# Research 2

# The Impact of the Nanotechnology-Treated Glass on Optimizing the Thermal Performance and Improving the Energy Consumption of the Public Schools Envelope in the Greater Cairo

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1

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2

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3

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4

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5

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6

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7

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8

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Congratulations!

We are pleased to inform you that, after the peer review, your article entitled "**The Impact of the Nanotechnology-Treated Glass on Optimizing the Thermal Performance and Improving the Energy Consumption of the PUBLIC Schools Envelope in the Greater Cairo**"" have been accepted for publication in **INTERNATIONAL JOURNAL OF MECHANICAL ENGINEERING** ISSN: **0974-5823** in the current issue, **2022.**

Notification of publication of your article will be sent to you once your article is online.

Thanking You

Regards,

**Editor**

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*International Journal of Mechanical Engineering*

# The Impact of Nanotechnology on Exterior and Interior Finishing Materials in Hospitals

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**ABSTRACT:**

This research deals with nanotechnology and its impact on the external and internal finishing materials in hospitals, as it sheds light on the remarkable recent development in the field of technology, which led to the discovery of nanotechnology, which was adapted in the field of architecture and finishing, which led to the emergence of many different nanotechnologies, which can Increasing the performance of buildings economically and environmentally in general, and for hospitals, which are among the most energy-consuming buildings in particular. These technologies include self-cleaning technology, air purification technology, easy-to-clean surfaces, anti-bacterial surfaces, anti-fog surfaces, anti-reflective surfaces, nano-treated wood, and nano thermal insulators, then the researcher discussed a comparison between some international hospitals that contain nano-finishing materials and a local hospital that relies on traditional finishing materials. The comparison showed the superiority of nano-finishing materials over their traditional counterparts in both economic and environmental aspects, as they were distinguished by their long-life span, reduced carbon dioxide emissions, reduced maintenance work and energy consumption, and thus reduced operating costs, which in hospital buildings reach approximately seven times the cost of their construction.

**KEYWORDS:** Nanotechnology - Self-cleaning - Air Purification - Anti-Bacterial - Hospitals - Running Costs.

## I. INTRODUCTION

Nanotechnology is one of the modern technologies that still needs a lot of research and studies, which also, as many nanoscale research centers have mentioned, is the technology of the next era, meaning we can call our next era a "nanoscale", and the widespread interest in this technology goes back to some period. Between 1996 AD to 1998 AD, when the American Global Technology Assessment Center (WTEC) conducted an evaluation study of nanoscale research and its importance in technical innovation. The study concluded with the most important points that nanotechnology has a great future and will herald a huge leap in many areas of industrial, medical engineering, and agricultural life[1], In the field of transportation, aviation, space research, water purification, and many important vital fields.[2]

The idea of this technique is summarized in rearranging the description of the atoms and molecules of the material next to each other in different formations, and of course, the more the atomic and molecular arrangement of the material changes, the more its resulting properties change to a large extent, which produces materials with distinctive properties, and from here scientists can avoid some unwanted properties For example, rearranging the atoms in coal enables us to obtain diamonds, as well as sand. Rearranging its atoms with the addition of some elements enables us to manufacture computer chips...and so on, and for this reason countries compete with its scientists and capabilities in producing those materials and

## Abstract

Egypt seeks to develop the educational system, and overcomes many of the challenges it faces. This can be achieved according to an ambitious plan aimed at raising the efficiency and improving the performance of schools to create a good learning environment for students. All of above can be achieved through the good design of the outer educational buildings envelopes. The buildings envelopes play an important role in thermal control operations, and they can isolate the internal environment from the outside. This research aims to indicate the importance of technological development in nanomaterials and its role in improving the properties of the building envelope components to reduce energy consumption. The research discusses the problem of thermal comfort and energy consumption in school classrooms in the Greater Cairo region, as a result of the inefficiency of the glass used in educational buildings envelopes. An applied study on one of the public schools in the Greater Cairo region was done using the Design Builder 6.1 software, in order to measure the efficiency of using nanotechnology to improve thermal performance and enhance energy consumption on the school classrooms envelopes. The results show, through the application of different types of glass treated with nanotechnology techniques on the facades of the southern and eastern classes ,and the comparison between the existing glass of the base case of study model ( The First District Secondary School for Girls in Sheikh Zayed city ), that the energy consumption for cooling is reduced by 34.74% in the case of using glass treated with nanotechnology (Double Low-E Elec Reflective Colored glass) with 6 mm thickness and 13 mm air (SHGC = 0.569), (LT = 0.578), (UV = 2.130).

**KEYWORDS:** Thermal comfort - Classrooms - Nanotechnology - Building envelop- Energy efficiency.

## ملخص البحث

تسعى مصر إلى تطوير النظام التعليمي وتجاوز العديد من التحديات التي تواجهها. يمكن تحقيق ذلك وفقًا لخطة طموحة تهدف إلى رفع الكفاءة وتحسين أداء المدارس لخلق بيئة تعليمية جيدة للطلاب. يمكن تحقيق كل ذلك من خلال التصميم الجيد لأغلفة المباني التعليمية الخارجية. تلعب أغلفة المباني دورًا هامًا في عمليات التحكم الحراري، ويمكن أن تعزل البيئة الداخلية عن الخارج. تهدف هذه الدراسة إلى إظهار أهمية التطور التكنولوجي في المواد النانوية ودوره في تحسين خصائص مكونات أغلفة المباني لتقليل استهلاك الطاقة. تناقش الدراسة مشكلة الراحة الحرارية واستهلاك الطاقة في فصول الدراسة في منطقة القاهرة الكبرى، نتيجة لعدم كفاءة الزجاج المستخدم في أغلفة المباني التعليمية. تم إجراء دراسة تطبيقية على إحدى المدارس العامة في منطقة القاهرة الكبرى باستخدام برنامجDesign Builder 6.1 ، لقياس كفاءة استخدام التكنولوجيا النانوية لتحسين الأداء الحراري وتعزيز استهلاك الطاقة في أغلفة فصول المدرسة. تظهر النتائج، من خلال تطبيق أنواع مختلفة من الزجاج المعالج بتقنيات التكنولوجيا النانوية على واجهات الفصول الجنوبية والشرقية، والمقارنة بين الزجاج الموجود في الحالة الأساسية للنموذج المدرسي (مدرسة الثانوية الأولى للبنات في مدينة الشيخ زايد)، أن استهلاك الطاقة للتبريد ينخفض بنسبة 34.74% في حال استخدام الزجاج المعالج بالتكنولوجيا النانوية) زجاج (Double Low-E Elec Reflective Colored بسمك 6 مم وفراغ بسمك 13 مم = SHGC) 0.569، (LT = 0.578)، (UV = 2.130).

الكلمات الرئيسية: الراحة الحرارية - الفصول الدراسية - التكنولوجيا النانوية - أغلفة المباني - كفاءة الطاقة

# The Impact of the Nanotechnology-Treated Glass on Optimizing the Thermal Performance and Improving the Energy Consumption of the PUBLIC Schools Envelope in the Greater Cairo

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**ABSTRACT**

Egypt seeks to develop the educational system, and overcomes many of the challenges it faces. This can be achieved according to an ambitious plan aimed at raising the efficiency and improving the performance of schools to create a good learning environment for students. All of above can be achieved through the good design of the outer educational buildings envelopes. The buildings envelopes play an important role in thermal control operations, and they can isolate the internal environment from the outside. This research aims to indicate the importance of technological development in nanomaterials and its role in improving the properties of the building envelope components to reduce energy consumption. The research discusses the problem of thermal comfort and energy consumption in school classrooms in the Greater Cairo region, as a result of the inefficiency of the glass used in educational buildings envelopes. An applied study on one of the public schools in the Greater Cairo region was done using the Design Builder 6.1 software, in order to measure the efficiency of using nanotechnology to improve thermal performance and enhance energy consumption on the school classrooms envelopes. The results show, through the application of different types of glass treated with nanotechnology techniques on the facades of the southern and eastern classes ,and the comparison between the existing glass of the base case of study model ( The First District Secondary School for Girls in Sheikh Zayed city ), that the energy consumption for cooling is reduced by 34.74% in the case of using glass treated with nanotechnology (Double Low-E Elec Reflective Colored glass) with 6 mm thickness and 13 mm air (SHGC = 0.569), (LT = 0.578), (UV = 2.130).

**KEYWORDS:** Thermal comfort - Classrooms - Nanotechnology - Building envelop- Energy efficiency.

## 1. INTRODUCTION

Improving education is the nucleus and the basis for advancing society towards comprehensive development, it is considered the first step towards the next generations. It is the base upon which countries rely to achieve economic, social and cultural growth. Therefore, education is the development source for any country. Educational buildings are among the most widespread buildings in the world because of its essential role in acquiring knowledge effectively for students of all ages. The number of schools in the Greater Cairo region has reached 12,314 schools, with a total number of classes of 138,342 classrooms[1]. Students spend a lot of time in their classrooms so thermal comfort should be achieved for them inside the classrooms ,and they should be protected from solar radiation during the study hours. A good internal environment can help to create a suitable conditions for student performance. Not only does classroom thermal performance affect student health and comfort, but it also affects student learning efficiency and productivity[2].

Recently, most of the new school buildings were constructed without considering the thermal comfort of the students. Many researches showed that when temperature rises above 26 degrees Celsius, students' performance significantly decreases[3]. Building envelope is the point of connection and separation between the inside and the outside, both in the process of seeing between the inside and the outside or the transmission of heat, light, air, noise, or other factors that can affect the environment and the internal space[4]. It consists of solid parts such as walls and structural elements, and transparent parts such as glass and openings. Building envelope is considered the most effective component of the building in saving energy consumption. It is responsible for more than 50% of the total energy consumption in the building[5] therefore, it is necessary to check the materials used in the composition of the envelope, especially the glass. Using ordinary transparent glass in the classrooms envelope increases the heat loads resulting from solar radiation[6], Which makes it a place where the sense of discomfort increases.

In order to achieve thermal comfort in school classrooms, glass standards must be verified that reduce heat exchange, and achieve comfort within the space. Nanotechnology contributes to the creation of various types of treated glass to protect the users from solar radiation on the classroom facades, and to improve the energy performance in the building.

## 2. STATEMENT OF THE PROBLEM

Increasing energy consumption, and inefficient thermal performance of schools building envelopes in the Greater Cairo region as a result of using untreated glass with nanotechnology in the openings.

## 3. RESEARCH SCOPE AND PURPOSE

Designers had to do studies on how to reach the optimal design for educational buildings envelopes by using the techniques of innovative technologies through the application of various types of glass treated with nanotechnology in the openings of school classrooms in the Greater Cairo region to improve the thermal efficiency and the energy performance.

## 4. RESEARCH METHODOLOGY

The methodology of this research focused on measuring the effect of nanotechnology on providing improvements for the thermal performance and the energy consumption of the public schools' envelopes, by applying different types of glass treated with nanotechnology on the envelope of an existing school. Many definitions related to nanotechnology and Its characteristics were explained in the theoretical part, as well as the most important nanotechnology applications in architecture. In the analytical part, the study showed the classification of nanomaterials that can be used in the building envelopes and affect the thermal comfort of users. A proposed methodology has been developed to to improve thermal performance and energy consumption for educational buildings. Finally in the applied part, a simulation of an existing public school (Sheikh Zayed Secondary School for Girls) was made using the Design Builder simulation software to compare the results between the measurements of the case study before and after applying different types of glass treated with an innovative nanotechnology in the building envelope to reach the optimal design for educational buildings envelopes that can raise the thermal performance and improve building energy consumption.

### 4.1 Nanotechnology Definition

It is the technology that gives us the ability to directly control materials, as it is a technology that deals with measurements between 1 to 100 nanometers, it is concerned with the properties of materials which play a significant role in architecture development. The main idea of using nanotechnologies is summarized in rearranging the atoms of materials, and of course, the more the atomic arrangement of the material changes, the more its resulting properties change to Hence. This help scientists to avoid some undesirable properties in some materials, and to add some new materials features that raise the efficiency of its performance[7].

### 4.2 Nanomaterials in Architecture

It is a group of materials that are produced with dimensions of their internal granules between 1 nanometer and 100 nanometers. These materials are characterized by distinctive characteristics that were not found in traditional materials. It can be organic or inorganic or natural or synthetic materials. Nanomaterials are building materials used for external building Smart envelopes to face the external influences. Thus, we can use these materials as structural or non-structural materials to improve the quality of construction and raise the efficiency of building envelop[8].

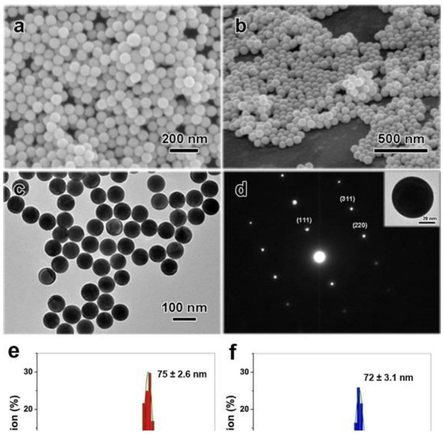



*Figure 2* : Explains shapes and dimensions of nanomaterials

Reference: https://cutt.ly/BKLwOU8

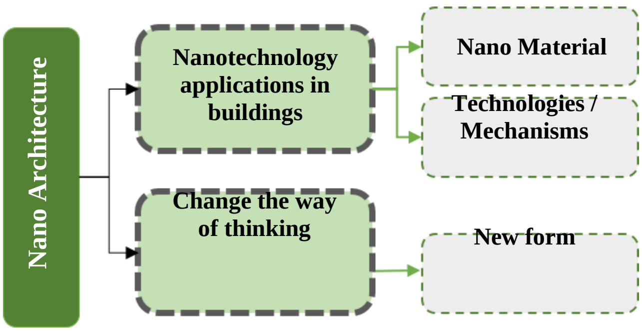



*Figure 1:* Nanotechnologies in architecture

Reference: The researcher based on [9].

### 4.3 Properties of Nanomaterials:

There are many chemical, physical and mechanical properties that appeared at the beginning of the twenty-first century. These properties distinguish nanomaterials from other traditional materials. We will summarize the most important of them[10]:

#### 4.3.1 Electrical conductivity:

Some insulating materials can turn into good conductors of electricity as a result of their presence in the size of the Nano and vice versa.

### 4.3.2 Hardness:

The hardness of nanoparticles exceeds the hardness of non-nanoparticles of the same material by hundreds of times. For example, the hardness of nanoparticles made of silicon is hundreds of times greater than the hardness of silicon.

### 4.3.3 The ability to change color:

Nanoparticles can change its color, size, and shape in different conditions. This phenomenon appears clearly in the nanoparticles of gold and silver.

### 4.3.4 Transparency:

Nanoparticles have dimensions less than the wavelengths of visible light, so they do not reflect visible light, which makes them highly transparent.

### 4.3.5 Efficiency:

Nanomaterials are more efficient and effective in building envelopes than traditional materials. A material treated with nanotechnology can perform the work of several traditional materials at a lower cost.

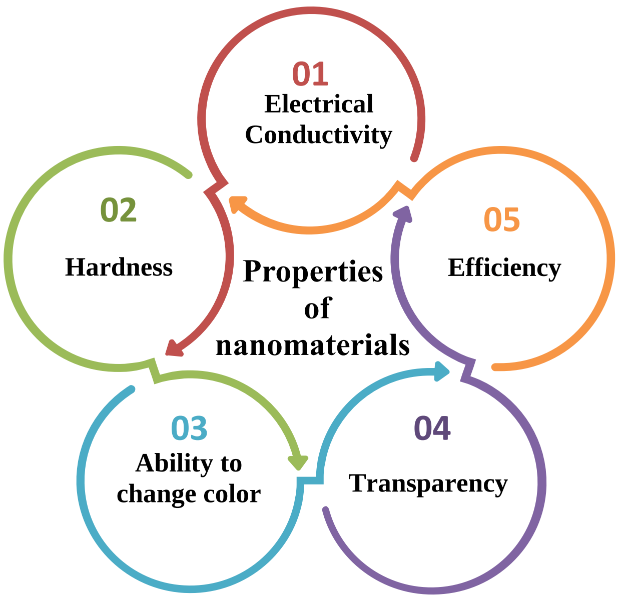



*Figure 3* : Some properties of nanomaterials . Reference: The researcher.

## 4.4 Classification of Nanomaterials in Architecture

Nanotechnology has affected the form and the age of the virtual building through structural and non-structural nanomaterials which used in building envelop. Nanomaterials contributed to improving the performance of the building by increasing the building insulation, fire protection, sound absorption, and provide thermal comfort for building users. Nanotechnology also contributed to the development of the performance of finishing materials such as glass, cladding, and aluminum to interact with all Surrounding conditions. Fig(4) shows the classification of materials treated with nanotechnology that affect the thermal comfort of users[11].

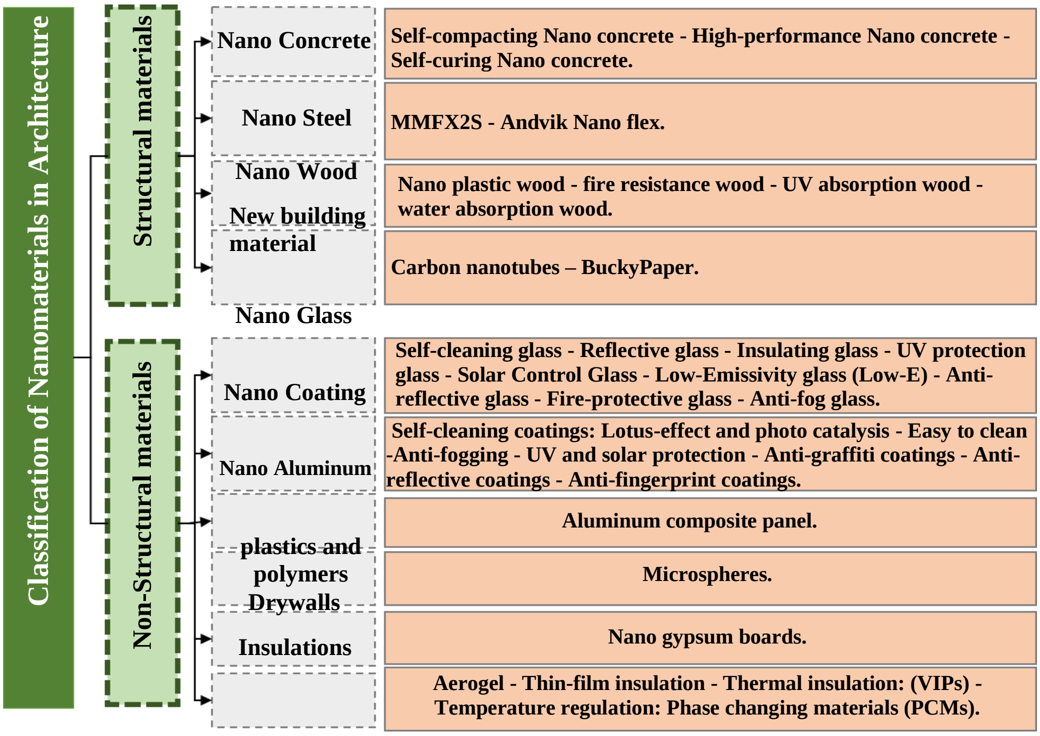



Figure 4 : Explains the classification of materials treated with nanotechnology that affect the therm

Reference: The researcher based on classification in

## 4.4 Nanotechnology Applications in buildings

Many applications of nanotechnology have contributed to the discovery of many solutions and alternatives to architectural and climatic problems that affect buildings. This is accomplished by improving and changing the properties of these materials in order to increase building efficiency and improve their environmental performance[12].

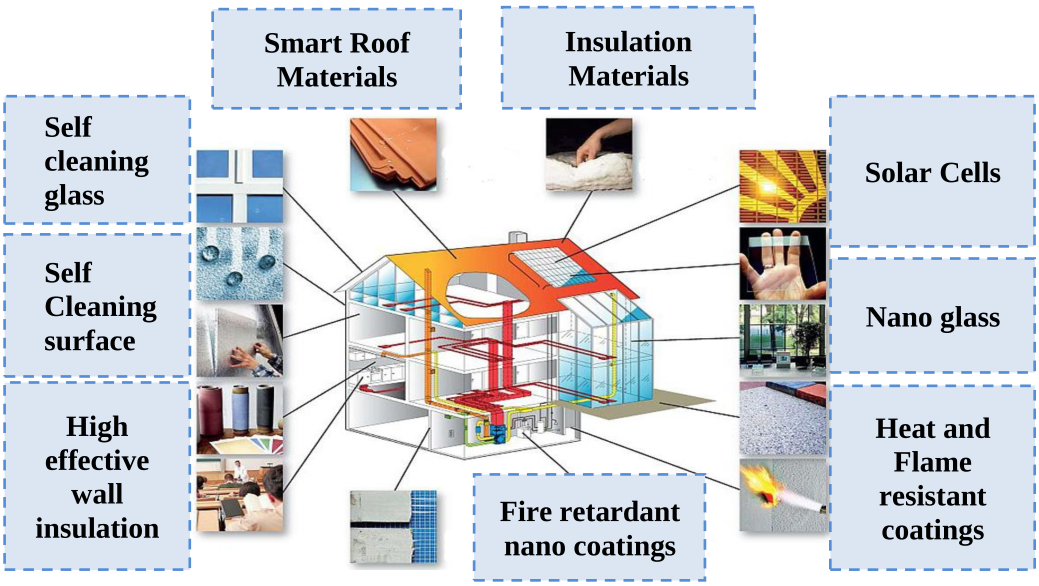



*Figure 5: Nanotechnology applications on the building envelope components.*

Reference: https://cutt.ly/FK89j7a

### 4.4.1 Applications of nanotechnology on glass

Glass is one of the non-structural materials used in building envelopes. it can affect the air quality inside the building, the heat gain and loss, and also control the level of sunlight entering. In order to reduce the energy consumption used to achieve thermal comfort for users. Nanotechnology has proposed many ways to improve the properties and efficiency of glass including:

#### 1- Self-Cleaning Glass:

It is a glass with a thin layer of titanium dioxide coating on one face with a thickness of 13 nanometers. It is a material characterized by its ability to absorb the ultraviolet radiation and interact with the organic dirt to break it up. The insulating layer works to attract water on the glass and turns into droplets ,thus the organic dirt is removed then it falls to the ground[13].

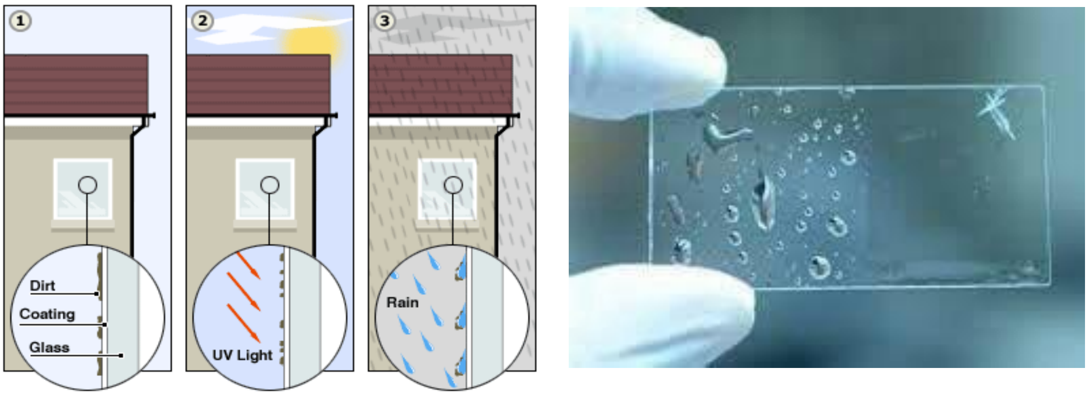
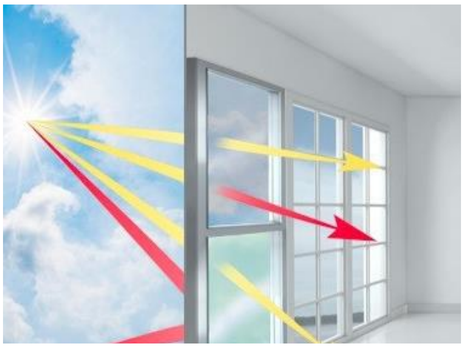



Figure 6: Explains self-cleaning glass and its difference from traditinal glass.

Reference: https://cutt.us/KnCvl

#### 2- Reflective Glass:

It is a glass that prevents the penetration of solar radiation into the internal spaces by using a thin transparent layer that is coated on the surface of the glass. This layer works to reduce the transmittance of the glass in general. This type of glass is characterized by the ability to reduce the consumption of energy, and give the building an aesthetic appearance. It is also very safe and has little impact on the environment [13] .



\ Figure 7 : Explains the effect of using reflective glass on the rays falling on it.

Figure 8 : Explains the effect of using reflective glass on one of the building facades.

Reference: https://cutt.us/4wpos

#### 3- Insulating Glass:

Insulating glass can be defined as multiple glazing comprising a pair or more of glass panels which have an air (or another gas) gap between panels ,and a metal wire that is encircle whole edges of air gap. This glass works to reduce heat gain, heat loss, glare and fading. It is also characterized by the ability of saving energy,reducing the noise, and providing thermal comfort to users [14].

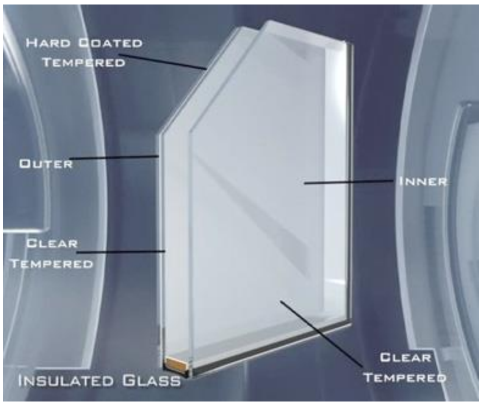



*Figure 10*: Insulating glass layers components.

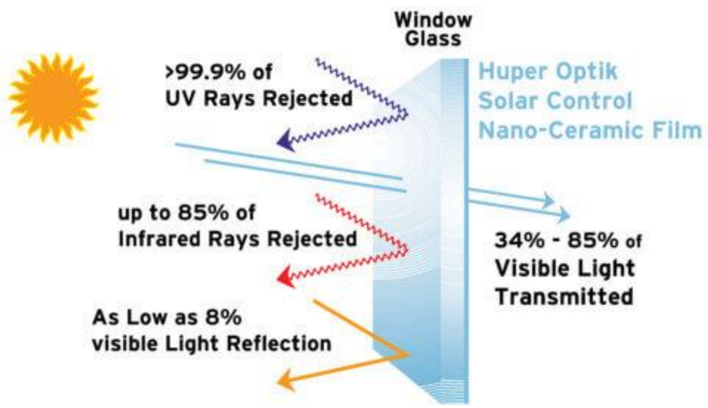
Reference: https://cutt.us/GIR3Z


Figure 9: Double or triple insulation glass.

Reference: https://cutt.us/Rum6Y

## 4- UV-Protection Glass

It is a glass characterized by the ability to block (90: 95%) of ultraviolet rays, and the tinted or reflective glass of it can block 99.5% of ultraviolet rays. For this reason this type is used in facades and glass ceilings to reduce thermal loads and prevent harmful rays from entering the building and benefit from beneficial radiation[14].




Reference: https://cutt.us/QKURF

## 5- Low Emissivity Glass (Low-E):

It is one of the best types of glass. It has the ability to control the internal temperature of the building by controlling the amount of heat radiation. In the summer, it works to provide the internal spaces with sunlight ,and blocks infrared and ultraviolet rays. In the winter it works to provide the greatest amount of thermal comfort and natural lighting. It also contributes to reducing heating costs[13].


Figure 12: Layers of low-E glass. *Reference:* https://cutt.us/UITcM

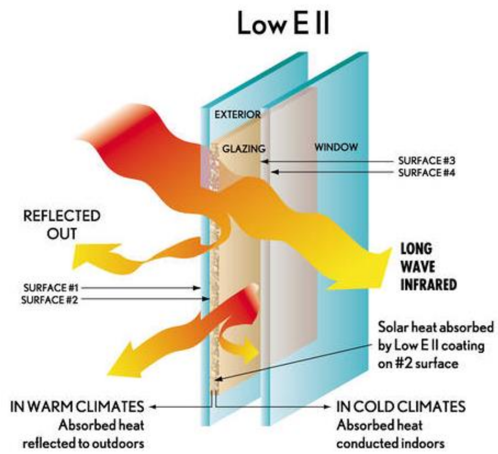



*Figure 13: Explain low-E glass and how heat and light pass through it. Reference:* https://cutt.us/MFuHQ

6- Solar Control Glass:

This type of glass is used with shading systems, whether fixed or dynamic. It can control the amount of gained or lost heat, and allow an appropriate amount of visible light to pass through it [13].

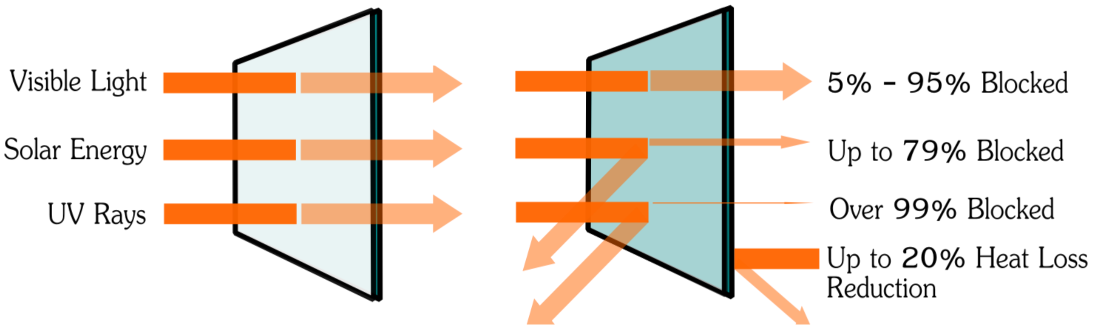



*Figure 14 : Explains the use of solar control glass and how to control the radiation and heat reaching the inside of the building.*

Reference: https://cutt.us/8XWt1

7- Fire-Protective Glass:

This type consists of two glass layers that contain between them a transparent bulging layer of 3 mm thickness (as an interlayer) that can withstand temperatures up to 1000 degrees Celsius. This type resists fire for a period of 45 to 120 minutes. When a fire occurs, the interlayer turns into a thick foam to form an insulating shield ,and prevent the fire from moving to the other side. It can be used in hospitals, schools, shopping centers and administrative buildings.

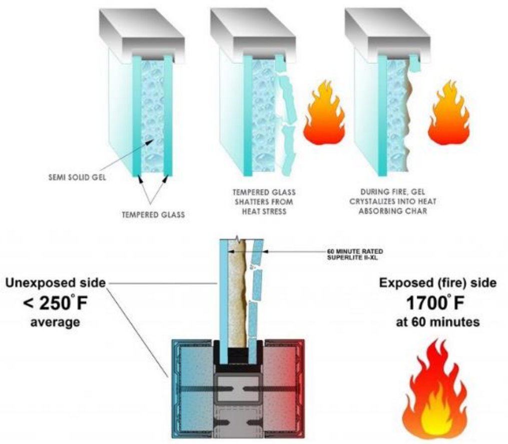



*Figure 16:* Explains the components of fire-resistant glass *Reference: https://cutt.us/2jjNJ*.

Figure 15 : Explains how fire protective glass work Reference: https://cutt.us/EhIBb

## 4.5 Applied Study:

This section represents the applied study of the research problem by Studying and analyzing one of the school buildings in the Greater Cairo region. The simulation was done by Design Builder software for the current building envelope to compare the results of applying some types of glass treated with nanotechnology with basic case without any envelop treatments. Through simulation we can compare the energy consumption of classrooms and assess the effectiveness of these treatments in raising thermal performance and improving energy consumption.

### 4.5.1 Simulation Limitations:

- This study was conducted using the Design Builder 6.1 simulation program. It considers an analysis tool which a wide range of data and functional analysis can be provided. The data is entered in a simplified method to make the building model on software, and to get an accurate results simulation closest to reality.
- The Climatic data of the Greater Cairo region were taken into account when making the simulation.
- The simulation was performed for one of the classrooms inside the school with consideration for the number of students in the classroom, the orientation of the classroom, the proportions of the openings, as well as the floor level of the classroom.
- A simulation of the U-VALUE for both basic model and the modified envelope and calculating the required cooling loads.
- Evaluating the thermal performance of the case study ,and comparing these results to find out the optimal thermal insulation, the highest U-Value, and the least energy consumption.

### 4.5.2 Study Case: Government School Model (6th of October city authority Model).

| School Name | First District Secondary School for Girls in Sheikh Zayed |
|---|---|
| owner | The Education Building Authority |
| Location | Sheikh Zayed city, Giza. |
| type of use | educational |
| state of building | Established building |
| Total building area | 4500 m2 |
| Number of Classrooms | 39 Classrooms |
| Number of floors | Ground floor and 2 typical floors |
| building | 14.35 m |

Figure 17: The First District Secondary School for Girls in Sheikh Zayed.

Reference: The researcher .

| | | |
|---|---|---|
| height | | |
| A brief about the school | Sheikh Zayed Secondary School for Girls is considered one of the largest schools in Sheikh Zayed City. It located in the first district, the fifth neighborhood, in Sheikh Zayed City, Giza Governorate. It is a public school that includes 39 classrooms, in addition to a part dedicated to educational administration within the components of the building. The school consists of a ground floor and two Typical floors divided into Several wings, and the school can accommodate approximately 1,200 students[1] | |

### 4.5.3 Architectural Description of Sheikh Zayed Secondary School for Girls:

The school consists of a ground floor and two floors, divided into two wings. The first wing includes 39 classrooms divided into 3 floors (13 classes for each academic stage), with an average number of 35 to 40 students per class, and an area of about 2000 square meters for each floor. The second wing includes the school administration, a multi-purpose hall, a gym, a chapel, and teachers' rooms in the ground floor. The first and second floors of this wing include an auditorium, teachers' rooms, and computer laboratories[16].

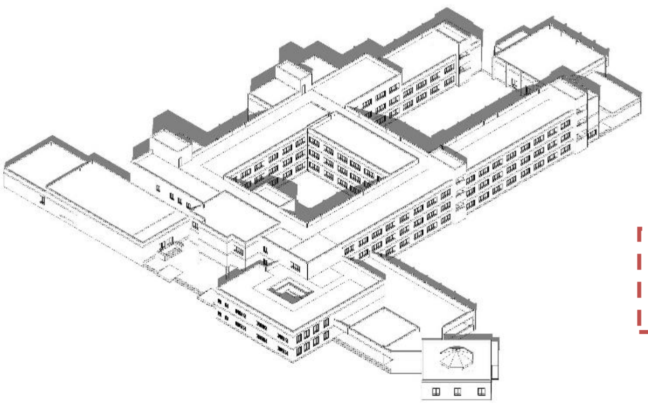


*Figure 19 : Perspective of the building.*
*Reference: The researcher based on educational buildings authority drawings*

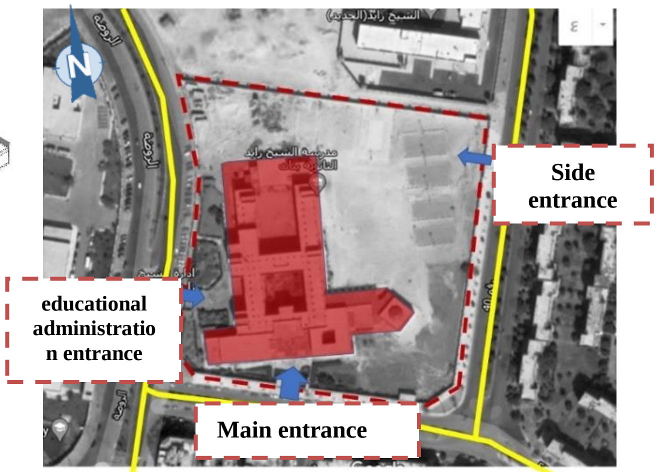
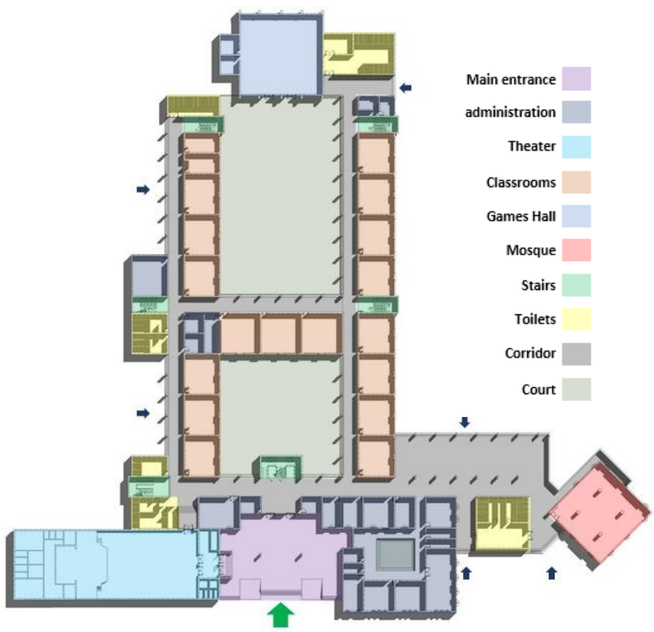
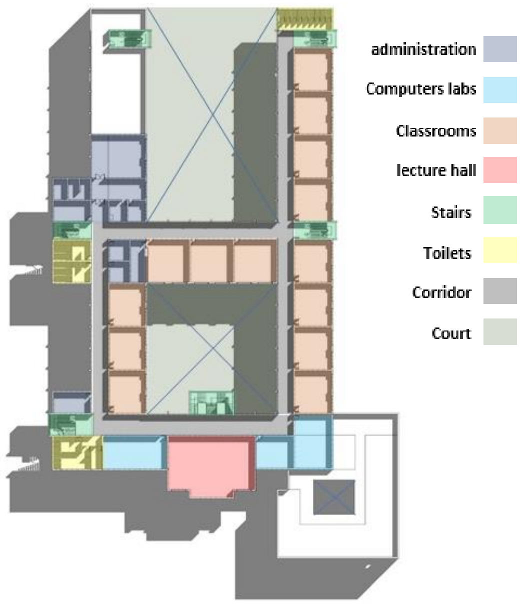



Figure18 : Layout and the main entrances of the school
Reference: Google Earth Pro.

- **school floor plans :**



- **Elevations and Sections :**

Figure 21 : Ground floor plan
Reference: Educational Buildings Authority.

Figure 20 : Second floor plan Reference: Educational Buildings Authority.

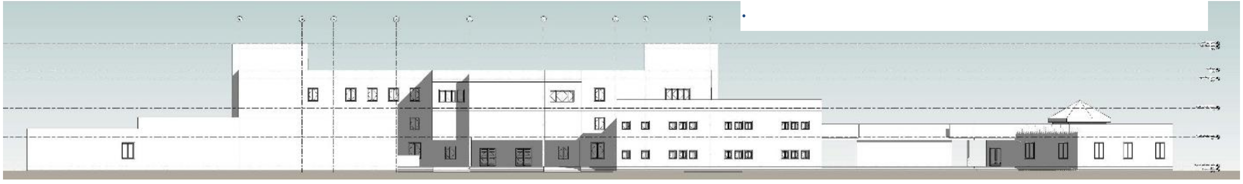


*Figure 22 : Main Elevation.*

Reference :The researcher based on the Educational Buildings Authority drawings.

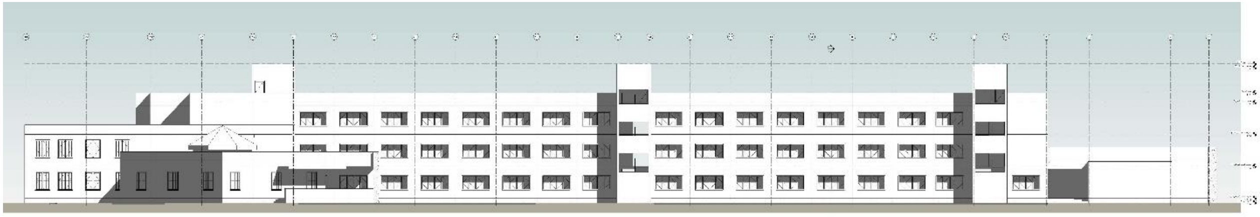


*Figure 23: East Elevation.*

Reference :The researcher based on the Educational Buildings Authority drawings.

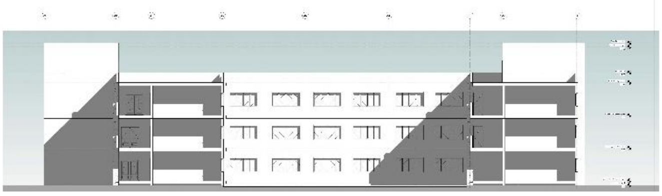


*Figure 24 vertical section of the school.*

Reference :The researcher based on the drawings of the Educational Buildings Authority drawings.

### 4.5.4 Design of Educational Spaces in the School:

The classrooms were designed with the aim of accommodating the largest possible number of students. The standard module used for the classroom dimensions is 8.40 * 7.35 m, and the classroom capacity is (35:40) students in an area around 60 square meters. The allocated space for every student is about 1.5 square meters.

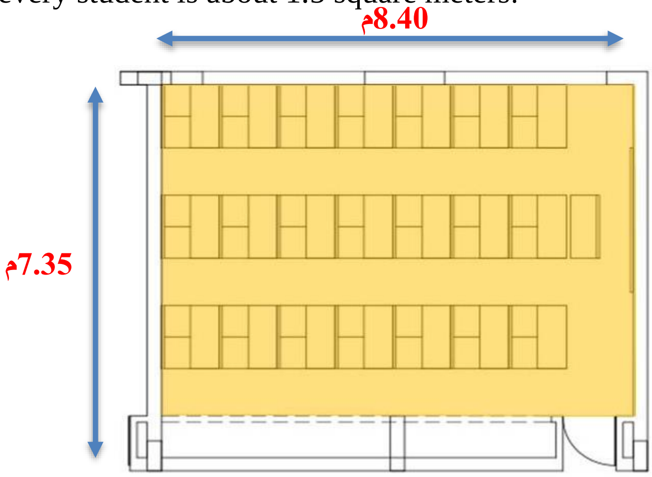



*Figure 26 : Classroom design dimensions at District One Secondary School for Girls*

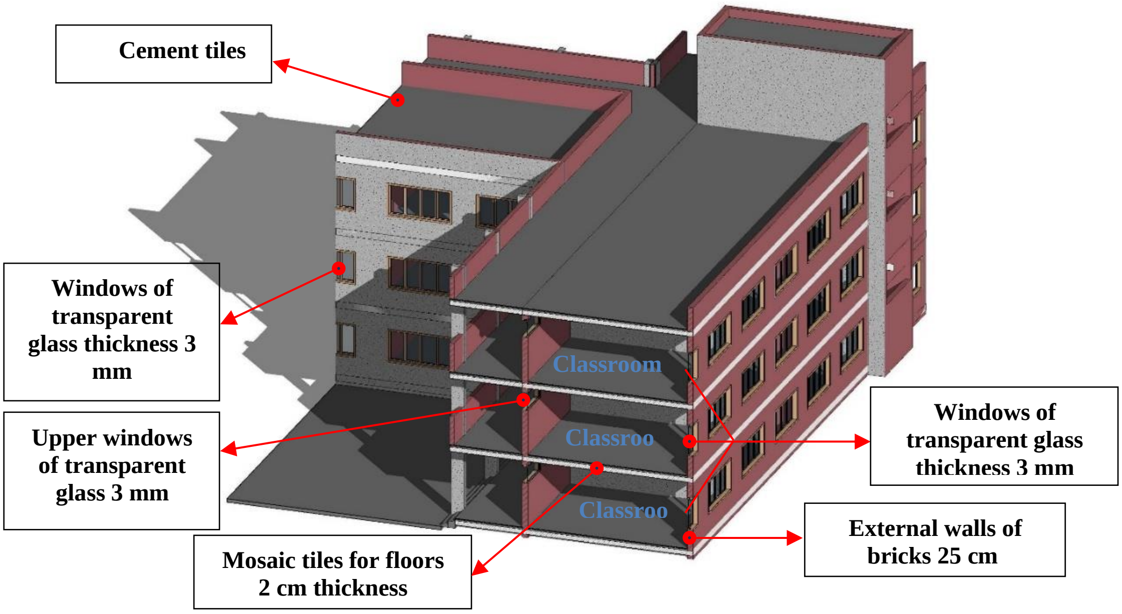
Reference :The researcher based on the Educational Buildings Authority drawings.

*Figure 25 : The interior of the First District Secondary School for Girls' classrooms.*

Reference : The researcher.

### 4.5.5 Envelope and Thermal Performance:

The exist building envelope consists from walls with 25 cm thick, in addition to the finishing layers without using thermal insulation materials or treatments to improve the thermal performance of the building. The external walls includes windows with a width of 2.80m and a height of 1.60 height. The used glass is a single clear glass layer of 3 mm thickness that is not treated. These windows aren't enough to provide a sufficient amount of natural lighting, and untreated used glass allows penetration of directed sun rays, heat and glare to pass through the classrooms. All of the above make the students feel uncomfortable inside all classrooms, so the students have to put barriers on the glass to reduce the glare as shown in the figure (3-15).



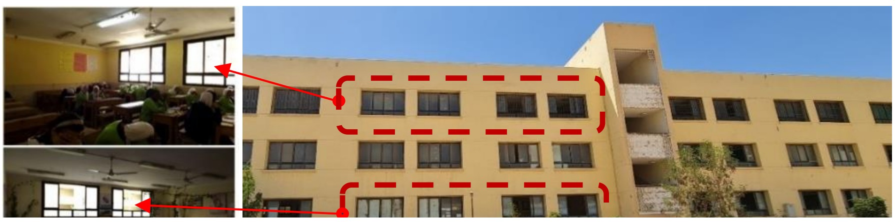



*Figure 27: 3D section the shows the external building envelope.*

Reference: The researcher

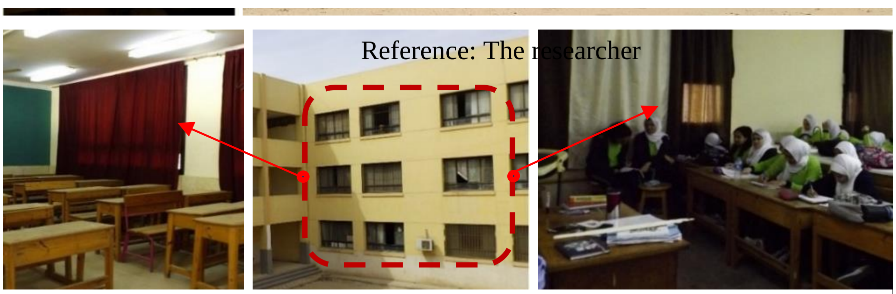


*Figure 28: Explains students use curtains and barriers on the windows to protect from glare and solar radiation inside the classroom.*

### 4.5.6 Analysis of Climatic Data of the case study:

#### 4.6.6.1 Analysis of Temperature and Relative Humidity:

A climatic analysis for the case study site and context of the Greater Cairo region was made using the climate analysis software (Climate Consultant 6.0). The results showed that the thermal comfort zone lies between (20°: 24°) degrees Celsius, and the relative humidity is variable throughout the year.

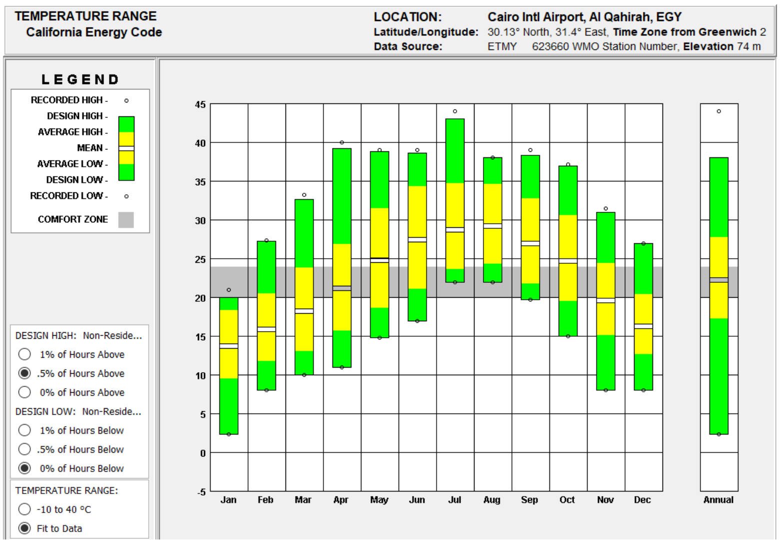



*Figure 29: the average temperatures throughout the year for the Greater Cairo region*
*Reference : Climate consultant. (10 November 2022).*

### 4.6.6.2 Analysis of the existing envelope using the (Design Builder v6.1) Program:

- **Program Inputs for the case study (class room):**

1- Occupancy: It is represented in the student density (person / $m^2$) =1.50 $m^2$

2- Metabolic rate: 0.90.

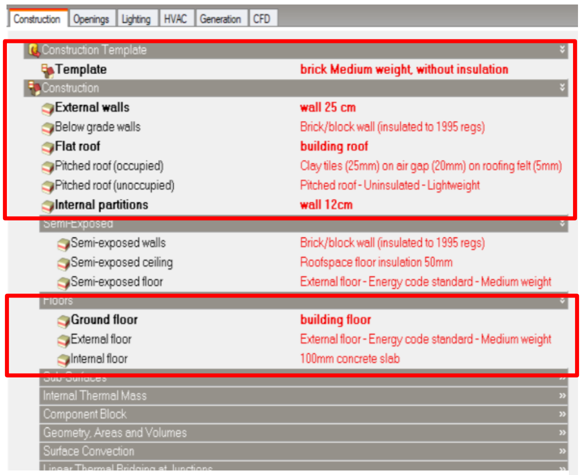



*Figure 30 : A picture of the program shows the construction of external and internal walls and ceilings.*

Reference : Design Builder 6.1.

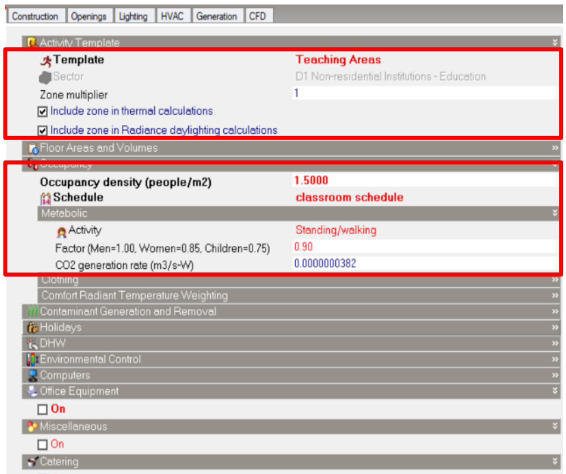



*Figure 31 : A picture of the program shows the type of building and occupancy.*

Reference : Design Builder 6.1.

3- Construction:

The simulation was performed on a classroom on the school's second floor level because it is the most exposed to thermal loads. The following results are the U-values for each structural element

- External walls (25 cm thick brick wall) U-Value = 1.543.
- Roof slab (20 cm thick reinforced concrete slab) U-value = 1.824.

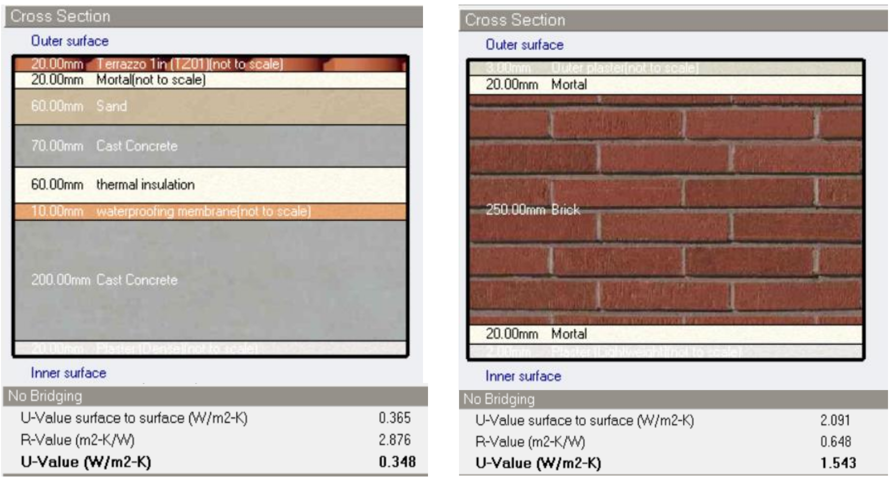
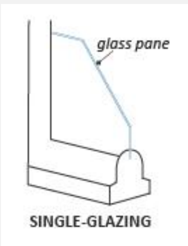



*Figure 32 : The entered wall layers and the roof floor slab finishes data to the program.*

Reference : Design Builder 6.1.

## 4- Openings:

The simulation parameters were specified by the software to enable an exact comparison of the envelope treatments of the existing case and the envelope following proposed treatments. The glass which used in the existing envelope is a single glass with a thickness of 3 mm and a width of 2.80 for the window opening. The height of the window is 1.60 m ,and the wall's opening percentage is 30%.

| Glass Type | Single 3mm clear glass |
|---|---|
| Shape |   |
| SHGC | 0.861 |
| LT | 0.898 |
| U-Value (W/m2-K) | 5.894 (W/m2-K) |

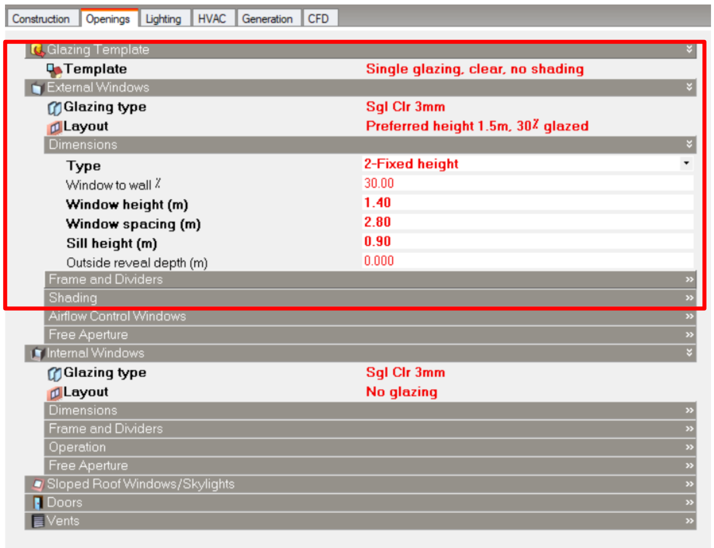



*Table 1 : Explains the type of glass and its thermal properties.*

Reference: The researcher.

Figure 33 : The type of glass and the wall-to-glass ratio (WWR) entered .to the program.

Reference: Design Builder 6.1.

### 4.5.7 Results of analysis and simulation of the classroom existing case from (Design Builder v6.1) software:

A simulation was made for the Sheikh Zayed Secondary School for Girls on (Design Builder 6.1) to measure the actual temperatures and the percentages of solar radiation ,which affects the vision inside the classrooms. It also measures the cooling and heating loads which required to achieve thermal comfort within each classroom. The analysis was done on two classrooms with two different orientations (east-south) as shown in Figure (3-11), with an area of about 60 m 2 for the classroom, and the second floor classrooms was chosen because it is the most exposed to thermal loads. The height of the classroom is 3.0 m from finishing, the window height is 1.60 meters and its sill height is 0.90 meters as shown in the figure:(34).

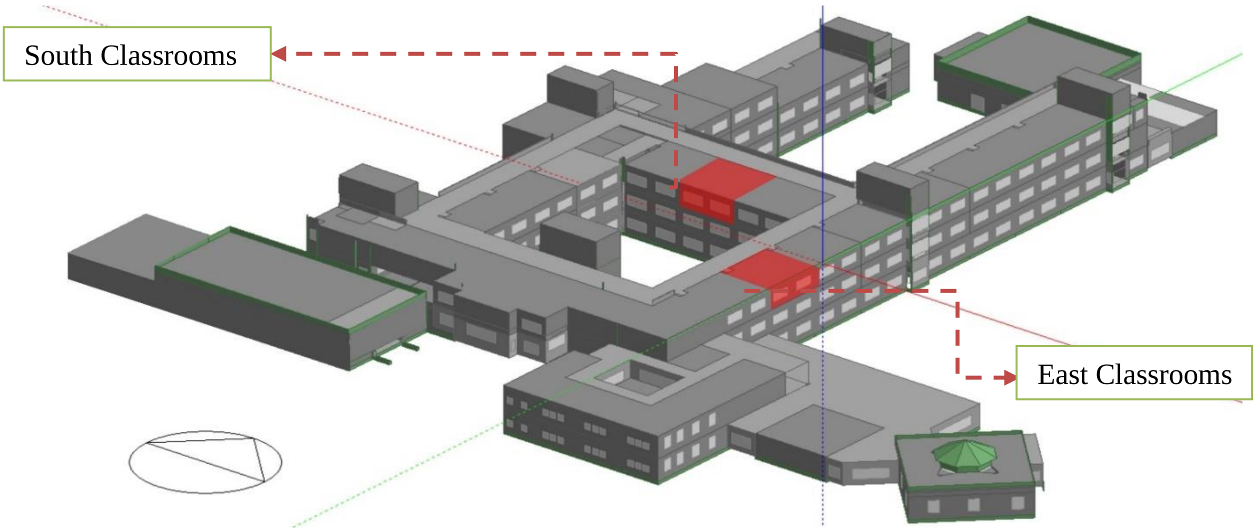



Figure 34 : The school model on the Design Builder v 6.1 program.

Reference : Design Builder 6.1.

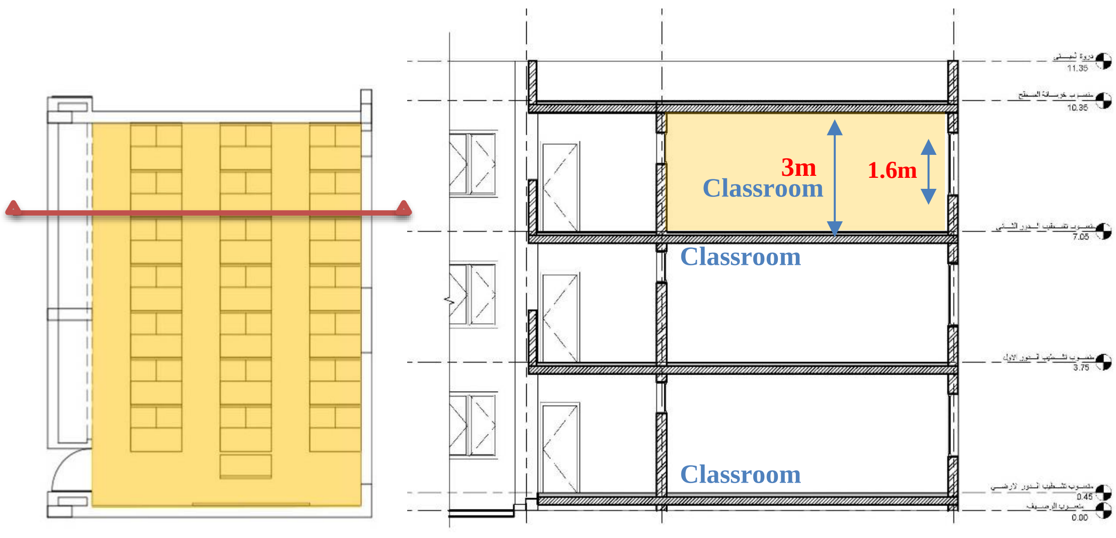
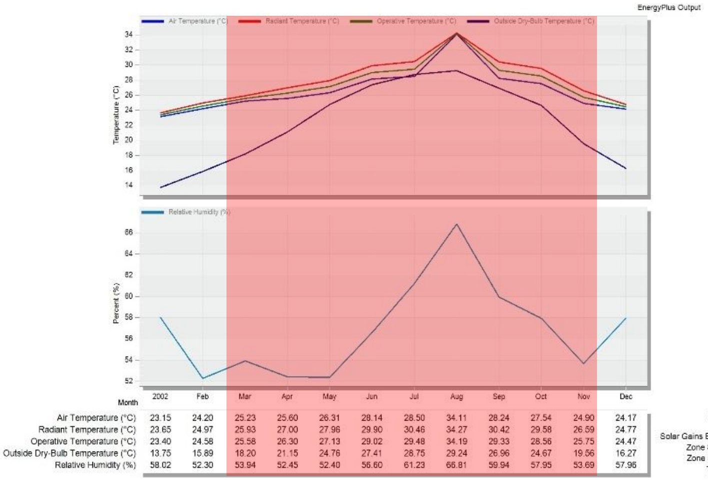



*Figure 35 :Plan and Section of one of the classrooms on the second floor in the building of the First District Secondary School for Girls in Sheikh Zayed.*

Reference :The researcher based on the drawings of the Educational Buildings Authority drawings.

### 4.6.7.1 The results of the analysis of the southern classroom in the basic case:

From the analysis and simulation results, we find that the months of discomfort are from March to November, according to the recommended temperatures in The Egyptian Code for Energy Efficiency in Buildings.



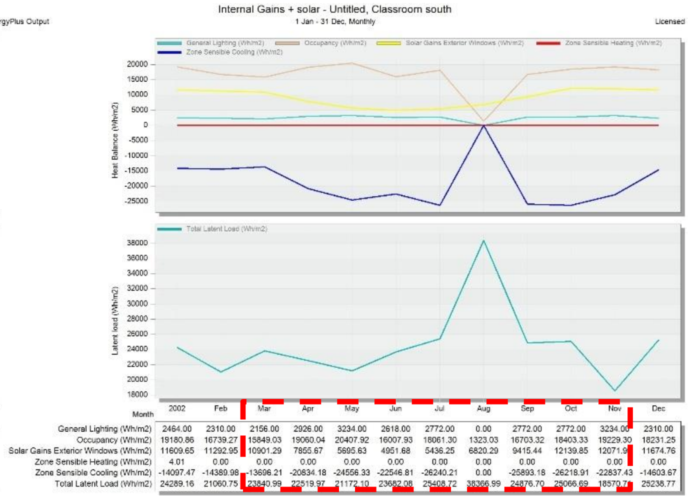



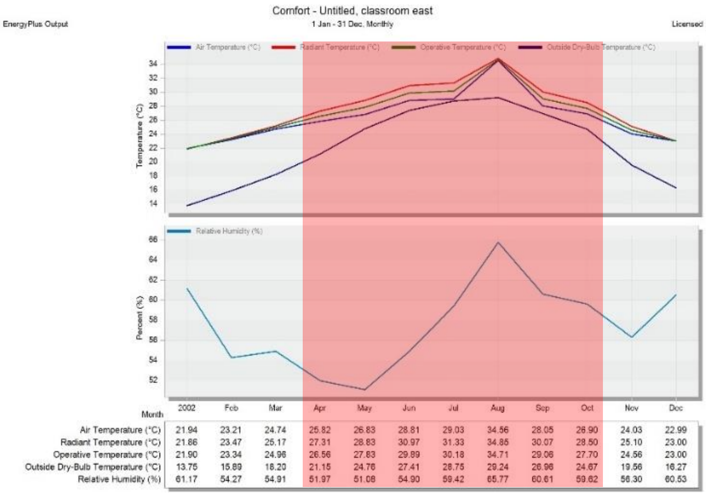

*Figure 36 : Explains the actual temperatures, relative humidity, and months of discomfort for the southern classroom in the basic case.*

*Figure 37 : Explains the amount of heat generated by lighting, occupancy, building type, as well as the amount of heat gained from the sun in the southern classroom.*

Reference: Design Builder 6.1.

### 4.6.7.2 The results of the analysis of the eastern classroom in the basic case:

From the analysis and simulation results, we find that the months of discomfort are from April to October, according to the recommended temperatures in The Egyptian Code for Energy Efficiency in Buildings.



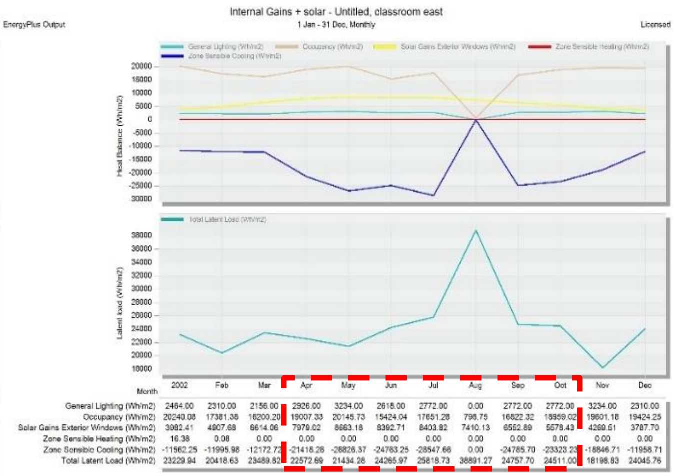




*Figure 38: Explains the actual temperatures, relative humidity, and months of discomfort for the eastern classroom in the basic case.*

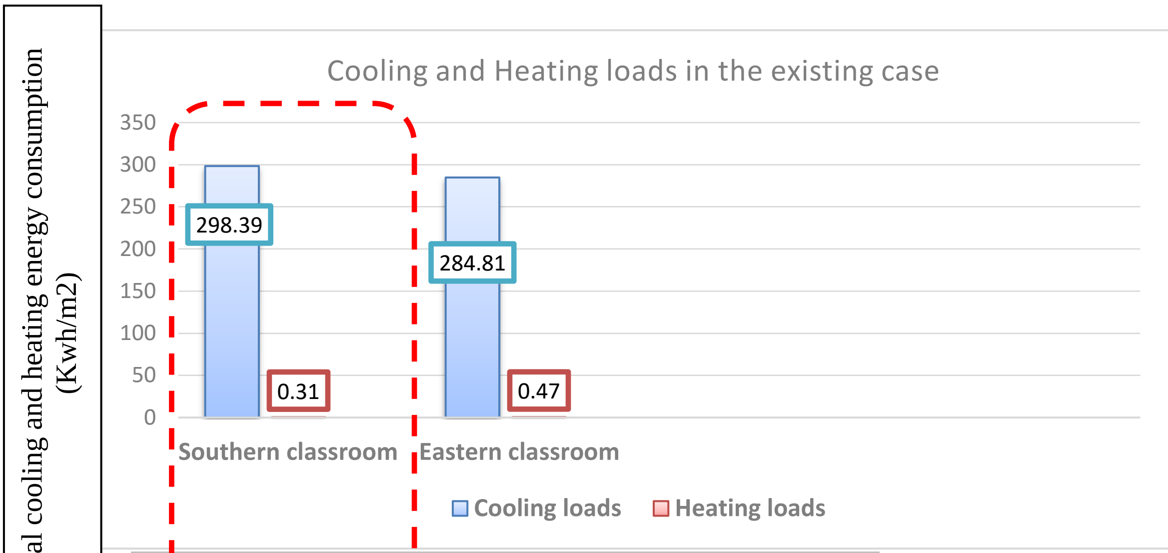
*Figure 39: Explains the amount of heat generated by lighting, occupancy, building type, as well as the amount of heat gained from the sun in the eastern classroom.*

Reference: Design Builder 6.1.

Reference: Design Builder 6.1.

### 4.6.7.3 Results of energy consumption Simulation for the southern and eastern classrooms of existing case:

Simulation results for energy consumption in the existing case using a red brick wall with a thickness of 25 cm, and single transparent untreated glass with a thickness of 3 mm (SHGC=0.861), (LT = 0.898), (UV=5.894) is shown in figure (40).




| Southern classroom | Eastern classroom | Energy Cons. |
|---|---|---|
| 298.39 | 284.81 | **Total Cooling** |
| 0.31 | 0.47 | **Heating** |

Figure 40: The simulation results of energy consumption in the basic case of a classroom with east-south orientation

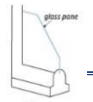
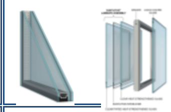
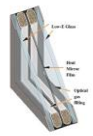
Reference : The researcher according to the simulation results.

The case study analysis results indicate that the envelope in the southern classroom is exposed to high thermal loads and consumes a large amount of energy in the cooling loads up to (298.39 Kwh / m2) annually. The results also indicate that the cooling energy of the eastern classrooms reach to (284.81 Kwh / m2) annually. Based on that, the envelope of the southern and eastern facades needs environmental treatments to raise the thermal performance efficiency and improve the energy performance of the building.

### 4.6.7.4 The southern and eastern classrooms envelope modification using smart materials:

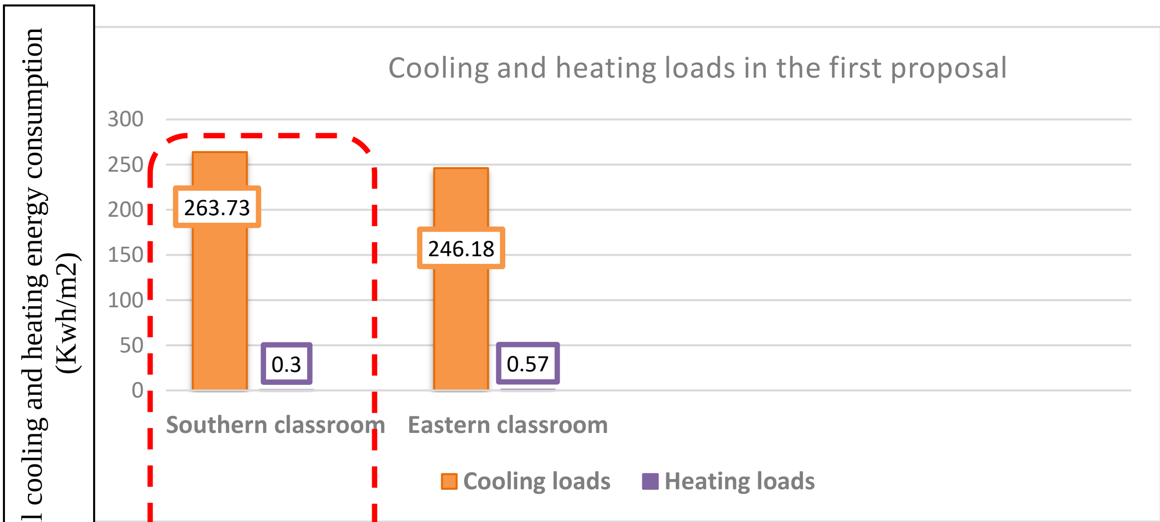
In this part, the study proposes the application of different types of glass treated with nanotechnology technology, as shown in Table (3-2), on the external windows of the eastern and southern classrooms of the case study. The comparison of the results between those types will determine the effectiveness of using nanotechnology treated glass in improving thermal performance and reducing energy consumption in the building.

Table 2 : Explains the physico-thermal properties of the smart glass types proposed to be applied to the envelop Reference : [17].
..

| The physico-thermal properties of smart glass types proposed to be applied to the envelop | | | | | |
|---|---|---|---|---|---|
| | Glass Type | Shape | SHGC | LT | U-VALUE (w/m$^2$-k) |
| 1- | (Single Low-E glass) 6mm. |  | 0.72 | 0.811 | 3.779 |
| 2- | (Double Low-E glass) 6mm and 13mm air. |  | 0.568 | 0.745 | 1.761 |
| 3- | (Thermochromic glazing) 6mm and 6mm air. |  | 0.569 | 0.578 | 2.130 |
| 4- | (SAGA Glass) 7mm and 12mm krypton gas. |  | 0.41 | 0.591 | 1.270 |
| 5- | (Double Low-E Elec Reflective Colored glass) 6mm and 13mm air. |  | 0.119 | 0.12 | 1.616 |

## The results of southern and eastern classrooms energy consumption Simulation in the first proposal :

Simulation results for energy consumption in the first case using a red brick wall with a thickness of 25 cm, and a single transparent glass treated with nanotechnology (Low-E glass) with a thickness of 6 mm (SHGC = 0.72), (LT = 0.811), (UV = 3.779) is shown in figure (41).



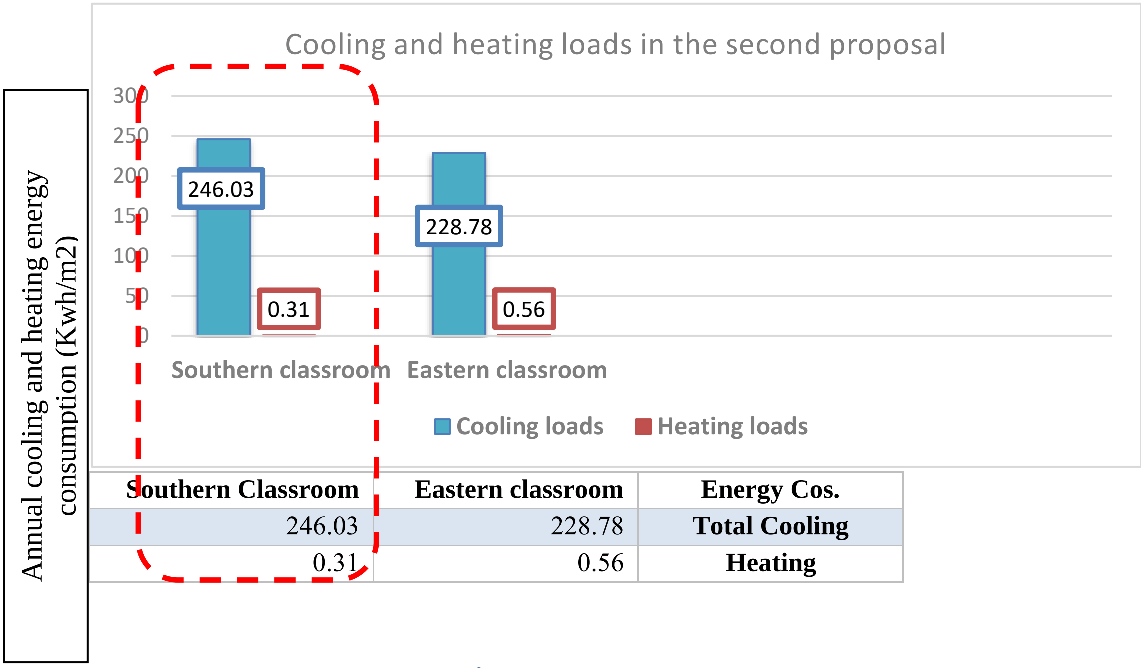

| Southern Classroom | Eastern classroom | Energy Cos. |
|---|---|---|
| 263.73 | 246.18 | **Total Cooling** |
| 0.30 | 0.57 | **Heating** |

The results

Figure 41: The energy consumption for the southern and eastern classrooms in the first

proposal:

Simulation results for energy consumption in the second case using a red brick wall with a thickness of 25 cm, and a double transparent glass treated with nanotechnology (Low-E glass) with a thickness of 6 mm and 13 mm air (SHGC=0.568), (LT = 0.745), (UV=1.761) is shown in figure (42).



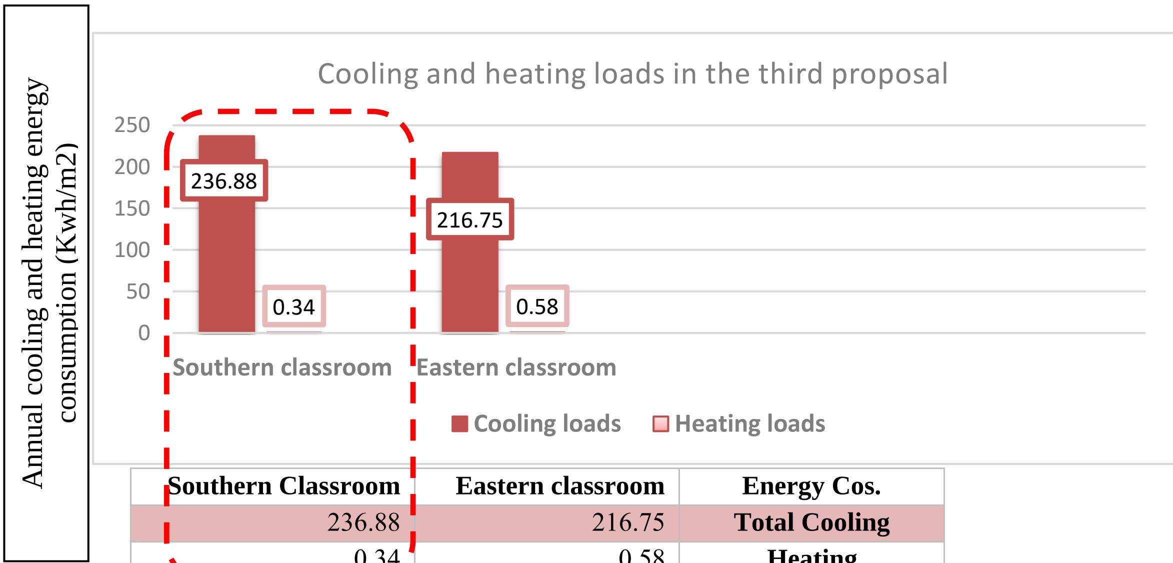

| Southern Classroom | Eastern classroom | Energy Cos. |
|---|---|---|
| 246.03 | 228.78 | **Total Cooling** |
| 0.31 | 0.56 | **Heating** |

Figure 42: : The energy consumption for the southern and eastern classrooms in the second proposal.

Reference: The researcher according to the simulation results.

## The results of southern and eastern classrooms energy consumption Simulation in the third proposal:

Simulation results for energy consumption in the third case using a red brick wall with a thickness of 25 cm ,and thermochroic glazing double transparent smart glass with a thickness of 6 mm and a 6 mm air cavity (SHGC = 0.569),(LT=0.578),(UV=2.130) is shown in figure (43).



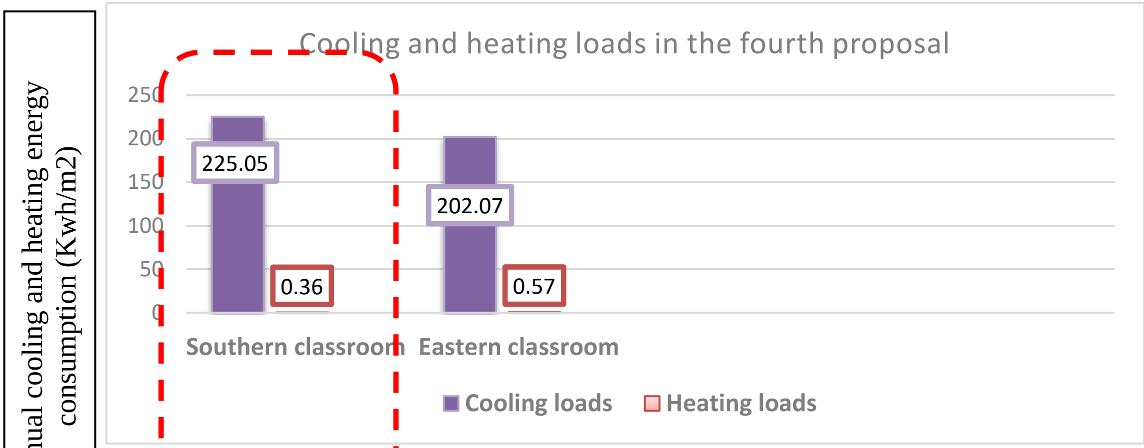

| Southern Classroom | Eastern classroom | Energy Cos. |
|---|---|---|
| 236.88 | 216.75 | **Total Cooling** |
| 0.34 | 0.58 | **Heating** |

Figure 43: The energy consumption for the southern and eastern classrooms in the third proposal.

Reference: The researcher according to the simulation results.

### The results of southern and eastern classrooms energy consumption Simulation in the fourth proposal:

Simulation results for energy consumption in the fourth case using a red brick wall with a thickness of 25 cm ,and a double transparent smart glass (SAGA Glass) with a thickness of 7 mm and 12 mm krypton gas cavity (SHGC = 0.569), (LT = 0.578),(UV=2.130) is shown in figure (44).



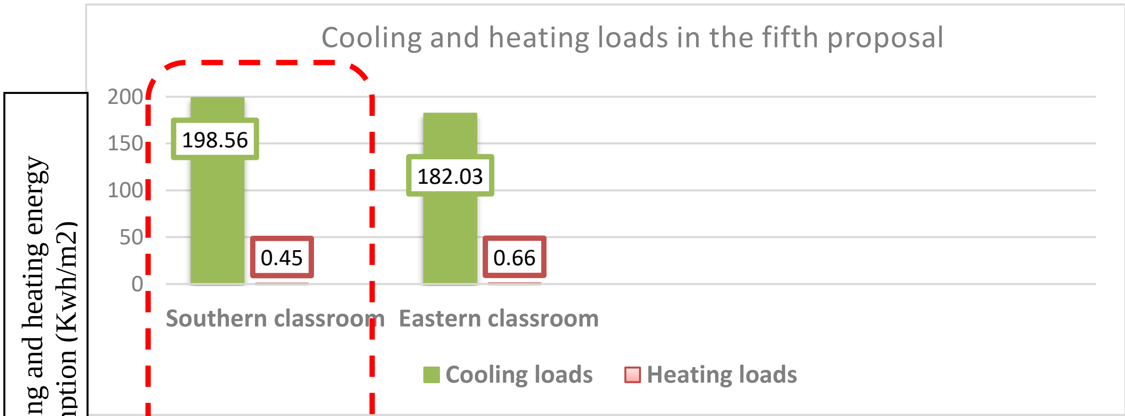

| Southern Classroom | Eastern classroom | Energy Cos. |
|---|---|---|
| 225.05 | 202.07 | **Total Cooling** |
| 0.36 | 0.57 | **Heating** |

*Figure 44:* The energy consumption for the southern and eastern classrooms in the fourth proposal.

Reference: The researcher according to the simulation results.

### The results of southern and eastern classrooms energy consumption Simulation in the Fifth proposal:

Simulation results for energy consumption in the case of using a red brick wall with a thickness of 25 cm, and a double glass treated with nanotechnology (Low-E Elec Reflective Colored Glass), with a thickness of 6 mm, 13 mm air cavity (SHGC=0.569), (LT = 0.578), (UV=2.130) is shown in figure (3-20)..



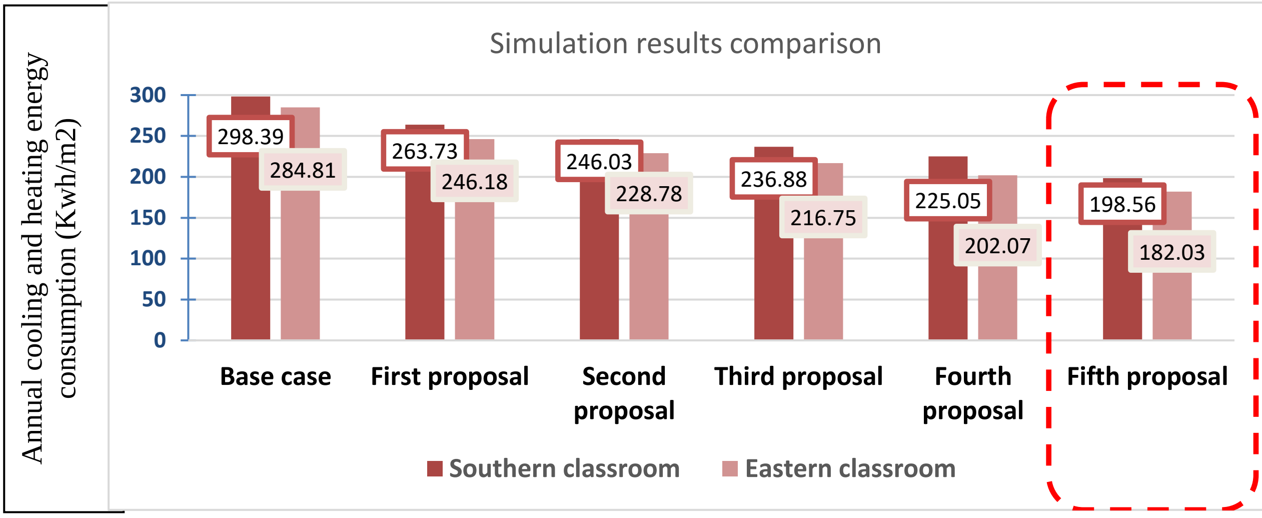

| Southern Classroom | Eastern classroom | Energy Cos. |
|---|---|---|
| 198.56 | 182.03 | **Total Cooling** |
| 0.45 | 0.66 | **Heating** |

*Figure 45:* The energy consumption for the southern and eastern classrooms in the fifth proposal.

Reference: The researcher according to the simulation results.

## Comparing the simulation results of energy consumption in the southern and eastern classrooms with the application of different types of glass with the results of the base case:

By comparing the results of applying different types of glass treated with nanotechnology techniques on the southern and eastern classrooms facades with the results of the basic case of the existing model ,We can conclude that the southern facade is the highest of cooling energy consumption with (298.39 kWh per square meter), and the eastern façade is (284.81 kilowatt-hours per square meter).The simulation results show that the Cooling energy decreased to 198.56 kWh per m2 in the southern classrooms ,and to 182.03 kWh per m2 in the eastern classrooms with a saving rate of 34.74% of total cooling. This considers the lowest rate of cooling energy consumption compared to the other proposed Glass types on southern and eastern classroom facades of the analyzed case study.




| Annual cooling and heating energy consumption (Kwh/m2) | Base case | First proposal | Second proposal | Third proposal | Fourth proposal | Fifth proposal |
|---|---|---|---|---|---|---|
| | (Single transparent glass) 3mm<br><br>(SHGC=0.861),(LT = 0.898),(UV=5.894) | (Single Low-E glass) 6mm.<br><br>(SHGC=0.72),(LT = 0.811),(UV=3.779) | (Double Low-E glass) 6mm and 13mm air.<br><br>(SHGC=0.568),(LT = 0.745),(UV=1.761) | (Thermochromic glazing) 6mm and 6mm air.<br><br>(SHGC=0.569),(LT = 0.578),(UV=2.130) | (SAGA Glass) 7mm and 12mm krypton gas.<br><br>(SHGC=0.569),(LT = 0.578),.(UV=2.130) | (Double Low-E Elec Reflective Colored glass) 6mm and 13mm air.<br>(SHGC=0.569),(LT = 0.578),.(UV=2.130) |
| Eastern classroom | 284.81 | 246.18 | 228.78 | 216.75 | 202.07 | 182.03 |
| Southern Classroom | 298.39 | 263.73 | 246.03 | 236.88 | 225.05 | 198.56 |
| Annual savings percentages in cooling energy consumption per m2 | | 12.56% | 18.58% | 22.21% | 26.76% | 34.74% |

Reference: The researcher according to the simulation results.

## The economic aspect of the proposed treatment's cost:

Building envelope design , materials , and architectural treatments have many aspects, for example, the environmental, aesthetic, and economical. The cost of treatment determines the possibility of applying, so we have to compare between the cost of proposed glass types and the type of glass which used in the existing case, as shown in Table No 3 .

*Table 3 : The economical analysis of the proposed glass types*

| The economical analysis of the proposed glass types | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Glass type | Energy consumption for one class (Area=60 square meters) | | | | Annual Energy savings for one classroom (KwH) | | The price of a square meter of the glass according to companies' prices for the year [illegible] | The cost of the glass used in the openings with an area of 8.06 [illegible] meters² in Egyptian pounds | energy consumption cost saving in Egyptian pounds, according to the prices of the fifth category of the Egyptian Electricity [illegible] 2023 | |
| | | East | | South | | | | | | | |
| | | Cooling energy demand rate KwH/m2 | Amount of energy KwH | Cooling energy demand rate KwH/m2 | Amount of energy KwH | East | South | | | East | South |
| 0 | single transparent untreated glass 3 mm | 284.81 | 17088 | 298.39 | 17903 | - | - | 180 | 1613 | - | - |
| 1 | single (Low-E glass) 6 mm | 246.18 | 14770 | 263.73 | 15823 | 2318 | 2080 | 350 | 3136 | 3082 | 2766 |
| 2 | double (Low-E glass) 6 mm and 13 mm air cavity | 228.78 | 13726 | 246.03 | 14761 | 3362 | 3142 | 650 | 5824 | 4471 | 4178 |
| 3 | double thermochroic glazing 6 mm ,6 mm air cavity | 216.75 | 13005 | 236.88 | 14212 | 4083 | 3691 | 790 | 7078 | 5430 | 4909 |
| 4 | double (SAGA Glass) 7 mm, 12 mm krypton gas cavity | 202.07 | 12124 | 225.05 | 13503 | 4964 | 4400 | 950 | 8512 | 6596 | 5852 |
| 5 | double (Low-E Elec Reflective Colored Glass), 6 mm, 13 mm air cavity | 182.03 | 10921 | 198.56 | 11913 | 6167 | 5990 | 1050 | 9408 | 8202 | 7966 |

Figure 46 : shows the simulation results and energy consumption ratios in the southern and eastern classrooms with the application of different types of glass.

In order to calculate the Payback time for the proposed treatment cost, we have to calculate the energy consumption cost saving rate for the case of glass treated with nanotechnology compared to the the existing case. We find that the saving rate in energy consumption in the eastern classroom is 6167 KwH annually, and the saving rate in the southern classroom is 5990 KwH annually. The cost of a kilowatt is 1.33 EGP according to the prices of the fifth category by the Egyptian Electricity Company for the year 2023. The average annual saving rate for the eastern classroom is 8202 EGP, and by dividing by 12 months, the average saving rate approximately equal to 683.5 EGP per month. The average saving rate for the southern classroom is 7966 EGP, and by dividing by 12 per month, the average saving rate approximately equal to 663.8 EGP per month. The cost of using a single transparent glass with a thickness of 3 mm in the opennings with a surface area of 8.96 square meters equals 1613 EGP, and the cost of double glass treated with nanotechnology (Low-E Elec Reflective Colored Glass), with a thickness of 6 mm, 13 mm air cavity in opinings with a surface 8.96 square meters equals 9408 EGP, so the cost of the proposed treatment = 9408-1613 = 7795 EGP.

The Payback time = the proposed glass type cost devided by the average of saving rate:

- The Payback time for the Eastern classroom proposed treatment cost : 7795/683.5 = 11.40 months, which is less than a year.
- The Payback time for the Southern classroom proposed treatment cost: 7795/663.8 = 11.70 months, which is less than a year.

## Conclusion:

According to the above analysis, simulation, and comparison between proposed treated glass types within the case study (the First District Secondary School for Girls in Sheikh Zayed city). The results illustrates that the southern classrooms annual energy consumption decreased from 298.39 kWh/m2 to 198.56 kWh/m2 , also the eastern classrooms annual energy consumption decreased from 284.81 kWh/m2 to 182.03 kWh/m2 with a total energy saving rate equivalent to 34.74% when we used Double Low-E Elec Reflective Colored glass with a thickness of 6 mm And 13 mm air cavity (SHGC = 0.569), (LT = 0.578), (UV = 2.130) in the fifth case instead of the glass type used in the existing case (a single 3 mm transparent untreated glass is used (SHGC = 0.861), (LT = 0.898). ), (UV = 5.894). From an economic standpoint, we also find that ,in the fifth case, the time to recover the cost of the proposed treatment is less than one year, which is considered a short period to compensate the cost. Based on the above, we can conclude that using glass treated with nanotechnology plays an effective role in improving thermal performance and reducing cooling energy demand in educational buildings in the Greater Cairo region.

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