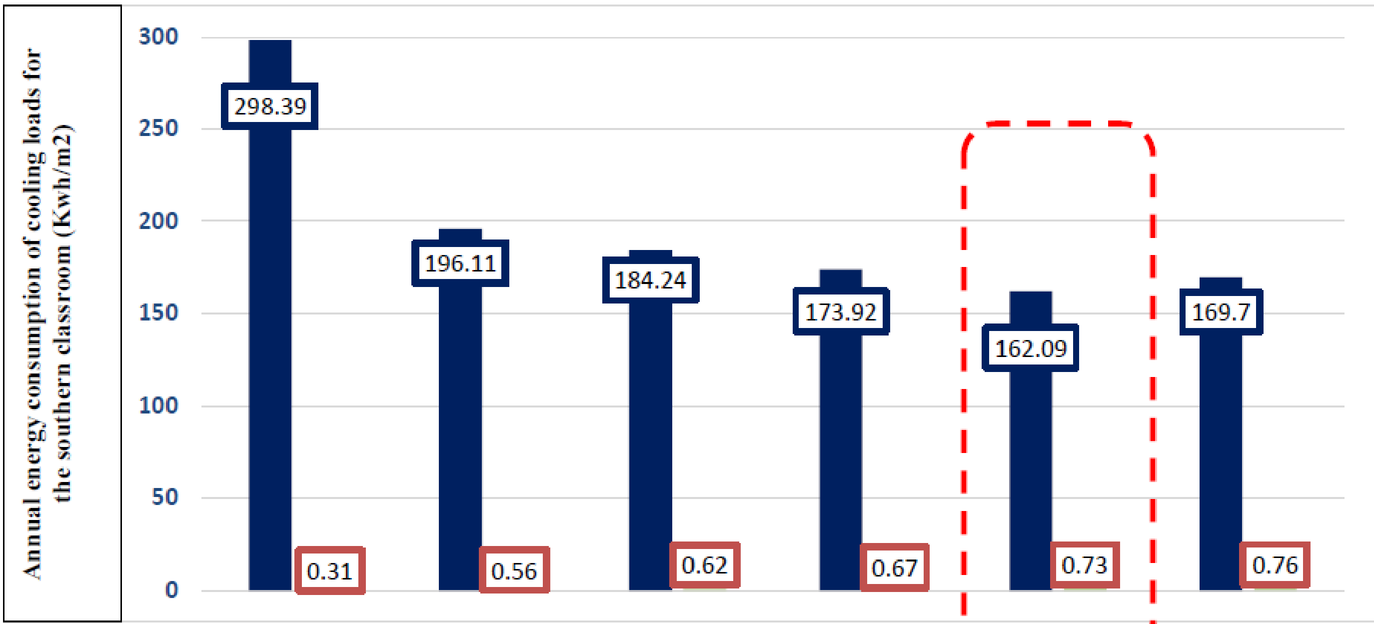
Glass type	form	SHGC	LT	UV
Double Low-E Elec Reflective Colored glass		0.119	0.12	1.616

Table (3): Specifications of glass treated with nanotechnology used with dynamic solar shading on the southern façade.

Simulation results of energy consumption in the case of using dynamic horizontal solar shading on the southern facade with a wall using 25 cm thick red brick, and colored glass treated with Nano technology (Double Low-E Elec Reflective Colored Glass) with a thickness of 6 mm and 13 mm air (SHGC=0.119),(LT = 0.12), (UV = 1.616) as it is one of the best types of energy-efficient glass [8].



Annual energy consumption of cooling loads Kwh/m2	BASE CASE	FIRST CASE	SECOND CASE	THIRD CASE	FOURTH CASE	FIFTH CASE
	Without solar shading	solar shading an angle of (15°/30°)	solar shading an angle of (30°/60°)	solar shading an angle of (45°/90°)	solar shading an angle of (60°/120°)	solar shading an angle of (75°/150°)
Cooling loads	298.39	196.11	184.24	173.92	162.09	169.7
Heating loads	0.31	0.56	0.62	0.67	0.73	0.76
Energy saving rate		%34.15	%38.11	%41.55	%45.49	%42.93

Figure (19): shows a comparison of energy consumption results through the combination of dynamic solar shading on .the façade of the southern chapter with the use of glass treated with nano technology

By comparing the results of the combination between dynamic horizontal solar shading and glass treated with Nano technology (Double Low-E Elec Reflective Colored glass) with a thickness of 6 mm and 13 mm air (SHGC = 0.119), (LT = 0.12), (UV = 1.616) as one of the types Glass treated with Nano technology, which saves energy consumption. It is clear that the energy consumption in this case changes with the change in the angle of the refractor, in addition to an increase in the percentage of energy savings as a result of the use of treated glass, as the lowest percentage of energy savings is achieved by the first case at a rate of 34.15% compared to the basic case. The highest percentage of energy savings is achieved by the fourth case at a rate of 45.49% compared to the basic case. We conclude from this that the greater the internal angle of the refractor with the use of glass treated with nanotechnology, the greater the percentage of savings in energy consumption.

12. Conclusions:

The results of the computer simulation on a school building in the Greater Cairo region (Sheikh Zayed Secondary School for Girls) using the Design Builder 6.1 software indicate the following:

-The energy consumption within the south-facing classrooms in the baseline case, with a 25 cm thick red brick wall and untreated single-pane glass (SHGC=0.861), (LT = 0.898), (UV=5.894), showed a higher energy consumption to achieve thermal comfort for students. The annual cooling and heating energy consumption for the south-facing classroom was 298.70 kWh/m2.

-Implementing dynamic solar shading systems on the building envelope of the south-facing classrooms resulted in a reduction in cooling and heating energy consumption, which varied with the angles of the shading devices. The lowest energy savings were achieved with a shading angle of (15°/30°) at a rate of 20.13%, while the highest energy savings were achieved with a shading angle of (60°/120°) at a rate of 30.80%.

-Combining dynamic horizontal solar shading with nanotechnology-treated glass (Double Low-E Elec Reflective Colored glass) with a dual-pane configuration of 6 mm and 13 mm air gap (SHGC=0.119), (LT = 0.12), (UV=1.616) showed increased energy savings. The lowest energy savings were achieved in the first scenario at a rate of 34.15% compared to the baseline case, while the highest energy savings were achieved in the fourth scenario at a rate of 45.49% compared to the baseline case.

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