"Toward Improving the Design of the Existing Building Envelope to Achieve Thermal Comfort in Educational Buildings: A Simulation-Based Approach" (Case Study of the Gezira Higher Institute of Engineering and Technology in Mokattam)

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Abstract:
The study aims to improve the design of the building envelope to achieve the best efficiency for the thermal performance of the existing building. The study sample was the Gezira Higher Institute of Engineering and Technology in Mokattam district. The study was based on thermal simulation of the building using the program Design Builder v4.2 - Energy Plus v.8.3 - Climate Consultant, through which a model of the building was developed that aims to improve the building envelope to achieve the best thermal performance. A questionnaire was conducted for the building users to study the impact of several variables and develop a model of the building after improvement that includes treatments that can be implemented. The research consists of three parts. The first part contains literature reviews of previous studies in this field. The second part contains an analytical study of the building envelope through conducting a field survey of building users over the year to collect data help in biomimetics to formulate the optimal concept for the experimental study. The third part contains an applied study of a proposed design for the building envelope to achieve thermal comfort for users in the selected drawing hall. The researcher recommends the need to establish mandatory laws for using specialized programs in the design process in its initial stages, and the need to use them in optimizing Building Envelope Design in the existing buildings and expanding the scope of research.

Keywords:
Thermal Performance, Educational Buildings, Simulation, Existing building, Environmental design

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Introduction:
The study aims to optimize building envelope design to achieve the best thermal performance efficiency for existing buildings. The study sample was the Al-Jazeera Institute of Engineering. The study relied on the thermal simulation of the building using the Design Builder v4.2 program the Energy Plus v.8.3 program and the climate consultant. Developing a model representing an educational building of the widespread type in the Mokattam district. The effect of building orientation, thermal insulation, shading, and alignment with the surrounding buildings on temperature, solar radiation, wind, humidity, and the building's thermal performance

Research Problem:
1- Using similar architectural styles for different climatic regions.
2- The environmental treatments in the building are insufficient to achieve thermal comfort for the user.
3- Design is not just arranged elements, but an analytical study and simulation of reality must be conducted to reach the best results.

Research Questions:
1- To what extent do modern technologies affect the thermal performance of the existing building?
2- What are the appropriate treatments for existing educational buildings to achieve thermal comfort?
3- What are the most important things that an architect must consider when designing to achieve the largest number of hours of thermal comfort without the need for heating and air conditioning equipment?

Research Aims:
1- Improving building envelope design to achieve thermal comfort in educational buildings (Gezira Higher Institute of Engineering and Technology in Mokattam)
2- The importance of the study lies in that it works on existing buildings whose users suffer from high temperatures in the summer and cold in the winter, by proposing design solutions and treatments that include adding new technologies to achieve thermal comfort and energy efficiency.
3- Using modern technologies to determine the impact of environmental design elements on the thermal performance of buildings.
4- Using modern technologies in the field of building modifications to improve their thermal performance.

Research Methodology:
The scientific method used in the research are:
- Descriptive method.

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- Deductive analytical method: by using the following search tools:
  - Questionnaires, field surveys, interviews and observations
  - Using the thermal simulation program for the quantitative analysis of the various variables. Design Builder v4.2, Energy Plus v.8.3 and Climate Consultant were used to reach the results and recommendations.

Three main axes were adopted to form the general composition of the study. These axes are:

- A theoretical framework: deals with the definition of basic terms and concepts, reviewing previous models, proposed theories, and Arab and international case studies.
- An information framework: includes a descriptive study of the reality of the building, knowledge of building density, quality, and existing problems through several tools such as field surveys, questionnaires, and interviews.
- Analysis, evaluation and conclusion framework: Analyzing the collected statistics and data. And the formulation of the results to come up with scientific and applied recommendations in re-adapting the existing buildings with the phenomenon of global warming.

1- Thermal Performance Definitions:

1-1 The British Environmental Efficiency Assessment System:

Building research establishment environment assessment (BREEAM) (1)

It was issued in 1988 AD and was designed by the British Research Authority. It aims to assess the environmental efficiency of existing buildings and modern buildings.

1-2 The United States Sustainable Building Rating System:

Leadership in Energy and Environment (LEED) (2): It was issued in 1998 and developed by the American Green Building Council, a voluntary, non-governmental body that aims to develop standardization systems and building efficiency standards that achieve sustainability goals and some international standards.

1-3 Canada's Green Building Rating System:

It was issued in 2004 AD in Canada, and it is a mixture of Breem & Green Leaf Canada systems (3) and was developed by the Sustainable Buildings Initiative for application in Canada. It is a computer program that aims to achieve the principles of sustainability in construction. It is a comprehensive system suitable for all types of buildings, whether they are existing or new.

1-4 UAE: Pearl Rating System:

Pearl Rating System[4] was issued in 2010 and is an initiative developed by the Abu Dhabi Council 2030 in the establishment of new urban communities, based on sustainability as the basis for every development that occurs in that emirate and embodies the values, ideals and conditions of the United Arab Emirates, through the "Pearl Degrees" system that establishes the status Abu Dhabi regionally and internationally in the field of urban development and provides Abu Dhabi and the entire organization with a system for measuring sustainability through its four pillars "environment - economy - culture - society".

1-5 The Green Pyramid System in the Arab Republic of Egypt: The Egyptian Green Building Council:

It was issued in 2011 (5), and it is an initiative undertaken by the Egyptian Council for Green Architecture in 2009 AD, aiming to provide a reference for new practices that enable designers and constructors to make logical decisions that reduce environmental pollution, as well as to raise awareness of sustainable green buildings and create informed dialogue with stakeholders and contribute to expanding the scope of the debate about green buildings in Egypt over the coming years.

2. International Experience:

- California College of Arts and Crafts Building
- Nanyang Technological University (NTU).
- The American university in Cairo.
- King Abdullah University of Science and Technology.

2-1 California College of Arts and Crafts Building (6)

This project received the Reusable Design Award from the California Conservation Foundation, and it also received the Energy Efficiency Award from the Plastic Energy Center of San Diego. This building is considered a model of applying the sustainable architecture idea of reusing buildings. In this project, an old building that was intended for maintenance was converted.

The building is completely heated using solar energy, and the water is heated using solar heaters through solar heaters located on the roof. Sustainable materials have also been used in the interior treatments of the building. For example, the panels used for sound insulation are made of recycled paper.

- Orienting the building on the site and exploiting the environmental aspects reduces energy use by 50%.
- Using recycled materials from local environment.
- Use recycles environmental materials such as tarpaulin and bamboo ceramic tiles reducing the cost in the construction and operation phase.
- The design was based on an integrated design method that is compatible with the environment.
- Design flexibility and use of durable material

Table 1: thermal analysis of California College of Arts and Crafts Building

California College of Arts and Crafts Building	Thermal performance treatment	A section of the laboratory showing the relationship of photovoltaic cells to the angle of incidence of sunlight in summer and winter Lighting and ventilation are normal. A section of the laboratory showing the relationship of photovoltaic cells to the angle of incidence of sunlight in summer and winter Lighting and ventilation are normal.	 Figure 2 section shows thermal treatments on building roofs
		Design flexibility and use of durable and local materials. easy-to-recycle environmental materials such as tarpaulin and bamboo ceramic tiles. Use moisture-proof finishing materials. Use of solar cells. Using solar refractors to direct light	 Figure 3 shows glass panels that provide natural lighting

2-2-1 Criteria for selecting thermal performance treatments:

To control the gain of solar heat and at the same time allow enough natural light to enter the occupied spaces. To ensure this balance is achieved, fixed external sash openings, movable external ventilation openings, and internal spaces with glass ceilings, skylights, and mechanical shading systems were used

2.1.2 The added value to increase energy efficiency:

Three concepts achieve the idea of sustainable design, which are (reuse -recycle- reduce) [7] to reduce the use of natural materials and energy, and these concepts are applied in the field of interior design and furniture.

For example, recycled wood fiber panels are used in wall cladding, as well as fibers made from green materials that can be recycled again.

2-2 Oregon University, Eugene, USA:

The University of Oregon is a public research university in Eugene, Oregon. Founded in 1876

Table 2: thermal analysis of California College of Arts and Crafts Building

California College of Arts and Crafts Building	**Thermal performance treatment**	1) "Umbrella" ceiling. Glass walls in buildings are considered ineffective in blocking heat, even if the glass is triple-paned, but a large roof suspended above them may play a prominent role in shading the windows. This roof, also known as the "umbrella roof," helps protect pedestrians walking outside (8). 2) Adding "solar wipers". In collaboration with the University of Oregon, Architects plan to begin testing a new retrofit, a room divided to create a "solar space," or an enclosed courtyard on the south side of the unit that acts as an additional façade to relieve heat from the building. The unit also includes a glass door that can be closed when temperatures outside reach their peak, in addition to shades that help block heat, and ceramic tiles that help capture it. Temperatures and energy consumption will be compared between the pilot project room and another adjacent room to study the possibility of using the same strategy to modernize buildings(9) 3) Green roofs and of white paint on roofs to help keep buildings cool by reflecting heat outside. 4) horizontal and vertical fins on the building facade to add shade. The building also benefits from the low temperature in the area at night, through windows, moving ventilation openings, and cross-ventilation systems that attract air. 5) Converting the location of the building's core. In large office buildings, elevators, stairs, and mechanical systems are often located in the middle, that is, in the core. But if this core is moved to the south side of the building, it can help insulate the office space from heat and reduce the need for air conditioning. This move also helps enlarge the open space inside(10) 6) Horizontal thinking. The glass facades that we usually see in high-rise buildings absorb heat, but designing the walls horizontally and providing them with a group of balconies will shade the floors below them.	 Figure 4shows glass panels that provide natural lighting  Figure5 shows glass panels that provide natural lighting

2-2-1 Criteria for selecting thermal performance treatments:

The solution to dealing with the heat begins with necessary design choices and not with the adoption of technically advanced equipment ,6 strategies currently used by architects for this purpose as shown in the previous table.

2-2-2 The added value to increase energy efficiency:

The redesign buildings in a way that helps keep users achieve thermal comfort, and avoid using air conditioners that put pressure on the electrical grid.

2-3 Nanyang Technological University (NTU), Singapore (11)

Nanyang technological university building consisting of five floors.The project area was a green space, so the roof of the building was designed to be harmony with the nature of the site on which the project was built, and it is characterized by the full transparency of the external walls to integrate with nature. The curved building contains a courtyard with water features and plants.

Table 3 thermal analysis for Nanyang Technological University (NTU), Singapore

<table>
<tr><th></th><th></th><th colspan="2"></th></tr>
<tr><td rowspan="2">Nanyang Technological University (NTU), Singapore</td><td rowspan="2">Thermal performance treatment</td><td>Located in the southwestern suburbs of Singapore, 2006.A university building consisting of five floors

Figure 6 Nanyang Technological University layout</td><td>

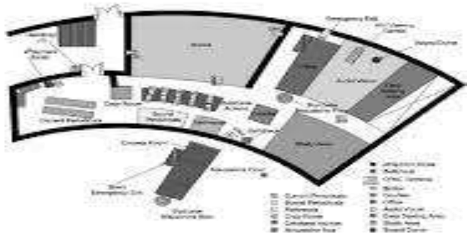



Figure 8 Nanyang Technological University design</td></tr>
<tr><td>- A rainwater harvesting system is installed on the green roof for irrigation.
- Rain sensors are installed on the green roof to automate the irrigation process
-Use triple glazing in the whole building.
- Double skin concept and nature ventilation
- The inner courtyard- green roof -fountain

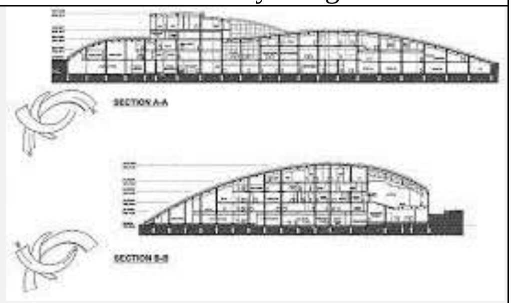
Figure 7 section shows the air distribution inside the building after thermal treatment of the facades</td><td>
Figure 6 section shows thermal treatments on building roofs and façade

Figure 9 section shows thermal treatments (fountain-courtyard- triple glazing-green roof</td></tr>
</table>

2-3-1 Criteria for selecting thermal performance treatments:

In this case, the thermal treatments depend on the use of natural elements in the ceilings and facades such as green roofs, courtyard and inner court. It has important benefits for the building and nature, as it improves the air quality of the building and creates a new space for pleasure.

2-3-2 The added value to increase energy efficiency:

The building saves energy approximately 120,000 kWh per year and more than 1170 cubic meters of water saved annually, which leads to lower operating and maintenance costs through the use of green roofs and natural lighting(12)

2-4 The American university in Cairo:

The American University building was chosen as an existing example that has uncomplicated heat treatments that can be used in existing buildings.(13) New Cairo – Egypt

Compatibility with the environment and sustainability:

Efficiency of the light environment: Ambient natural lighting has been taken advantage of by (Air catchers- hollow concrete slabs- Al-Shakhsheikha)

Table 4 thermal analysis for American university in Cairo, Egypt

	Thermal treatment	Orientation: The building was oriented in a north direction to take advantage of the prevailing wind direction.  Figure 10 American university location and environmental analysis Air catchers: Wind catchers are considered one of the most important distinctive elements in Islamic architecture, and they are towers connected to buildings used for cooling(14) Using hollow concrete slabs: In the library building on the south and west sides to reduce the intensity of lighting and increase the proportion of shade(15)  Figure 11 shows hollow concrete slabs	 Figure 12 distribution of architectural spaces -Al-Shakhsheikha: it provides natural lighting and is used to moderate the air temperature inside the outer space. It was used above the meeting hall at the university. -External windows and internal courtyards: To provide natural lighting at the university.  Figure13shows the wooden facades, mashrabiyas, and internal corridors and fountains,

2-4-1 Criteria for selecting thermal performance treatments:

The efficiency of the internal environment of the American University buildings is of a high degree of efficiency and quality. This is due to the interest in controlling the internal environment of the building through passive control systems in addition to mechanical systems to increase the efficiency of the building's light, air, and thermal environment.

- Efficiency of the lighting environment: taking advantage of the ambient natural lighting through external windows and internal courtyards. A study was conducted on different areas of classrooms and offices to determine the optimal size of windows.
- Efficiency of the air environment: natural ventilation is carried out through guidance equipment, internal courtyards, air hangers, and rattles.
- Efficiency of the thermal environment: relied on the idea of thermal oases to reach the optimal level of comfort without the use of mechanical systems, by creating thermal interactions between a group of spaces or elements that are represented in the courtyards. Squares, tunnels, and communication elements

2-4-2 The added value of increased energy efficiency:

The American University building is the only local school case that approached the building intelligence standards and received an acceptable rating when evaluated by the intelligence attributes method. This is due to its interest in compatibility with the environment and sustainability, in addition to automation. Environmental design was able to increase the rate of compatibility with the environment and sustainability through treatments of the negative environment used in the building and control of the light, air and thermal environment in the building. This is evidence that the use of approved environmental intelligence control systems is a basic condition for achieving the environmental aspect of smart architecture, and it is possible with the least available capabilities to achieve Smart architectural product

2-5 King Abdullah University of Science and Technology:

King Abdullah University of Science and Technology(9), located in the Seoul Center, 80 kilometers north of Jeddah Governorate, overlooking the entire Red Sea. The university has an area of 11.6 million square feet. The university obtained a LEED certificate with a platinum degree in 2011. (16) (17)

Table 5 King Abdullah University of Science and Technology

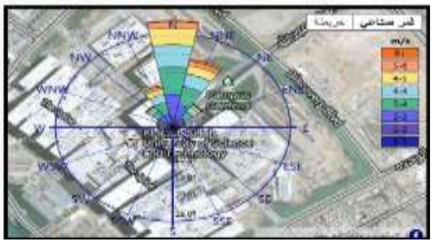
King Abdullah University of science and Technology	**Thermal performance treatment**	Factors such as abundant sunlight with a desert climate and limited rainfall, it was a limitation and an advantage at the same time to achieve points from the LEED checklist. The design took into account the exploitation of coral reefs in the sea. achieve greater sustainability and higher energy savings in the project Building orientation is considered one of the important points in sustainable design, as it increases the effectiveness of the use of both natural lighting and ventilation in the building, The re-orientation of lighting and ventilation is an initial stage in the sustainable design process and a way to reduce the energy consumed in the building	  Figure14 king andullah University of Science and Technology location
		The inner courtyard: it stores cold air at night to intense heat during the day, in addition to providing natural lighting and ventilation, and containing trees and green plants that give psychological comfort. - Fountains: water mixes with air, moisturizes it, and then transfers it to the internal spaces. -Green roofs: it improves the air quality of the building -Using construction systems such as, the ECF system, Plus Fiber Rein 4.GRC system  Figure 15The green concrete	 Figure 16 The inner courtyard  Figure 17 The wooden façade

Figure 18 shows thermal treatments in materials used in facades

All wood used is purchased from sustainably managed forests certified by the Forest Conservation Council. Over 75% of all packaging waste is recycled for the campus and includes glass, metal, plastic, cardboard, batteries, compact fluorescent lamps, electronic devices, and other materials.

Figure 19 shows thermal treatments in materials used in interior finishes

Interior finishes contain low levels of volatile organic compounds and high levels of recycled content. Gypsum boards, carpet tiles, ceiling tiles, paint materials, adhesives and woodwork. Interior foundation systems contain no volatile organic compounds and certified and include high levels of recycled content.

2-5-1 Criteria for Selecting Thermal Performance Treatments:

Determine the construction system, materials involved in the implementation are locally available materials which reduce the use of electrical energy by 30%. 40 of the energy used.

2.5.2 The added value to increase energy efficiency:

Using systems such as Fiber Rein 4.GRC system and ECF system reduces the emission of carbon dioxide by 80%, it considered one of the environmentally friendly systems. It also reduces energy consumption. It is characterized by strong load capacity and high resistance to various weather factors.

3- Case Study (Al-Jazeera Higher Institute for engineering and technology):

Figure 20 Al-Jazeera Higher Institute for engineering

Al-Jazeera Higher Institute is located in Mokattam region(10) at Street 9, in the middle of a residential and educational area, next to it are residential buildings with a maximum height of 6 floors, a school on the north side, and another school on the west side, and it is built on an area of 10289 square meters, including open spaces and green spaces.

3.1 Thermal Comfort Survey (18):

This survey is intended to provide an assessment of the thermal comfort provided by this building to its occupants. These survey questions indicate the performance of the building's indicators providing conclusions to optimize building envelope design to achieve the best thermal performance efficiency. The survey is divided into four sections.

- Background information.
- Assessment of the current conditions in your space.
- Assessment of the conditions in your space over the course of the winter months.
- Assessment of the conditions in your space over the course of the summer months.

Figure 21 Thermal Comfort Survey

1- Temperature: Temperature study

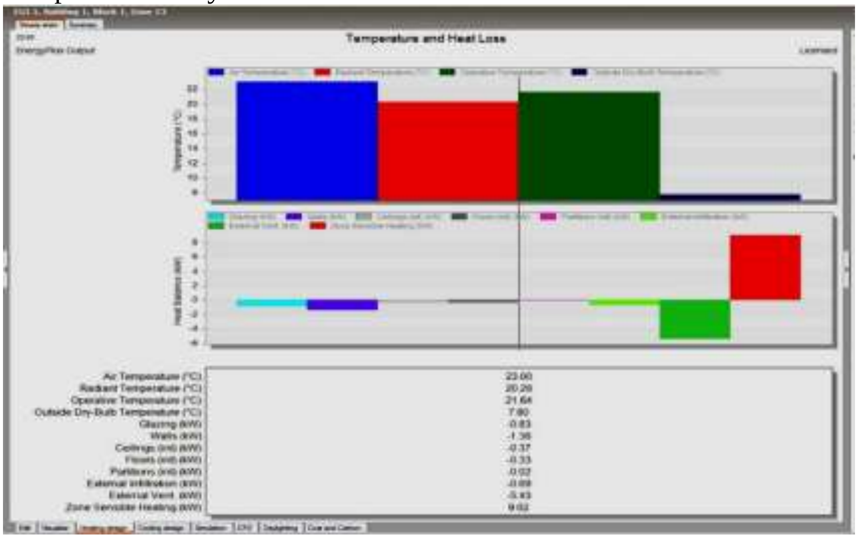


Figure 22 shows Temperature study

- Average temperatures in the region range from 7 degrees Celsius to 42 degrees Celsius
- The temperatures from January to March and the months of November and December are lower than the thermal comfort temperatures and the lowest is in January, so we need solutions for heating
- The temperatures in the months of June, July and August are higher than the thermal comfort temperatures and the highest is in June, so we need cooling
- April, March, September and October are characterized by thermal comfort.

2- Solar radiation:

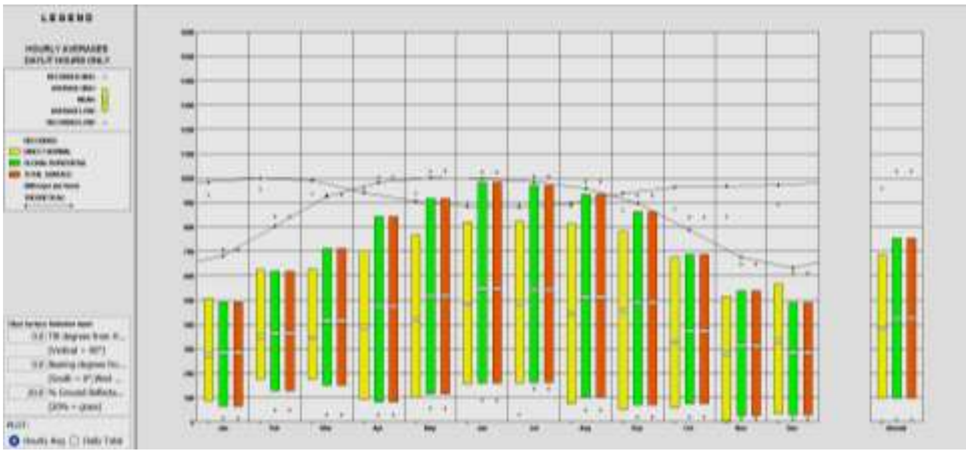


Figure 23 shows the temperatures throughout the year

At an angle of zero-zero-20, the highest percentage of rays falling on the solar cells in June and July

- Destinations exposed to solar radiation and high temperatures (in the months of June, July, August)
- Given the connection between solar radiation and temperatures, we can suggest some solutions to enhance building efficiency
- High temperature in summer
- High solar radiation

Thermal Performance treatment:

- Umbrella" ceiling A large roof suspended above play a prominent role in shading the windows. This roof, also known as the "umbrella roof," helps protect pedestrians walking outside
- Using solar cells and taking advantage of the high temperatures in the summer to reduce energy consumption.

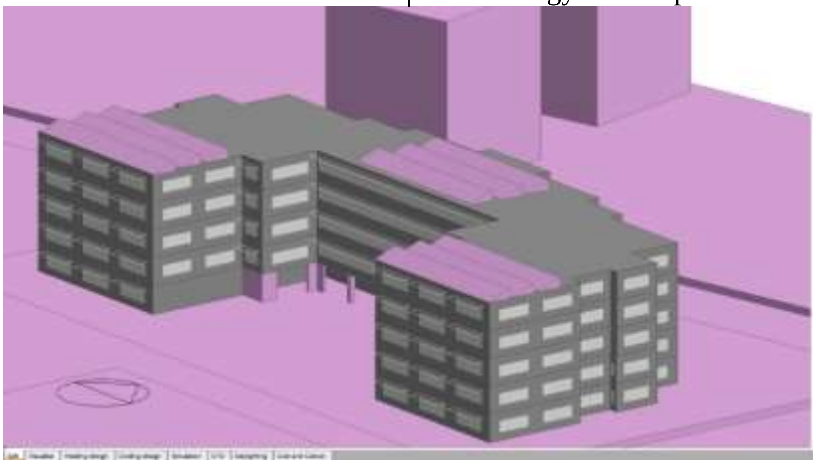


Figure 24 shows the thermal treatments for ceilings and solar cells

Northern facades:

- Increasing the ratio of openings on the northern facades to receive the greatest amount of light and ventilation
- Two-layer glass windows were made to disperse sunlight and limit it inside the space, in addition to being equipped with heat-treated aluminum frames to reduce heat transfer.

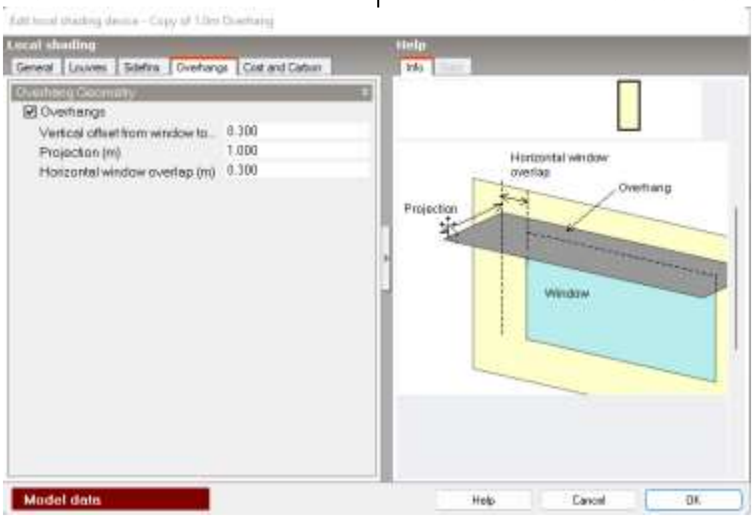


Figure 25 shows horizontal window overlap, projection and overhang

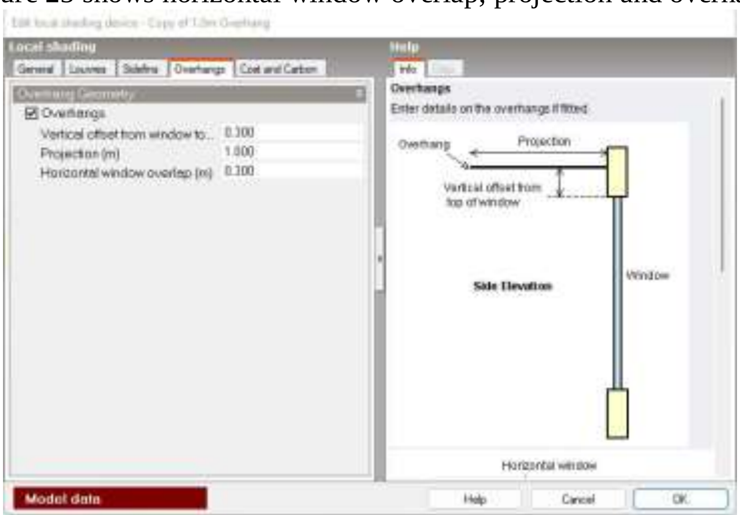


Figure 26 side elevation shows vertical offset from top of window

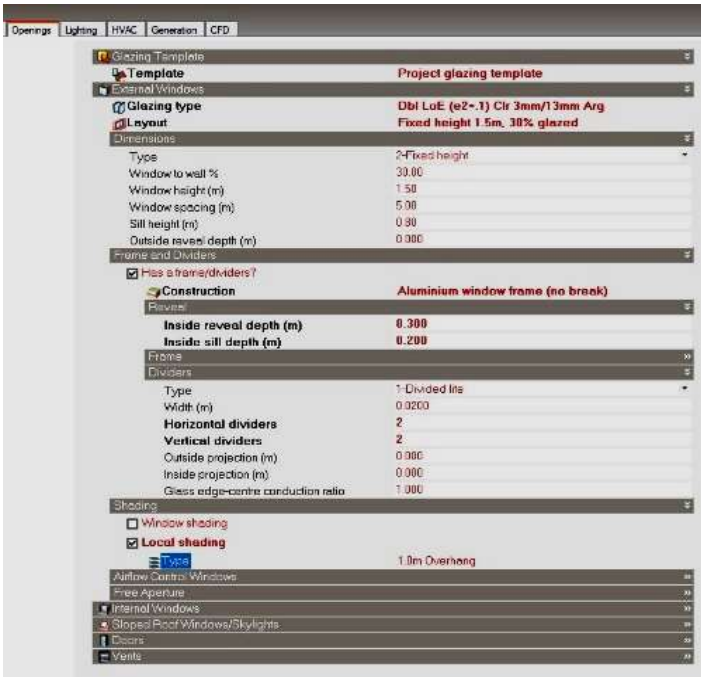


Figure 27shows glazing type

- Use insulating materials:

Figure 28 shows cross section of inner and outer surface

Double varying thickness were used and insulating materials were added to enhance the building's efficiency

1- Architectural treatment was provided on the southern and western walls of the drawing hall to provide thermal balance, as the hollow wall was used in five layers.

- Outer layer: marble
- Second layer: bricks
- The third layer: insulation
- Fourth layer: bricks
- Inner layer: cement

3- Wind:

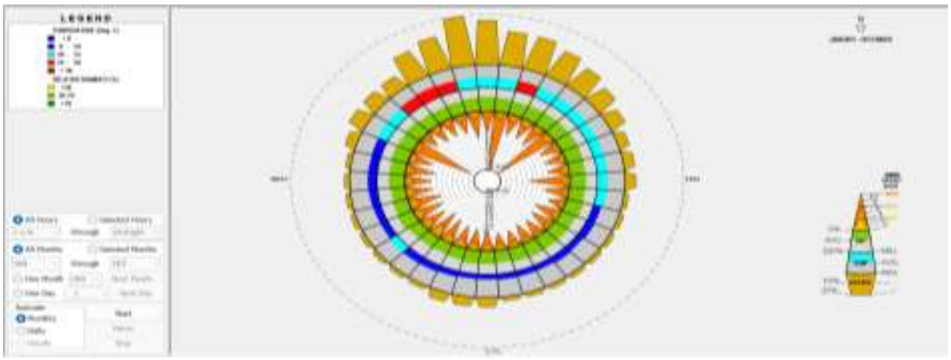


Figure 29 shows wind circle

- The wind direction comes from the northeast of the building
- Low relative humidity.
- Wind speed does not reach 8 m2/s in the area, so it is not recommended to use turbines to generate power.
- The highest wind speed is in April and the lowest in December.

Thermal treatments:

- Increasing the proportion of openings on the northern facades, which helps provide the greatest amount of ventilation
- Increasing the proportions of openings overlooking the inner courtyard, which helps provide the greatest amount of ventilation

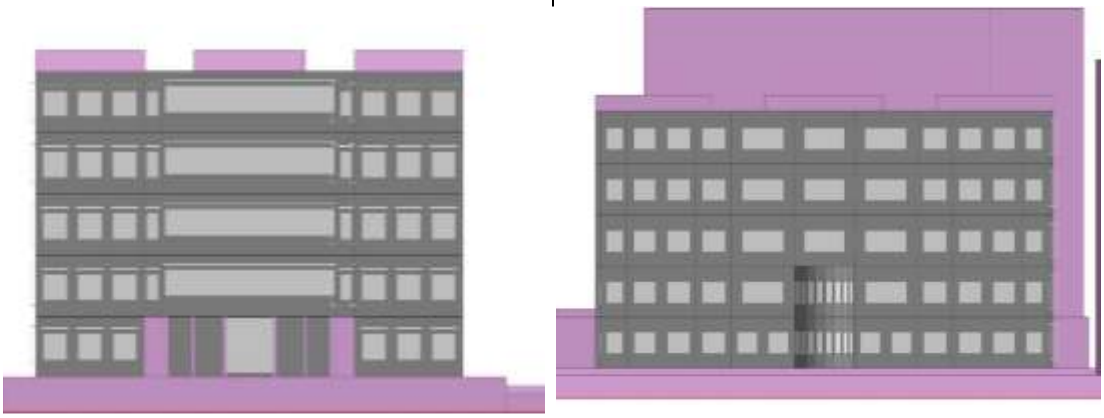


Figure 30 shows thermal treatment for front and side facades

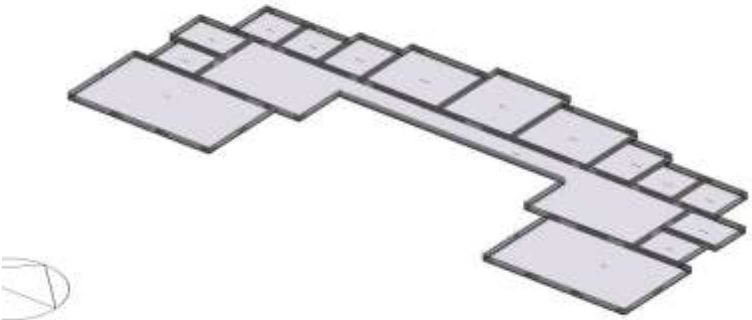


Figure31 horizontal projection showing the widths of the openings to achieve the highest lighting and best ventilation

4- Lighting:

- The amount of lighting in the area reaches 110,000 lux, and the minimum is 50,000 lux, and from this we can rely on daylight lighting, especially in the summer.
- The greatest amount of lighting in this area is in the months of June, July, and August
- The least amount of lighting is in the months of January and December.

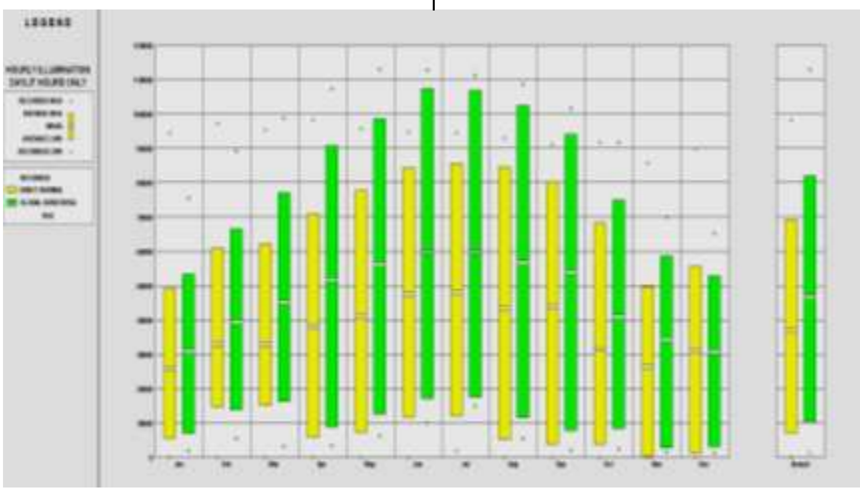


Figure 32 Shows the percentage of solar radiation

- At an angle of zero - zero - 20, the highest percentage of rays falling on the solar cells in June and July
- The lowest percentage of solar radiation falling on solar cells in January
- The largest amount of lighting in this region in the months of June, July and August
- The least amount of lighting in the months of January and December.

Thermal treatments:

The design and orientation of the vertical solar breakers are crucial for their effectiveness. The angle, spacing, and depth of the fins are carefully considered to optimize shading while still allowing natural light to enter the building. Computer simulations and modeling techniques are often used to determine the ideal configuration for specific geographic locations and building orientations.

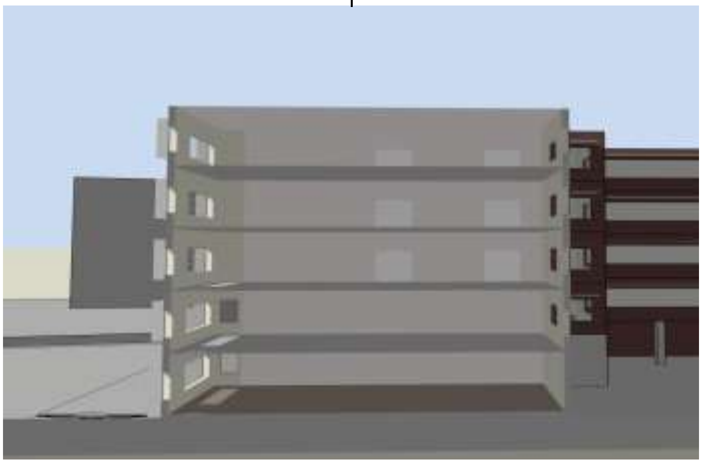


Figure 33 section showing openings width and position to obtain the best lighting and the least solar radiation

In addition to their energy efficiency benefits, vertical solar breakers can contribute to sustainability by reducing the building's reliance on artificial cooling systems. By minimizing the need for air conditioning, they help conserve energy and reduce greenhouse gas emissions.

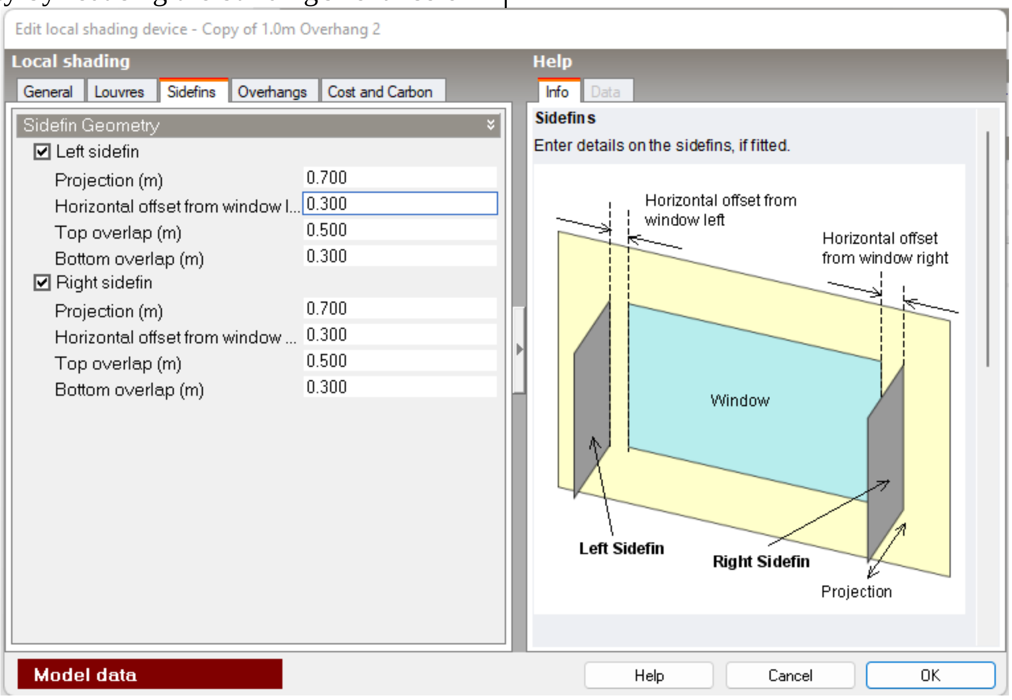


Figure 34 shows right and left side fin

Vertical solar breakers are an innovative architectural solution that combines functionality, aesthetics, and sustainability. They provide effective solar control, improve energy efficiency, and enhance the visual appeal of buildings, all while promoting a more sustainable built environment.

5- Humidity:

Humidity levels range from 25% to 44% according to the temperature difference

- From 0-21 Humidity 44%
- From 21 to 27, the humidity level is 31%.
- From 27-38, humidity 25%

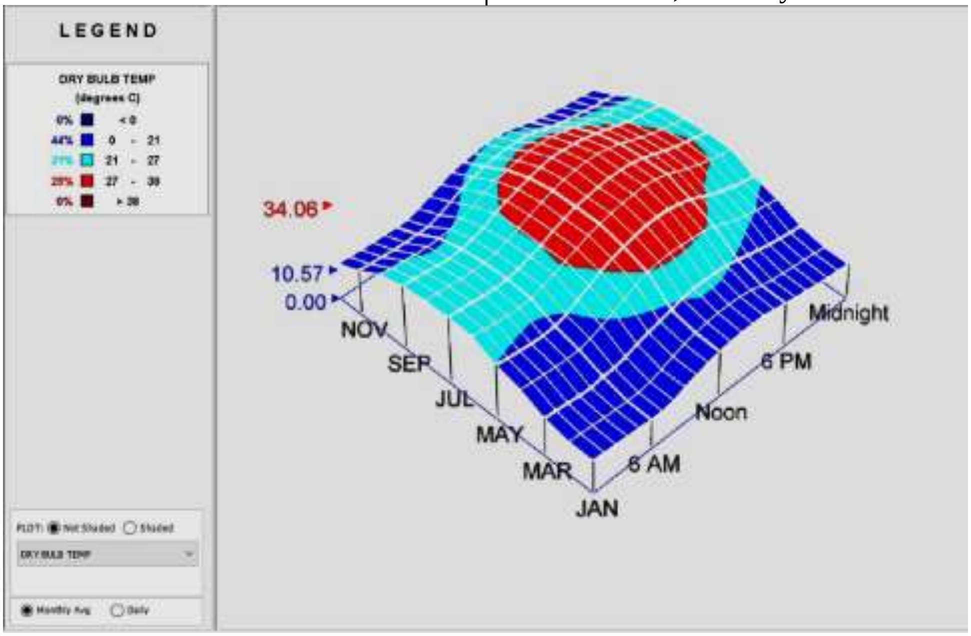


Figure35 shows dry bulb temp

Thermal treatments:

Humidity control refers to the management and regulation of moisture levels in the air to achieve desired conditions for various applications.

- Dehumidifiers: Dehumidifiers, on the other hand, are used to reduce excessive humidity in the air. They extract moisture from the environment, helping to control mold growth, prevent condensation-related damage, and create a more comfortable living or working environment. Dehumidifiers are commonly employed in areas with high humidity levels or where moisture control is essential, such as basements, bathrooms, and storage spaces.
- Moisture Barriers: Moisture barriers are materials or coatings applied to surfaces to prevent moisture migration. They are commonly used in construction to control moisture transfer from the ground, walls, or roofs into the building. Moisture barriers can help maintain a controlled indoor environment, prevent water damage, and protect structural integrity.
- Ventilation: Proper ventilation plays a crucial role in humidity control. Ventilation systems facilitate the exchange of indoor and outdoor air, which can help remove excess moisture and regulate humidity levels. By introducing fresh air and exhausting stale, humid air, ventilation helps maintain a healthy indoor environment.
- Desiccants: Desiccants are substances that have a high affinity for moisture and are used to absorb excess humidity. They are commonly used in applications such as moisture control in storage areas, electronics, and food preservation. Desiccants can be solid materials, like silica gel or activated carbon, or liquid absorbents.
- Humidity control is essential for maintaining comfort, preserving materials, and preventing issues related to excessive moisture or dryness. The specific methods and technologies used for humidity control depend on the desired humidity levels, the application, and the environmental conditions.

ACTIVITY:

Drawing hall was chosen to analyze its thermal comfort based on human and environmental factors

- By applying the following equation (density = number of individuals/ area)
- The energy expended varies according to activity and gender. The thermal balance was determined with regard to clothing, cooling, and heating

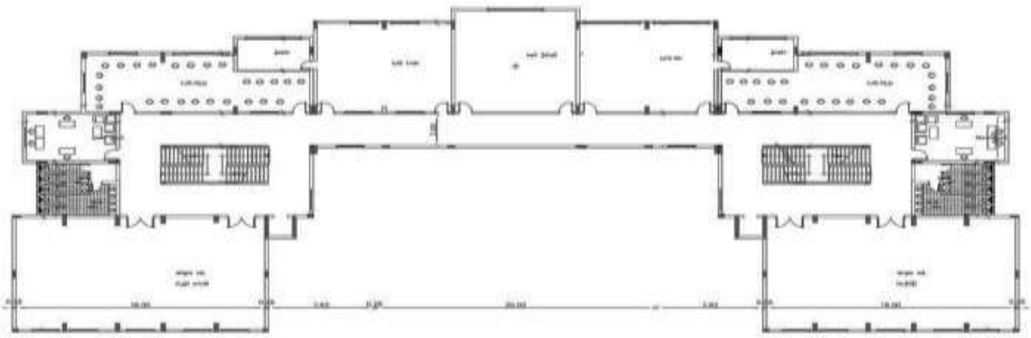


Figure36 the existing plan before thermal treatments include drawing hall, study case

Simulation:

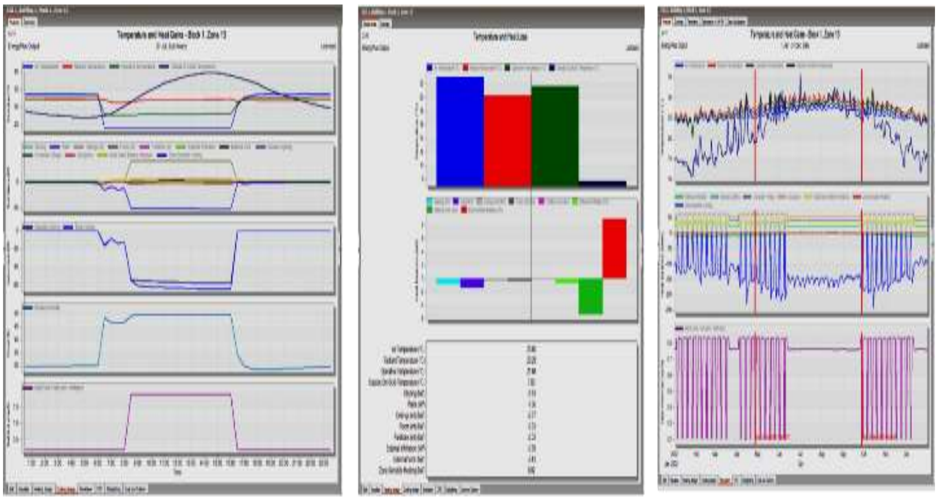


Figure37 shows simulation by using the program

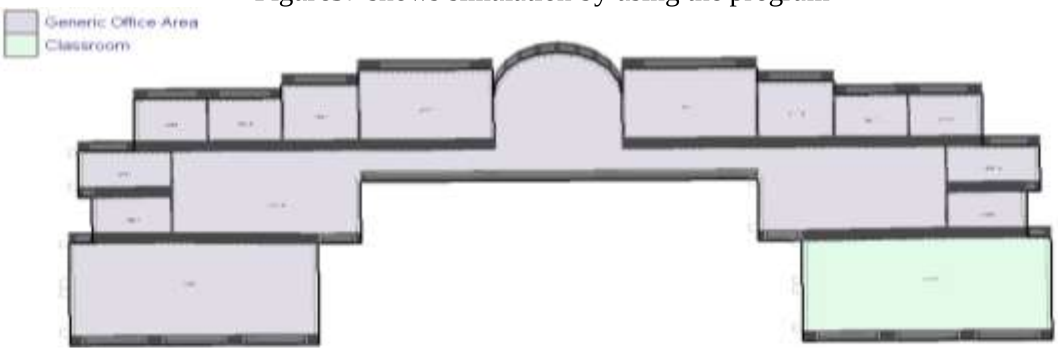


Figure38 shows the building after the thermal treatments proposed by the program

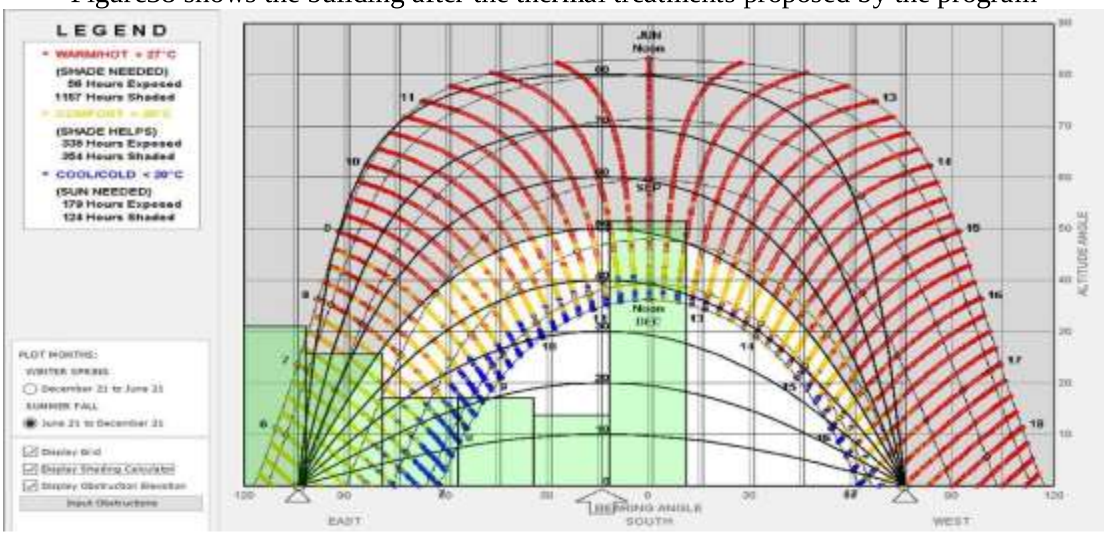


Figure39 comfort zone proposed by the program

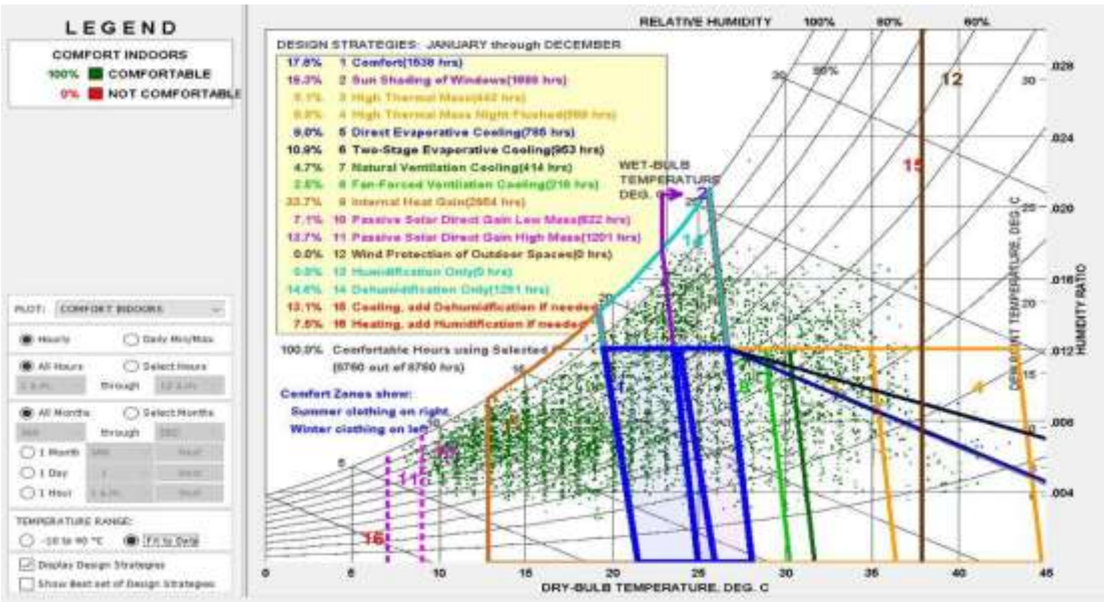


Figure40 shows comfort zone indoor

DESIGN STRATEGIES: JANUARY through DECEMBER:

17.6% 1 Comfort (1538 hrs.)
19.3% 2 Sun Shading of Windows (1688 hrs.)
6.1% 3 High Thermal Mass (443 hrs.)
6.5% 4 High Thermal Mass Night Flushed (569 hrs.)
9.0% 5 Direct Evaporative Cooling (785 hrs.)
10.9% 6 Two-Stage Evaporative Cooling (953 hrs.)
4.7% 7 Natural Ventilation Cooling (414 hrs.)
2.6% 8 Fan-Forced Ventilation Cooling (218 hrs.)
33.7% 9 Internal Heat Gain (2954 hrs)
7.1% 10 Passive Solar Direct Gain Low Mass (622 hrs.)
13.7% 11 Passive Solar Direct Gain High Mass (1201 hrs)
0.0% 12 Wind Protection of Outdoor Spaces (0 hrs.)
0.0% 13 Humidification Only (0 hrs.)
13.1% 16 Cooling, add Dehumidification if needed.
7.5% 16 Heating, add Humidification if needed.

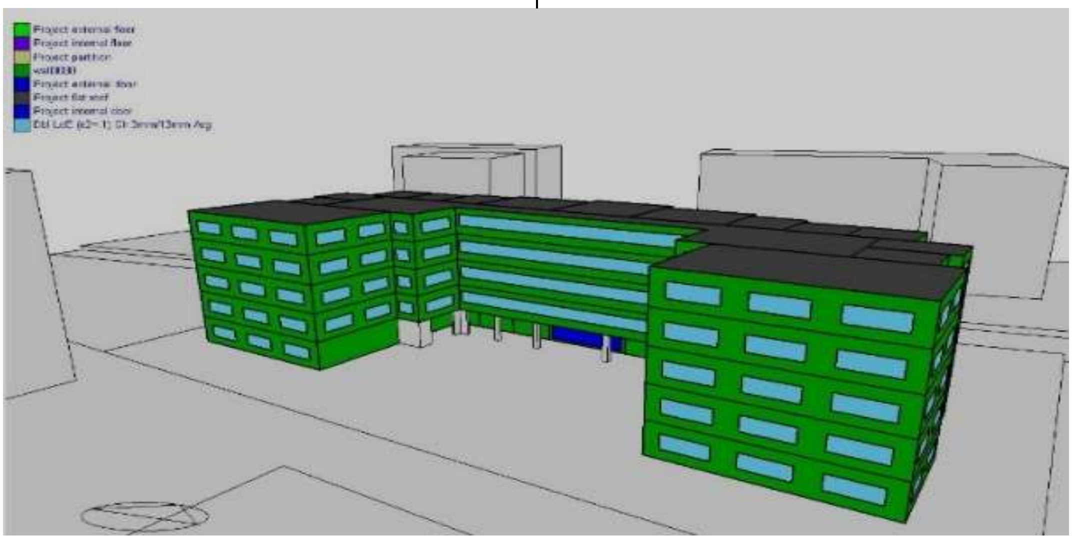


Figure (41) shows 3D to thermal analysis needed to achieve comfort for users

Result and conclusion:

Thermal comfort is one of the most important quality-of-life indicators, which has a direct impact on the architectural and urban formation of any building. The thermal comfort elements were identified and the major factors influential in the building were detected from the field survey. the researcher chose El Gezira Higher Institute for Engineering and Technology as a case study. The building was studied in detail. The study relied on the thermal simulation of the building using the Design Builder v4.2 program the Energy Plus v.8.3

program and the climate consultant to develop the module to solve problems facing users and achieve thermal comfort over the year and propose thermal treatments that could be implemented on it, considering it an existing building. A model of an architectural space, the drawing hall, was tested to link it to the four climatic elements (temperature - humidity - solar radiation - wind), and a set of architectural treatments were proposed to be applied to the Al Jazeera High Building for Engineering and Technology as an existing building. Through the survey, it was revealed that there are some thermal problems among its users (students - employees - visitors), which are:

1- The building facades and floors are ceramic
2- Green spaces are not sufficient
3- The inner courtyard is not exploiting
4- Window openings are not used to direct wind and light
5- The distribution of uses in the building is not well thought out

from the analytical study, some thermal treatments were suggested for the building

1- Use the" Umbrella" ceiling which plays a prominent role in shading the windows and the roof, and also helps protect pedestrians walking outside
2- Using finishing materials that absorb heat during the day and lose it at night without allowing it to penetrate the wall.
3- Redirecting the building away from the wind by completing the tree formation and surrounding it at the back of the building, which creates a negative pressure area that reduces the total atmospheric pressure difference and deflects the wind away from the building.
4- Use horizontal and vertical awnings in the facades to redirect solar radiation and wind into drawing rooms.
5- Using natural lighting such as light shelves, which are horizontal light-reflecting surfaces extending from the outside of the building to its interior. The useful range of sunlight can be extended on southern faces. In addition to preventing glare from entering the drawing room space, it reflects external light toward the ceiling and redistributes light to achieve visual comfort
6- Using mirrors (light pits): Use portable mirrors to shed light on dark places inside spaces through light pits, which are external pits with reflective mirrors that reflect light up to 20 times more than natural light. It is designed to receive the required levels of sunlight and the light can be delivered to a depth of three floors underground, thus illuminating the workshop spaces in the basement.
7- Prismatic glazing: using the method of refraction of light instead of reflection. It is used to take advantage of daylight during school hours. Light is redirected through total refraction and reflection by using a material that has edges on one side to deflect and spread the light at specific angles.
8- The optimal level of thermal comfort was reached without the use of mechanical systems, through thermal interactions between a group of spaces or elements, such as a courtyard and basement.
9- Only sensors for the air conditioning system are used in the building. It was suggested to use sensors used to measure air temperature, and others to measure relative humidity.
10- Using solar energy to obtain natural lighting, and wind blowing to obtain natural ventilation.
11- An attempt has been made to rationalize energy consumption in institute buildings through the efficiency of the building's internal environment through architectural treatment systems and the use of passive control systems in addition to mechanical systems in addition to the use of the cogeneration system (CO) which helps generate 35-60% of The energy used, and this led to an acceptable annual energy consumption, although this consumption rate did not make the building an energy-efficient building, as the smart building and the building guide indicate that the average acceptable consumption of the building reaches 130 kilowatts/m2 annually

Figure (42) the mechanism of light pits and prismatic solar collectors

Recommendations:

All specialized studies have confirmed that a healthy natural environment contributes to improving the general health of users within architectural spaces. Architectural design plays a major role by using the principles of sustainable architectural design and developing designs that take into account the environmental dimension to improve the quality of resource management, achieving thermal comfort, and increasing the efficiency of environmental quality of life indicators

Therefore, the researcher recommends expanding the scope of the research

- Not only focusing on legislation to govern modern buildings only but also obligating existing buildings to add environmental treatments to the building to achieve thermal comfort for users in addition to reducing the energy consumed and emissions resulting from mechanical solutions.
- Increase environmental awareness among individuals and clarify the economic benefits of applying it in our buildings. Return to applying traditional architectural methods that achieve thermal comfort inside the building and emphasize their importance in achieving comfort for the user and reducing the energy used.

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