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Methodology for Design Criteria Affecting the Energy Efficiency of High-Rise Buildings

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Abstract: The research addressed the technological and environmental evolution of high-rise buildings, and studied how to achieve the optimal use of modern technological techniques represented in smart architecture to improve the indoor environment of high-rise buildings and achieve thermal comfort for users, as it has become necessary to keep pace with development, accommodate the increasing population density, in addition to working to improve and rationalize energy consumption in buildings to provide the principles of sustainability. High-rise buildings have become symbols of some countries or major cities, and they are sometimes a necessary requirement and an indispensable need, and at other times they are in themselves a unique creative artistic work. The importance of the research highlights the attempt to find a methodology to reduce energy consumption and environmentally friendly building materials in new high-rise administrative buildings to achieve thermal comfort inside the administrative spaces for the occupants, relying on technology, techniques, and measuring the efficiency of energy consumption and carbon emissions in line with the 2030 goals in both the design stage and the post-occupancy stage. Hence, there is an inevitable necessity to take unconventional scientific measures so that the building harmonizes with the surrounding environment to achieve the maximum degree of thermal comfort for the occupants, which requires further research to create a new generation of high-rise administrative buildings that have the ability to fully interact with the surrounding environment through an integrated system for the efficiency of the performance of administrative buildings in terms of providing the rate of energy consumption and compatibility with the surrounding environment. The construction of high-rise buildings requires advanced techniques in all technical aspects. It also represents architectural challenges at the same time. The research aims to prove the hypothesis that we can develop a methodology to improve the indoor environment of high-rise buildings and rationalize energy consumption to achieve sustainability principles through good design and optimal application of smart architecture techniques on the building envelope and its structural system. The goal is also to create an integration between the concepts of smart architecture and its tools with the principles and techniques of environmental architecture, and then to study a new architectural trend that can be called (high efficiency and architectural performance in skyscrapers) by developing a methodology to achieve energy efficiency for new administrative skyscrapers in Egypt. The research aims to reach an environmental approach in the process of achieving energy efficiency through the use of treatments on the envelopes of smart and sustainable buildings, as well as to reach applicable standards and mechanisms to activate the concepts and standards of improving building efficiency through the application of the latest advanced structural systems and modern building materials to find the relationship between the use of treatments on building envelopes in a methodology to reach the highest performance of energy efficiency for the exterior envelope of the administrative skyscraper using modern techniques in an applied approach. This represents a new field of study to find scientific and practical solutions to the energy problem in general, and to rely on the integration between design techniques and the use of modern treatments to achieve thermal comfort to improve the thermal performance of glass facades and their influence by modern technological systems, while maintaining the thermal comfort of the occupants of the space. This will work to reduce energy consumption, pollution rates, and the individual's sense of thermal comfort within the building.

Keywords: *High-rise administrative buildings, thermal performance, LOW-E glass, curtain walls, smart architecture, environmental architecture technologies.*

1. Introduction

In recent years, the world has witnessed a clear integration between various sciences and scientific developments witnessed by the modern era in all directions. It has become necessary for architecture to interact with these variables and for the architectural product organization to contain all technological systems or those that lead to the success of the building's operating mechanisms and improve its efficiency. Glass facades are among the important elements that affect the internal temperature of the building's spaces. Energy represents one of the axes of sustainable development in various countries of the world. As a result of the importance of this axis, many study and research programs have been developed to evaluate the performance of energy efficiency in residential, commercial and governmental buildings in order to develop scientific solutions to rationalize their energy consumption. Most countries of the world have also developed codes to improve energy efficiency in various sectors, but the trend of high-rise administrative buildings (1) is new in Egypt in this era and this is currently appearing

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in new cities such as the administrative capital and the new worlds. Egypt is facing environmental and energy challenges today due to the increase in urban and population expansion, which leads to an increase in demand for energy, especially in the administrative sector, to achieve better thermal comfort. Therefore, there is an increase in air conditioning units that consume about 56% of the total energy annually. The problem is the lack of a clear approach in Egypt to reduce energy consumption and not use environmentally compatible building materials to achieve thermal comfort. The experience of countries in applying technology to design and architectural formation differed (2), and the degree of benefit from it varied, as developed countries succeeded in achieving integration between distinguished design and good architectural formation. As a result of the increasing needs, most modern architectural techniques were applied to skyscraper buildings (3), so it was necessary to adapt some of these techniques to suit the circumstances and societal needs. This research presents an analysis of selected models of high-rise administrative buildings that achieve thermal comfort for contemporary architects. Architectural treatments, building materials and glass techniques were used on the external facades, in addition to shading methods on the facade to raise the efficiency of high-rise administrative buildings in terms of achieving thermal comfort, rationalizing energy consumption, and keeping pace with the principles of green architecture and sustainability. Given the multiplicity of global administrative buildings and their different types, it was necessary to choose the best designs that are characterized by their complete reliance on ventilation and natural lighting, in addition to the difference in design ideas according to the school to which each architect belongs. A group of local, regional and international high-rise administrative buildings were chosen that optimally exploit the available environmental data, through which the required thermal comfort for the individual inside high-rise administrative buildings is achieved. The buildings are characterized by the diversity of architectural thought and its impact on contemporary design thought, and the difference in ventilation and lighting treatments, keeping pace with the principles of green architecture and sustainability for high-rise administrative buildings in Egypt (4).

2. Literature review

Many studies in recent years have addressed a clear integration between various sciences and scientific developments witnessed by the modern era in all directions, so it has become necessary for architecture to interact with these variables and for the architectural product organization to contain all technological systems or that lead to the success of the building's operating mechanisms and improve its efficiency, as glass facades are one of the important elements that affect the internal temperature of the building spaces. In 2011, Shaimaa Mohamed Reda Fayed, a master's thesis, Cairo University, presented a study entitled "Hybrid ventilation in office buildings in Egypt, a well-ventilated double facade." The thesis deals with ventilation as the process of supplying a closed space with fresh air and removing polluted air. Proper ventilation requires that there be movement or circulation of air within the space and that the temperature and humidity be maintained. The hybrid ventilation system is designed to maintain acceptable indoor air quality within the comfort zone while maintaining energy use in the building. Since the critical element in any building is the facade as it interacts with the internal and external environment, the well-ventilated double facade is certainly an innovative method that requires development and technological support. This thesis deals with the role of the double facade in the ventilation system. The effective elements of the double facade performance are distinguished. The conceptual elements of the double facade are created by combining different effective elements at different levels based on climate analysis. Prediction and simulation are used to demonstrate the effect of a well-integrated double facade design compared to a conventional design. The proposed methodology is tested on a prototype building to evaluate and improve ventilation, using the “DESIGN BUILDER” simulation that combines rapid building modeling and ease of use with the latest dynamic energy simulation techniques. An improvement in the indoor environment is observed, with a temperature drop of 3-6°C being regulated by providing a ventilation rate greater than the minimum requirement of ASHRAE 62-2001. The research concluded that the application of an integrated design for the double facade as part of the ventilation system has a significant impact on improving the indoor environment while reducing cooling loads and conserving energy use. Another study in 2013, Ahmed Nour Qandil, Port Said University, presented a doctoral thesis entitled “A Vision for the Design of the External Envelope of a Residential Building in Hot, Dry Regions”. The research addressed the problem of the relationship between the design of the external envelope of a residential building in hot, dry regions and the extent to which the internal space achieves thermal comfort. It also addressed the effect of using the optimal thickness of the thermal insulation layer on the environmental and economic efficiency of the space. Studies have shown that thermal comfort has a significant impact on the performance of the occupants of the administrative building, and that psychological thermal comfort may affect the morale of its occupants and has a significant impact on the well-being of the individual. Therefore, it must be achieved in high-rise administrative buildings because it affects the performance of the occupants of the space due to creating unsatisfactory conditions for them. To achieve accurate thermal performance, simulation programs must be used, which will lead to reaching an environmental monitoring strategy (5).

Through this research, we can identify the latest Smart technologies and systems, their components and operating methods, as well as identifying new materials used in the external envelopes of administrative buildings and their role in raising the efficiency of building performance and adapting to external influences. This is done through analyzing models of global and regional smart administrative buildings, and reaching the most important smart technologies used and methods of applying them, and the most important obstacles that hinder the use of these smart technologies in developing countries. Attiya, Ashraf (2018) also discussed identifying different types of glass treated with nanotechnology to reduce energy consumption from administrative buildings. The methodology followed was to use the simulation tool (Design Builder 3.1). Then a comparison was conducted to test the performance of different types of glass and different orientations with the same glass thickness. The model chosen for application was an office building in 6th of October City, Giza Governorate. The result was that using Double-glazed SB R100 Clr 6 mm/13 mm glass in office buildings can save a large amount of energy. The research did not discuss the dynamics of climate changes and their impact on glass in summer and winter in order to study heating and cooling over annual operating periods to reach an integrated solution due to their importance in affecting the quality of the indoor environment in summer And winter (6)

Modern scientific solutions include the use of modern technical systems such as kinetic facades in combination with glass facades by shading the facades. The use of materials with modern technologies in the construction of facades is also a field that has been studied below, as discussed by (2014 Mingzhe, et al.) A new simplified calculation study to calculate the energy and comfort performance of the double-glazed facade accurately in terms of energy consumption and thermal comfort. The methodology followed is to develop the simplified method by solving its heat balance equations. The type of glazing used in the experiments was a double-glazed unit with a 22 mm argon-filled cavity and a low-E coating on the interior. The results of this study show that this method can be used in the early design stage of the building and facade to predict the energy and comfort performance of the double-glazed facade. The research did not discuss the dynamics of climate changes and their effect on the glass in summer and winter in order to study heating and cooling over the annual operating periods to reach an integrated solution due to their importance in affecting the quality of the indoor environment in summer and winter (7).

2.1. Research problem

Lack of sufficient attention to the foundations and standards guiding the design process of high-rise buildings, which produced buildings that do not meet the environmental and functional requirements desired from these buildings (8) and the lack of a clear approach in Egypt to reduce energy consumption and not use environmentally compatible building materials to achieve thermal comfort inside administrative spaces for occupants of the space in new high-rise administrative buildings.

2.2. Research objectives and practical study

The study aims to develop a methodology for design standards affecting the energy efficiency of high-rise buildings to benefit from them in innovative designs for high-rise buildings and high-rise glass facades so that they are consistent and compatible with the Egyptian architectural environment and can be implemented using these modern technologies to create high-rise buildings in addition to designing high-rise glass facades compatible with the Egyptian environment.

This study will focus on using advanced technologies (artificial intelligence) to create a new type of high-rise buildings called (smart sustainable high-rise buildings) in an attempt to demonstrate the importance of applying new technologies to improve the performance of these buildings.

2.3. Research Questions

- Can energy efficiency be achieved using processors on new high-rise administrative buildings?
- Can new high-rise administrative buildings in Egypt reduce energy consumption and achieve thermal comfort by integrating processors on the high-rise building with different high-efficiency materials available in the local and global market at reasonable prices?
- How much energy will be saved by integrating processor technologies on the high-rise administrative building?
- "What is the energy-efficient processors for high-rise administrative buildings that are available for use and where have they been used successfully?"
- What are the available retrofit simulation tools/software to assist in decision making?

2.4. Research Hypothesis

- Is it possible to achieve sustainability principles in high-rise buildings and provide climatic comfort for people as well as conserve energy, through good design, implementation and optimal operation of each (smart structure, smart envelopes, and smart materials) as patterns of smart architecture?
- Fixed design methods do not achieve optimal protection for the building, but rather flexibility and the use of dynamic methods are required to change their direction throughout the year according to

climatic conditions.

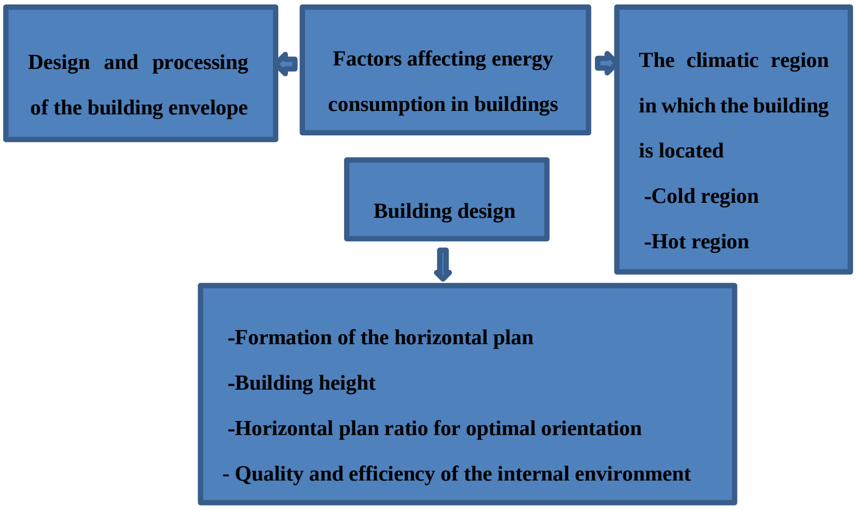


Fig 1. Factors affecting energy consumption in buildings (9)

3. Methodology followed

To achieve the research objectives, a theoretical approach is followed that relies on reviewing previous studies and what has been reached and its impact on the current study, and an analytical approach through studying local and international examples and analyzing and recording their own data: analyzing selected examples of high-rise administrative buildings globally, regionally and locally. The research relied on the comparative analysis approach for the results of analyzing data obtained from analyzing similar local and global projects from an energy-saving point of view and knowing the elements used to raise the efficiency of energy performance and the percentage of energy savings and reducing carbon emissions, while comparing the methods and elements used in high-rise administrative buildings in different climatic areas and countries (study sample) and trying to apply the mechanisms and standards extracted from the theoretical part (and knowing the points of difference and similarity and modern construction methods and methods, and identifying the elements and different standards) to develop high-rise administrative buildings and reach improving energy efficiency and using treatments on glass facades and sustainable smart covers and an analytical approach. To measure the extent of achieving thermal comfort and the quality of the building's internal environment in terms of the availability of natural lighting and providing good ventilation, while reducing energy consumption to achieve energy efficiency and performance for high-rise buildings, achieve sustainability principles, and contribute to achieving comfort for occupants of the space in new high-rise administrative buildings.

4. Glass curtain wall systems in buildings

Curtain walls are non-load-bearing walls placed on the exterior facades and are not components of the structural frame of the building. They are metal frames with glass panels between them to cover the building facades and are connected to it by fixing them to the columns and ceiling tiles. Their advantages include weight reduction, which does not affect the loads and dimensions of the foundations. They are also characterized by speed of implementation, but in return they require specialized workers or systems to clean them.

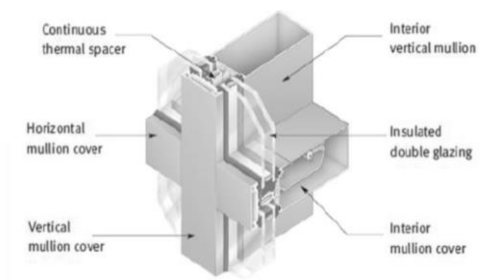


Fig 2. Components of the structural frame for glass facades (10)

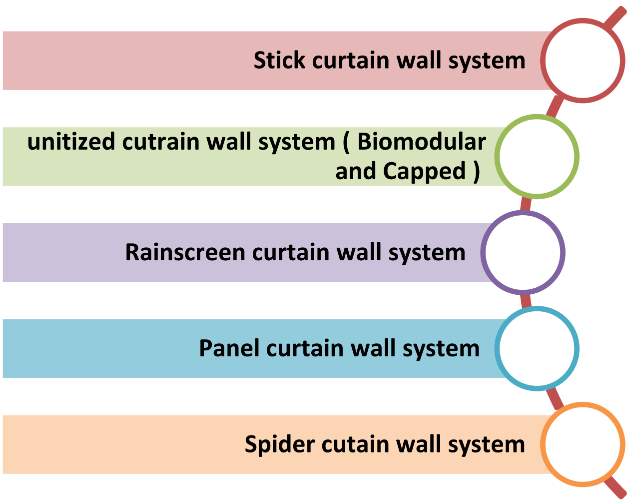


Fig 3. Glass curtain wall systems in high-rise buildings (11)

4.1. Types of glass and techniques for using it in high-rise building facades

Glass has undergone a great deal of continuous development and modernization in its manufacturing techniques by major international companies. As a result of the development of technology in the glass industry, different types have been produced that are of great importance in rationalizing energy consumption in buildings. Heat is transmitted through glass by direct radiation and also by conduction through glass due to the difference in temperature (6). Its flow is controlled in three ways:

- Reducing the thermal transmission U value

- Reducing the shading coefficient of glass SHGC

- Controlling light transmittance through thin film technology.

Therefore, it is necessary to study the mechanism of heat transfer through glass panels to know the differences between each type and another in terms of thermal. Because a percentage of solar rays is reflected outward, a percentage is absorbed by the glass itself, and a percentage is transmitted inward depending on the type of glass used. The sun's rays (Solar Spectrum) consist of several rays with different wavelengths, including ultraviolet rays (Ultra Violet), visible light (Visible Light), and infrared rays (Infra-Red). Each type of glass has a different behavior towards each type of the above rays. The best type of glass is the one that allows visible light to enter and prevents ultraviolet and infrared rays from entering the interior. The following is a review of some advanced types of glass, which are as follows:

Laminated glass:

Laminated glass consists of two or more layers of glass, glued together and with a layer of plastic in between.

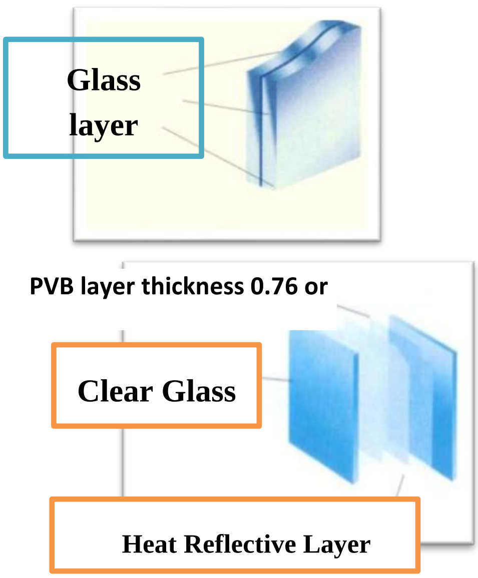


Fig 4. shows the layers of multi-layered glass (12)

4.1.1. Sound insulating glass

Installation of sound and heat insulating glass: Two or more layers of glass are combined using sound-insulating inner layers.

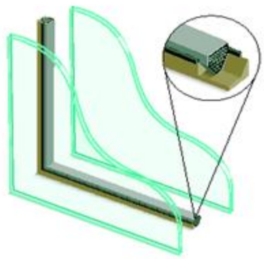


Fig 5. shows the components of sound-insulating glass (11)

4.1.2. Insulated double glazing

Glass consisting of two or more panes with spaces between them that can be filled with dehydrated air or an inert gas.

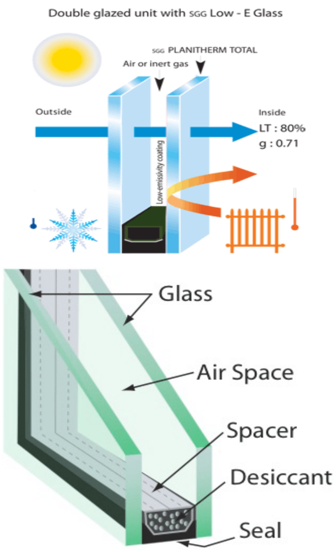


Fig 6. shows the components of insulated double glazing (12)

4.1.3. Low E glass

It is a glass treated with metal layers that are characterized by low radiation emissivity, which reduces the occurrence of heat gain from the outside to the inside by about 80%.

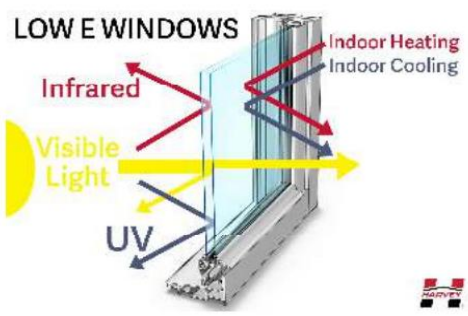


Fig 7. shows the components of low-emissivity glass (14)

4.1.4. Insulated Glass

Insulating glass consists of at least two glass panes, parallel and fixed together, based on the principle of filling the cavity between the glass panes with dry air or a gas such as argon, which provides sound insulation and thermal insulation of about 85%.

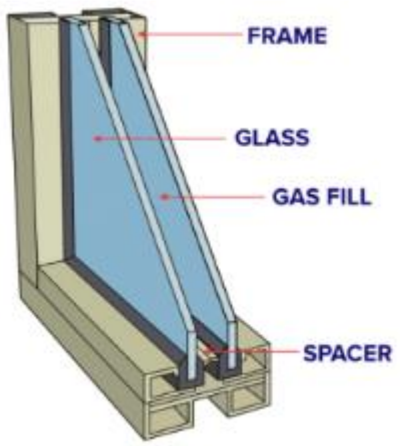


Fig 8. shows the components of low-emissivity glass (15)

4.1.5. Bullet Resistant Glass

It consists of several layers of galvanized glass, and is highly resistant to breakage and bullets.

Fig 9. shows the components of bullet-resistant glass (16)

4.1.6. Bent Tempered Glass

Shock resistant 5-7 times than ordinary glass, tempered glass can withstand internal and external temperature differences of up to 300 degrees Celsius. Tempered glass is classified into two different groups:

• Heat Strengthened Glass: Glass that is twice as hard as annealed glass.

• Fully Tempered Glass: Glass that is five times as hard as annealed glass, and is used in glazing works that require high durability.

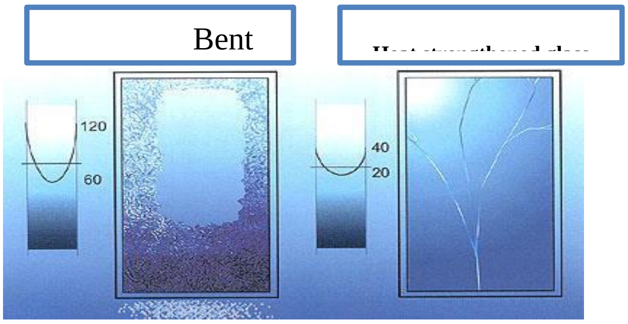


Fig 10. shows the components of bullet-resistant glass (17)

4.1.7. Grey Colored Glass

• It has a high ability to absorb visible light more than it absorbs infrared rays and is used to reduce glare caused by light.

• It reduces the amount of solar radiation absorbed through glass walls.

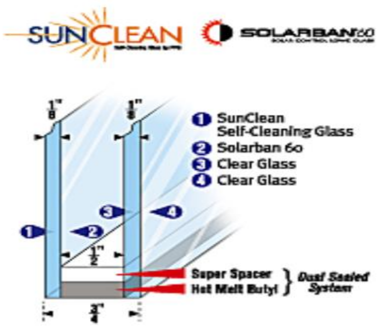


Fig 11. shows the components of colored gray glass (18)

4.1.8. Photochromic glass

This type of glass is characterized by changing its physico-thermal properties according to the level of solar radiation intensity falling on it, due to the presence of a gelatinous substance between the layers of glass that changes its optical properties:

• The color of the glass becomes opaque, especially in the summer.

• The color of the glass turns transparent in the winter

Fig 12. shows the optical glass (19)

5. Reasons for choosing the case studies

- This study requires special types of high-rise buildings in which the latest construction methods were used, taking into account the location. The case studies were chosen from high-rise buildings located in the Arab world and some other buildings in the world.

- This section represents the practical and analytical study of the thesis through the analysis and study of some local and international high-rise buildings known for their technological advancement and compatibility with the surrounding environment

- Buildings with a distinctive design nature were chosen, famous for their ability to accommodate high technological capabilities and smart technological systems, and the case studies were chosen from modern high-rise administrative buildings.

- In addition to its success in conserving energy, this is to prove that the correct application of the mechanisms and foundations of smart architecture in high-rise buildings increases the efficiency and performance of those buildings as well as achieving human comfort.

• Foundations for selecting countries and examples of the study sample

The architecture of the Arabian Gulf entered a phase of openness to the West, because of the oil boom in it, and the intensive immigration movement, and the architectural styles in the region have diversified, because of the establishment of many large and gigantic projects.

- Some regions of the Arabian Gulf, specifically Saudi Arabia and the Emirates, were chosen as a case study for many reasons, the most important of which are:

1. The Arabian Gulf region is one of the regions most interested in modern architectural technology and has employed it in its architecture.
2. The economic reality of these countries: They have great material capabilities, which has led to the application of modern architectural technology and complex architectural formations, which are characterized by their high costs.
3. The general trend of these countries is to use available technology to create architectural works that are landmarks and symbols of the comprehensive renaissance in the country.
4. The examples were chosen to reflect the diversity in the different classifications of skyscrapers. Also, the examples that had a strong impact on modern architecture were chosen, as the selection of examples embodies the overall architectural trends in the region.

5.1. Criteria for selecting the study sample

- The study aims to study the architectural applications of some countries and mention some examples that show the diversity in the architectural formation of skyscrapers. The research in this section is directed towards studying tall buildings in the world and the Arab world.

- Identifying the methods and systems responsible for the type of glass used and its impact on the thermal performance of the high-rise administrative building and at the level of planning, design and selection of technologies so that the study cases include the applied aspects of the characteristics of systems with modern technologies and some sustainability standards and the extent of their application in the high-rise buildings under study.

• Examples were selected that meet the following basic standards and that achieve the objectives of the analytical study:-

- Selecting a group of distinguished architectural projects due to their high height in addition to projects that show the impact of modern technologies in achieving the standards of efficiency and environmental suitability

- Selecting projects in different regions in different climatic, social and political environments to explore the impact of different environments on the architectural product.

- Diversity in projects in terms of employing technologies in them.

5.2. Analysis and case study of the study sample projects in terms of

- The buildings under study are analyzed by studying a set of elements that achieve the research objectives, which include the architectural description of the building, then the elements of the analytical study are extracted. The researcher studies the impact of technological development on these high-rise buildings by focusing on studying the following points and through analysis tables that include the following evaluation points.
- Glass facade system.
- Type of glass used and thermal performance rates.
- Treatments on facades
- The impact of technology elements on the architectural formation of high-rise buildings
- Depths of spaces in relation to facades
- Proportions of openings and their relationship to directions (actual percentage of openings)

5.2.1. First: Burj Khalifa - Dubai - UAE

• Area: 334,000 m2

• Building type: Multi-storey building (entertainment, residential, administrative)

• Number of floors: 163 floors, underground: 2 floors

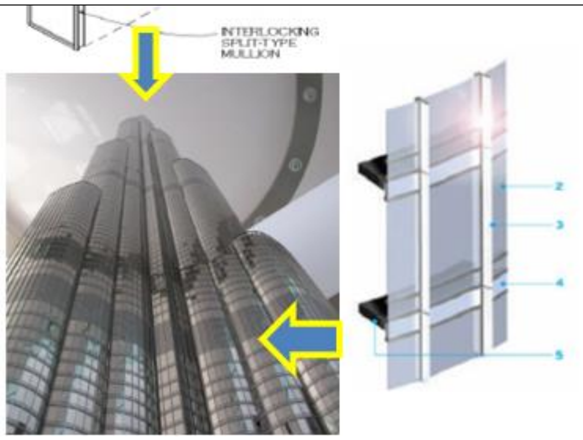
• Number of elevators and escalators used in the tower: 57 elevators consisting of two floors with a capacity of 12-14 people in each cabin, and the elevators move at a speed of 10 meters per second, 8 escalators (the tower can accommodate about 35 thousand people served by 57 elevators at a speed of 10 m / s with an elevator capacity of 10,000 kg, and 8 escalators)

• The climatic zone in which the building is located: The facades were designed to withstand the extreme temperatures in the summer in Dubai, and it consists of 142,000 square meters of reflective glass, aluminum and stainless steel, and the climatic zone is a hot dry climate

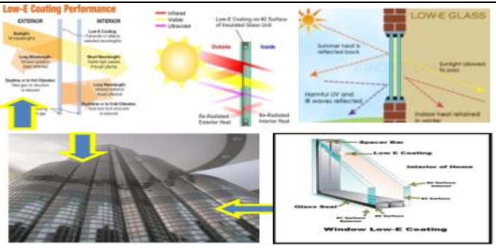
Building design: The design of the project's facade is one of the smart glass facades that have a character Distinctive, and the design idea of the tower was based on the abstraction of the Hymenocallis flower, which is found in abundance in Dubai. The basic design of the tower is an organic shape with a three-axis geometry and an ascending growth that can be easily seen in the final design. In addition, traditional Islamic forms were used to enrich the design of the tower, incorporating visual references to the culture and history of the surrounding area. The horizontal plan of the building consists of three elements around a vertical Y-shaped movement space consisting of three separate wings connected to a central core. As the tower rises, one wing on each floor recedes in an ascending pattern, further emphasizing its height. The Y-shaped layout is ideal for residential, and hotel use as it allows maximum views outwards without overlooking a neighboring unit. As the building rises, the horizontal section becomes smaller, and the mass becomes more gradual. The main mass of the building is oriented and designed to counteract wind movement by smoothing the outer edges of the mass. The mass is progressively thinner as it rises. The engineers in charge of the building have sought to rotate it at an angle of 120 degrees from its original design to mitigate the prevailing winds.

Fig 13. shows the main facade of Burj Dubai (20)

5.2.1.1. Glass facade system used in the tower

 **Fig** 14. shows the treatments and glass used and the effect of solar radiation entering the low-emissivity glass (low E coating) on reducing solar radiation (21)**.**	Panelized Curtain Wall System This system is a ready-made, pre-fabricated, large-sized unit, and the panels consist of several components such as glass, structure, and other cladding, and they are like one piece (, lifted, and installed in the place prepared for them in advance	Panelized Curtain Wall system was used.

5.2.1.2. Type of glass and thermal performance used in the tower

Illustrative images	Glass type, thermal performance and characterization
 **Fig 15.** shows reflective glass, glass coated with a reflective layer (22)(	Low E glass coating Thermal performance as a result of using double glazing treated with metal layers characterized by low E coating U value = 0.35 and SHCG value = 0.39 led to the design of the building with the minimum energy efficiency requirements, saving 30% of electrical energy use

5.2.2. Second: Hearst Tower - New York - America

Area: 79,525 m2

Construction date: 2003, completion date: 2006

Building type: Administrative building

Number of floors: 46 floors, underground: 1 floor

Building height: 182 m

Architect: Norman Noster

LEED certification: Hearst Tower is the first skyscraper to obtain the LEED Gold certificate in New York

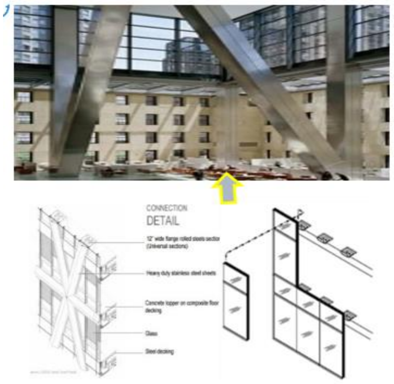
Number of elevators and escalators used in the tower: 21 elevators and the escalators and elevators were placed in the heart of the service along the western part of the tower

Climate zone in which it is located: Cold climate The materials used by the designer in the work of this tower, which are steel and glass, made it work as offices that consume less energy than office buildings in New York City by relying on natural ventilation for about 75% of the year

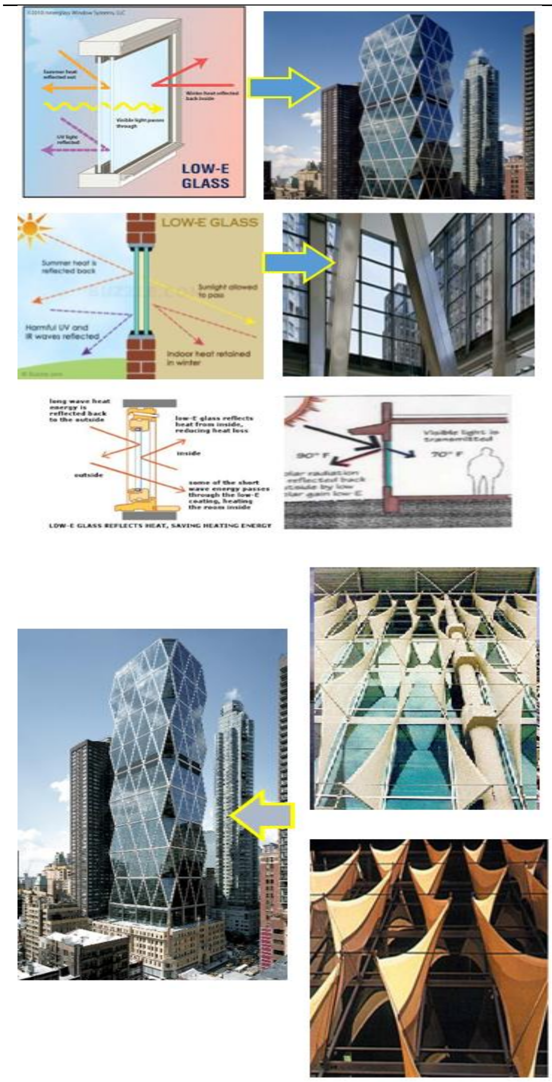
Building design: The design idea for the tower was based on preserving the existing historical facade and integrating it into the design of the new tower. Hearst's original goal for this building was to provide a high-quality work environment for its employees. The new building was designed as a stunning steel and glass skyscraper that enshrines a number of landmarks related to the environment and design. Hearst Tower has become a true pioneer in environmental sustainability, after being declared the first "green" office building in New York City. As the first skyscraper certified by LEED in New York City. Thermally conductive limestone paves the atrium floor. The design preserves the façade of the existing structure and creates a creative dialogue between old and new. The 46-story tower rises above the old structure. The massing was previously defined by the footprint of the existing Hearst Building. The tower's design sought to protect the existing podium, while expanding the building with a distinctive new tower. This resulted in the addition of an award-winning New York Skyline, which used polyethylene-coated pipes that circulate water year-round to help control the building's ambient temperature. The designer's materials for this tower—steel and glass—make it a less energy-efficient office building than New York City office buildings, relying on natural ventilation for approximately 75% of the year.

Fig 16. shows the main facade of Hearst Tower (23)

5.2.2.1. Glass facade system used in the tower

 **Fig 17.** shows the Hearst Tower and the user system in the interface (21)	Panelized Curtain Wall System Panelized Curtain Walling System + Photovoltaic Curtain Walls This system, sometimes called “Truss wall”, is designed from large panels that are manufactured off-site, mostly in factories, and each has a width determined according to the width of the vertical structure - Mullions - and a height of up to the height of an entire floor for the horizontal elements - Transom -, and the weight of a piece of it can reach 15 tons depending on the type of building cladding material used, whether it is stone or glass	Panelized Curtain Wall system was used.

5.2.2.2. Type of glass and thermal performance used in the tower

Illustrative images	Glass type, thermal performance and characterization
 **Fig 18.** shows the photovoltaic facade and low-emissivity glass (low E glass) (24)	• Low-E glass coating • It is a glass treated with metal coating layers that are characterized by low emissivity for long-wave radiation, i.e. infrared rays, which reduces the occurrence of heat gain from the outside to the inside by about 80% better than regular clear glass without a layer, thus achieving the best prevention of unwanted sun rays, especially in hot times. Double glass is used in the form of two layers of thin glass, 3 mm thick and sometimes 6 cm thick, between which there is a space filled with an inert gas (krypton - argon - olive) that acts as a thermal insulator that leads to a decrease in emissivity between the interior space of the building and the surrounding environment. Low-E glass has been developed to become self-cleaning • Photoelectric facade user The photoelectric facade is characterized by the feature of tracking the movement of the sun, which is an independent system that works with a mechanical and thermal control system Therohydrolic System, which works to integrate the components of the facade (windows - glass - breakers - optical technologies) with each other in an integrated system to track the movement of the sun during the day without the need for electromechanical control systems connected to the management system Building Operation • Thermal Performance To reduce solar gain, the building envelope contains high-performance low-emissivity glass, with integrated roller blinds that can be used to reduce glare and use low-emissivity glass (low E glass) U value = 0.26 in summer and U value = 0.28 in winter and SHCG value = 0.32, which led to the building being designed with minimum energy

efficiency requirements, saving energy by 26% less than the energy

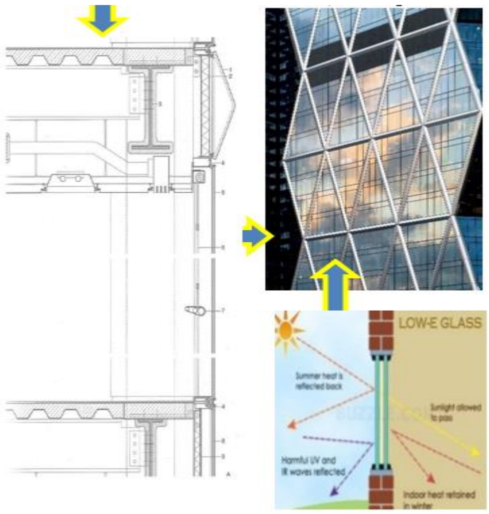


Fig 19**.** shows the treatments and glass used and the effect of solar radiation entering the low-emissivity glass (low E coating) on reducing solar radiation (25)

- The building's exterior cladding uses glass to reduce solar gain, the building envelope contains high-performance low-emission glass, with integrated roller blinds that can be used to reduce solar glare.
- - The facades are generally fully glazed and equipped with computer-controlled breakers that allow maximum natural light to enter and have the ability to track the sun's position in the sky through (Sensors) with pivot supports.
- - Smart technologies were used to protect against glare and excessive solar radiation, as the building is covered with tensile fabrics designed to shade and avoid direct natural lighting problems. These are perforated smart fabric fabrics coated with Taflon, stretched across aluminum masts tilted at an angle of (72°) and attached to the curtain wall from one end, while the other end is perpendicular to the facade and stretched to cables parallel to the facade. To reduce wind load on the structure, perforated fabrics were used in a way that does not obstruct vision, while at the same time protecting the facade from potential glare during some periods of the year.

Fig 20. shows the photovoltaic facade and low-emissivity glass (low E glass) (25)**.**

- The eastern and western facades of the building are covered with copper and do not contain openings to avoid direct solar radiation, as they contain central air conditioning units.
- The method of wrapping the building with perforated fabrics (Crbri form Woven Fabric) was studied through specialized computer programs to reach the best angle of inclination to avoid glare without depriving the view and external communication.
- The building uses a photovoltaic facade. The photovoltaic facade is characterized by the feature of tracking the movement of the sun, which is an independent system that works with the mechanical and thermal control system Therohydrolic System, which works to integrate the components of the facade (windows - glass - breakers - optical technologies) with each other in an integrated system to track the movement of the sun during the day without the need for electromechanical control systems connected to the building management and operation system.
- Features of the photovoltaic facade:
  1. Generating electrical energy.
  2. Protection from glare and solar radiation.
  3. The facade achieves the formative and functional requirements and reduces thermal loads on the building.
  4. Improving the efficiency of directing natural lighting.

5.2.2.3. Treatments on the facades used in the tower

5.2.3. Third: Shanghai Tower - Shanghai - China

Area: 380,000 m2

Construction date: 2009, completion date: 2015

Building type: Multi-storey

Number of floors: 128 floors

Architect: Gensler, American architectural firm Gensler

Building height: 632 m

LEED certification: LEED Platinum

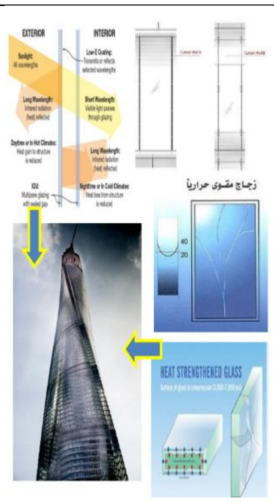
Number of elevators and escalators used in the tower: 97 elevators

Climate zone: Hot and humid The materials used by the designer in the construction of this tower, which are steel and glass, made it work as offices that consume less energy than office buildings in Shanghai by relying on natura l ventilation for approximately 75% of the year

Building design: The tower was designed in the form of a smooth vertical spiral that rotates at about 120 degrees and expands at a rate of 55% multiples and the tower works as a self-sufficient vertical city. It is a multi-use building of unique neighborhoods connected vertically. The design concept for the tower is based on a cylindrical shape of nine buildings stacked on top of each other, totaling 128 floors, each surrounded by an inner layer of glass facade. Between this and the outer layer, which twists as it rises, nine interior areas will provide a public space for visitors. Each of these nine areas will have its own atrium. The flowing, flowing shape of the tower is created from a circular triangle plan. This circular triangle is derived from the relationship between the curved bank of the Huangpu River, the Jin Mao Tower and the Shanghai World Financial Center. This attractive and distinctive shape will be a landmark in the city of Shanghai, representing China as a global financial power.

Fig 21. shows the main facade of Shanghai Tower (21)

5.2.3.1. Glass facade system used in the tower:

Illustrative images	Glass type, thermal performance and characterization
 **Fig 22.** shows reflective glass. Glass coated with a reflective layer (26)	• Heat-strengthened glass • Low-Iron SentryGlas ® interlayer • Insulated Glas • It is a glass also called SGP SentryGlas Plus SGP has a high strength, the load-bearing capacity of SGP laminated glass is twice that of PVB laminated glass • It works on the long-term weather resistance of the glazing systems SentryGlas interlayer 2- It can improve the system • Provide greater security, energy efficiency, noise reduction, healthy living, safety, and ease of maintenance • Allows the use of a light coating in conjunction with the interlayer for solar control • Glass is twice as hard as annealed glass and when broken, it shatters into fragments slightly larger than the fragments of fully tempered glass, and is the type generally used in glazing works that require additional durability • Transparent and high mechanical strength, good impact resistance Safety glass made of SGP interlayer has high safety performance: ,

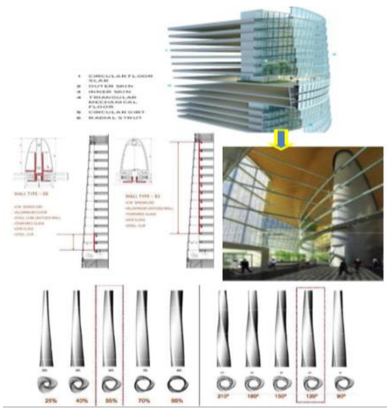


Fig 23. shows the treatments and glass used and the effect of solar radiation entering the glass, heat-strengthened.

bulletproof, hurricane-resistant glass

- Thermal performance as a result of using
- The exterior cladding of the building will be used: 12 mm low-iron heat-strengthened glass + 1.52 mm SentryGlas® interlayer + 12 mm Low-Iron heat-strengthened glass.
- Interior glass facade composition: 6 mm low-iron glass + 0.89 mm SentryGlas® interlayer + 6 mm low-iron glass + 12 air + 6 mm low-iron glass.
- The design of the tower's glass facade, which twists 120 degrees when it rises, aims to reduce the wind loads on the building by 24%. This reduces the amount of building materials needed.
- The double-layer insulating glass facade is designed to reduce the need for indoor air conditioning, and consists of advanced tempered glass with high tolerance to temperature changes, and consists of advanced tempered glass with high tolerance to temperature changes.
- A torsion rate with a scaling factor of approximately 55% and a 120 degree rotation can save up to 24% in structural wind loading and reduce cladding pressure compared to a tapered box with a basic case.

5.2.4. Fourth: Kingdom Center - Riyadh - Saudi Arabia

Area: 185,000 m2

Construction date: 1996, completion date: 2002

Building type: Multi-use building

Number of floors: 41 floors, underground: 2 floors

Architect: Ellerbe Becket

Building height: 302.3 m

Cost: 1.7 billion US dollars

Number of elevators and escalators used in the tower: 45 elevators and 22 escalators

Climate zone in which it is located: Hot, dry climate Materials used by the designer in the construction of this tower are steel, glass and reinforced concrete

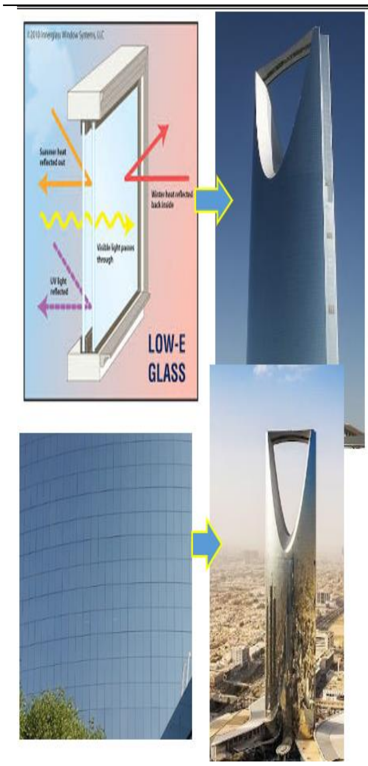
Building design: The design idea was adopted. Kingdom Tower is considered one of the prominent landmarks in the Kingdom of Saudi Arabia, as it enjoys wide fame in the region and the world, and it is one of the tallest towers in the world as a whole. This tower is considered one of the most important commercial markets in the Kingdom, as it is distinguished by its location and charming view of the city of Riyadh. The Kingdom Center was designed by the US-based architecture firm Ellerbe Becket in a joint venture with the Riyadh-based architecture and engineering firm Omrania & Partners. The Kingdom Center was selected as the best new high-rise building of the year in terms of design and functionality in the 2002 Skyscrapers.com Architectural Awards. The Kingdom Tower is considered the most important financial and economic center in Saudi Arabia; as the designers of the building wanted its building to look to the horizons of the future with a human perspective; the shapes used are characterized by simplicity, lightness, and fluid lines that anticipate a brilliant future characterized not only by technological superiority, but also by concepts of beauty and purity; to be a symbol of the city.

Fig 24. shows the Kingdom Centre Tower (23)

5.2.4.1. Glass facade system used in the tower

 **Fig 25.** shows the Kingdom Tower system used in the facade (21)	• Using the But glazed System • In this system, the main structure of the curtain wall, consisting of beams and columns, is assembled in an inconspicuous manner on the facade, then the glass is installed and the spaces between the glass panels are filled with silicone, which gives the facade a semi-continuous shape without clear horizontal and vertical lines.	Use the system But glazed System

5.2.4.2. Type of glass and thermal performance used in the tower

Illustrative images	**Glass type, thermal performance and characterization**
 **Fig 26.** shows reflective silver glass and low-emissivity glass (low E glass(27)	• Double glazing of silver reflective glass and low-E glass coating • Silver reflective glass is one kind of heat reflective glass, it adopts magnetic coagulation method to spray several layers of metal and metal oxidizing materials on the glass surface in super high vacuum chamber after coating process, due to its energy saving functions and features 1. Good physical and chemical performance, permanent surface adhesion 2. Excellent thermal performance such as good NO value, SHGC. 3. Multiple options for exterior appearance such as gray, gray-blue, light blue, and neutral colors, 4. Super good uniformity with color difference 1.5>AE • Double glazing from a layer of reflective silver glass and a low-emissivity layer is glass treated with metal coatings that are characterized by low emissivity for long-wave radiation, i.e. infrared rays, which reduces the occurrence of heat gain from the outside to the inside by about 80% better than regular clear glass without a layer, thus achieving the best prevention of unwanted sunlight, especially in hot times. Double glazing was used in the form of two layers of thin glass, 3 mm thick and sometimes 6 cm thick, between which there is a space filled with an inert gas (krypton-argon-olive) that acts as a thermal insulator that leads to a decrease in emissivity between the interior space of the building and the surrounding environment. Low-E glass was developed • Thermal performance • To reduce solar gain, the building envelope contains high-performance low-emissivity glass and low-emissivity glass (low E glass) was used with a value of U=5.36 in the summer The U value = 0.28 in winter and the SHCG value = 5.92 a Dt led to the design of the building with the minimum energy efficiency requirements, saving energy by 40% less than the energy.

5.2.4.3. Treatments on the interfaces used in the tower

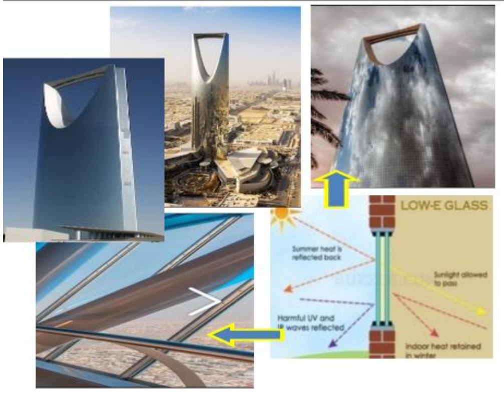


Fig 27. shows the treatments and glass used and the effect of solar radiation entering the reflective silver glass and .low-emissivity glass (low E coating) on reducing radiation

1. The building's exterior cladding contains reflective silver glass and, on high-performance low-emission glass to reduce solar gain, environmentally friendly and reduce energy consumption by 40%
   - It consists of insulating and heat-resistant glass, which helps reduce energy consumption inside the tower.
2. The eastern and western facades of the building are copper-clad and do not contain openings to avoid direct solar radiation gain, as they contain central air conditioning units

- Features of reflective silver glass:

1. Good physical and chemical performance, permanent surface adhesion
2. Excellent thermal performance such as good value, SHGC.
3. Multiple options of external appearance such as gray, light blue, and neutral colors, 4- Good super-uniformity with color difference 1.5>AE

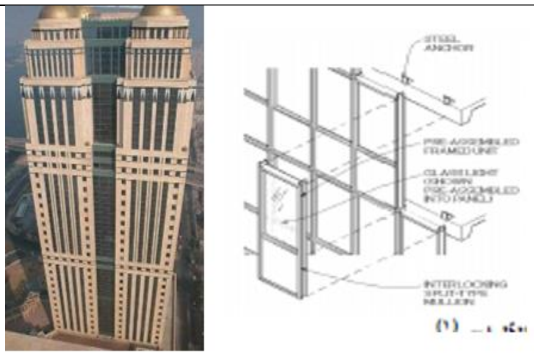
5.2.5. **Fifth: Nile City Tower - Cairo - Egypt**

Area: 59,500 m2

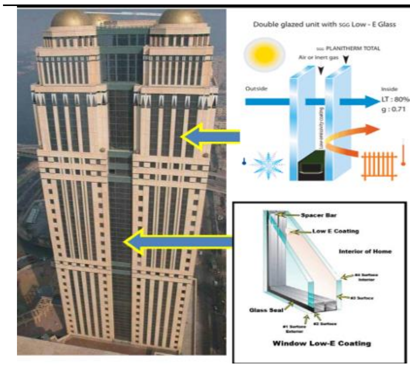
- Construction date: 1998, completion date: 2004
- Building type: Multi-storey building (entertainment, residential, administrative)
- Number of floors: 35 floors, underground: 4 floors
- Architect: Atelier d'Art Urbain, Belgium
- Building height: 142 m
- Cost: 174 million US dollars.
- Number of elevators and escalators used in the tower: 24 elevators, and 4 escape stairs)
- Climate zone in which it is located: Hot and humid climate. The facades were designed to withstand temperatures from double insulated and reflective glass
- Building design:
- The design idea for the tower was adopted: Due to the high price of the land, the architectural designer exploited the total area of the land (which is 16 thousand square meters) where the first three floors (ground, first and second) were built on the entire area of the land, then the building is separated into three blocks: the northern tower and the southern tower with a height of 34 floors (with an area of 1700 square meters for the tower) and the hotel with a height of 24 floors (with an area of 2000 square meters). It is considered one of the most important projects in Egypt and is characterized by the speed of implementation

Fig 28. shows the Nile City Tower (23)

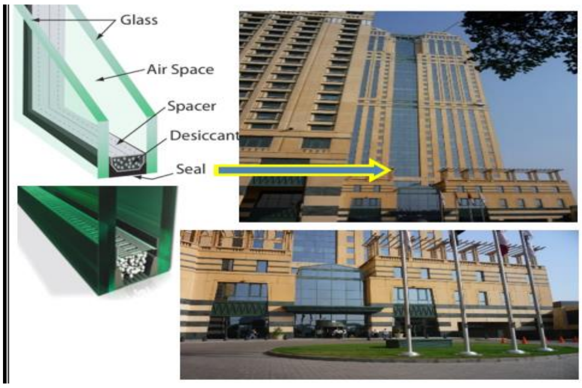
5.2.5.1. Glass facade system used in the tower

 **Fig** 29. shows the Nile City Tower and the user system in the interface (21)	The assembled system is a system similar to the panel system, but the unit sizes are smaller, and also vary in size, and these units are installed on a pre-prepared structural frame**.**	Use of unit system or aggregate system unutilized Curtin Wall

5.2.5.2. Type of glass and thermal performance used in the tower

Illustrative images	**Glass type, thermal performance and characterization**
 **Fig 30.** shows reflective glass, glass coated with a reflective layer.	• Insulated double glass 6 MM used in the external cladding of the building. Glass consisting of two layers • It includes two or more panels with different dimensional gaps between them. The cavity or void is sealed, resulting in cavities of 6 mm: 20 mm between the panels. They can be filled with dehydrated air or inert gas or mechanical equipment. Sun shading devices are placed in order to block direct sunlight in the summer and prevent glare without reducing the lighting levels in the room or the amount of energy gained in the winter. • Thermal performance resulting from the use of insulated double glass U=0.85 and the use of a solid insulated building block U=0.4950 led to the design of the building with the minimum energy efficiency requirements in ASHRAE 90.1-2004, which is 20% more efficient

5.2.5.3. Treatments on the interfaces used in the tower

 **Fig 31.** shows the treatments and glass used and the effect of the entry of solar radiation into the low-emissivity glass (low E coating) on reducing solar radiation.	- The exterior cladding of the building uses double-layered glass, which is insulated double glazing. It includes two or more panels with different dimensional spaces between them. The cavity or space is sealed, resulting in cavities of 6 mm: 20 mm between the panels. Sun shading devices are placed in order to block direct sunlight in the summer and prevent glare without reducing the levels of lighting in the room or the amount of energy acquired in the winter. The exterior facades are finished with GRC material.

- The impact of technology elements on the architectural formation of high-rise buildings, comparing these samples under study
- Depths of voids in relation to facades
- Proportions of openings and their relationship to directions (actual proportion of openings)

First: Depths of voids in relation to facades for the five towers under study

Fig 32. shows the depths of the voids in relation to the facades of the towers under study.

- By reviewing the average depths of the spaces in relation to the facades of the five towers under study, it was found that the ratio of 1:2 is the highest ratio, followed by the ratio of 1:1.5 in the design of the spaces of the five towers.
- We note that the average ratio of 1:2 in Burj Dubai is 94%, the ratio of 1:1.5 is 2%, and the ratio of 1:1 is 4%.
- We notice the average ratio of 1:2 in Hearst Tower is 22%, the ratio of 1:1.5 is 52%, and the ratio of 1:1 is

26%

- We notice the average ratio of 1:2 in Shanghai Tower is 32%, the ratio of 1:1.5 is 48%, and the ratio of 1:1 is 20%
- We notice the average ratio of 1:2 in Kingdom Tower is 6.1%, the ratio of 1:1.5 is 47.8%, and the ratio of 1:1 is 46.1%
- We notice the average ratio of 1:2 in Nile City Tower is 63%, the ratio of 1:1.5 is not -%, and the ratio of 1:1 is 37%
- Second: The proportions of the openings and their relationship to the directions of the five towers under study.

Fig 33. shows the depths of the spaces in relation to the facades of each of the towers under study.

By reviewing the proportions of spaces and their relationship to the directions in addition to the opaque parts of the five towers under study, represented in the graph showing the proportions of the opaque parts in the Burj Dubai, the smallest tower, followed by the Shanghai Tower, followed by the Kingdom Tower, followed by the Hearst

Tower, followed by the Nile City Tower. The proportions of the cover parts in the Shanghai Tower, the largest tower, followed by the Dubai Tower, followed by the Kingdom Tower, followed by the Hearst Tower, followed by the Nile City Tower. The proportions of the actual parts in the Burj Dubai, the largest tower, followed by the Shanghai Tower, followed by the Kingdom Tower, followed by the Hearst Tower, followed by the Nile City Tower. By reviewing the previous study, it is to create an integration between the concepts of smart architecture and its tools with the principles and techniques of environmental architecture, then studying a new architectural trend that can be called (high efficiency and architectural performance in high-rise buildings) by developing a methodology to achieve energy efficiency for new high-rise administrative buildings in Egypt, reaching an environmental approach in the process of achieving energy efficiency by using treatments on the envelopes of smart and sustainable buildings and also reaching standards and application mechanisms to activate concepts and standards for improving building efficiency by applying the latest advanced construction systems and modern building materials to find the relationship between the use of treatments on building envelopes in a methodology to reach the highest performance of energy efficiency for the outer envelope of the high-rise administrative building by modern technologies in an applied approach, and this represents a new field of study to find scientific and practical solutions to the energy problem in general and rely on the integration of design techniques and the use of modern treatments to achieve thermal comfort to improve the thermal performance of glass facades and their impact on modern technological systems and maintains thermal comfort for occupants of the space, which works to reduce energy The consumed energy, pollution rates and the individual's feeling of thermal comfort inside the building through the elements of an integrated system to achieve thermal comfort to improve the thermal performance of glass facades and their impact on modern technological systems and maintain the thermal comfort of the occupants of the space. This works to reduce the consumed energy, pollution rates and the individual's feeling of thermal comfort inside the building through the elements of an integrated system of treatments specific to the facades, whether at the level of the different systems of glass facades and the type of glass used and the techniques and treatments specific to the facades.

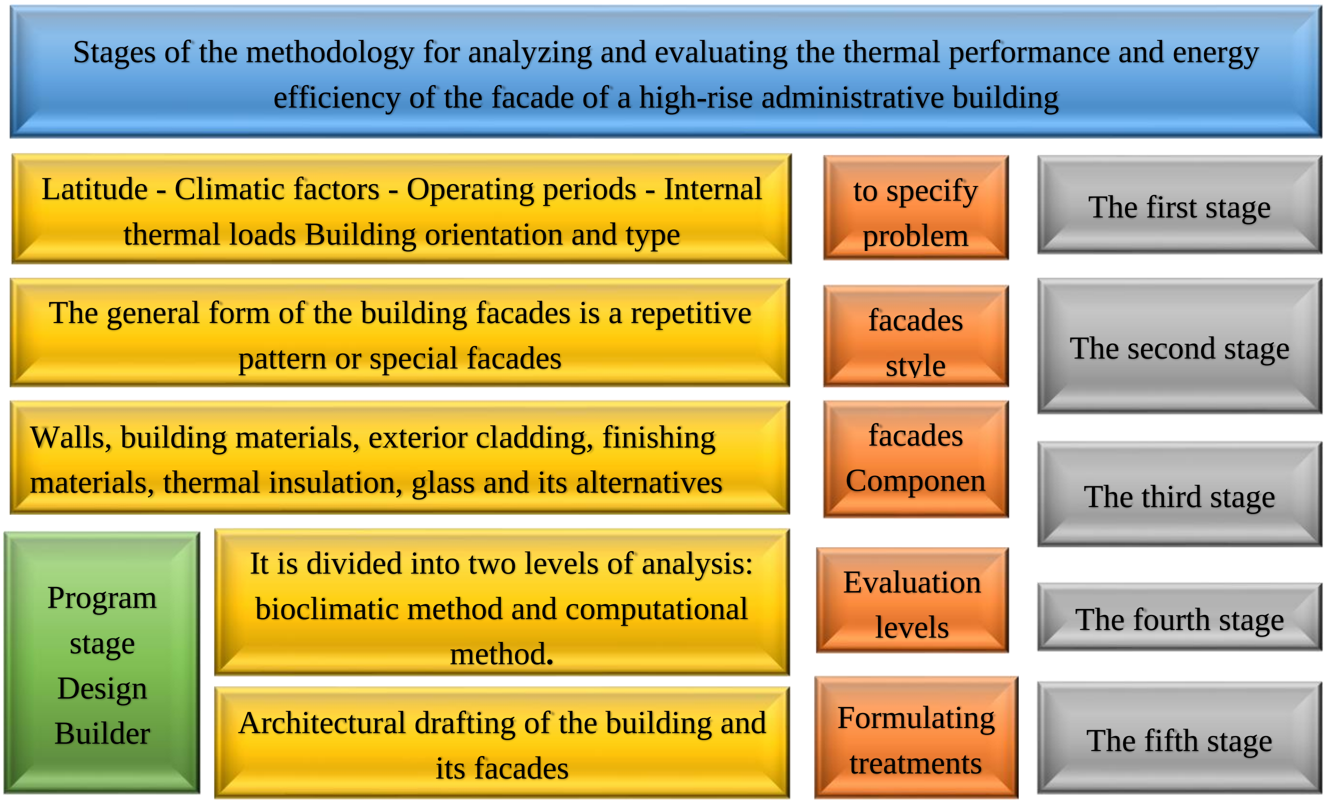


Fig 34. shows the proposed approach for each of the zodiac signs under study.

6. General results

- Through smart design, sustainable smart skyscrapers provide spaces with ideal conditions for human well-being in the broadest sense while using minimal non-renewable resources.
- Using nanotechnology techniques in construction, with a focus on lighter and stronger coatings, low maintenance, cementitious materials reinforcement, fire retardants, insulation, and nanosensors in construction.

- The envelope of high-rise buildings has an effective role in the performance and presentation of any building, it is an integral part of any building components and bears different responsibilities at the same time.
- Use light sensors to measure the amount of natural light and react automatically depending on what is required
- Use green architecture and sustainability techniques, including (energy conservation and rainwater collection to be used to cool the lobby in the summer and humidify it in the winter, and the rainwater collected from the roof is fed to a central tank and used for irrigation
- The LEED system has been applied to high-rise administrative buildings.
- Use pipes covered with polyethylene that circulate water throughout the year to help control the ambient temperature of the building.
- • The use of nano-treated glass called Low E works on energy efficiency in the building and reduces its cost to achieve appropriate thermal performance in hot environments by using nano-treated glass with a low-emission coating with solar control coating and reflective coating
- Achieving proposals that include the foundations and standards that determine the optimal use of glass facades to use them correctly in our local environment and make the most of them and allow for the provision of more free and independent solutions, and the use of new materials with properties Features that achieve the concepts of sustainability, reduce energy consumption, reduce environmental impact, create a comfortable work environment, improve users' health and increase their productivity rates.
- Implementing diverse and innovative designs for high-rise glass facades that suit the Egyptian architectural environment and improve the functional and aesthetic performance of glass in architecture, and can be implemented using different techniques such as digital printing and leaded glass.
- Finding many alternatives and solutions to the problems of designing high-rise glass facades by taking advantage of different methods for fixing and assembling them, which can be implemented using modern techniques and suit the Egyptian architectural environment.

7. General recommendations

- Architects should use the role of technological development in environmental control and energy efficiency in high-rise buildings to achieve user comfort.
- The complex interaction between the various structural elements of iron and concrete must be studied, with the complex behavior of the building predicted before construction using specialized computer programs.
- Work must be done to reduce reliance on artificial lighting sources and exploit natural lighting by choosing the best types of glass according to the environment in which the building is designed.
- The use of nano-treated glass, emission-reducing coating, and solar control coating must be generalized in energy-consuming buildings to save energy.
- Increase reliance on smart construction materials, which may include modern technologies to reduce energy consumption and excess heat gain in the summer in hot areas and heat loss in the winter.
- Conduct a study to evaluate the thermal performance of high-rise administrative buildings in Cairo and the rest of the Egyptian governorates and submit a proposal to treat these buildings through the systems reached by the research to increase the effectiveness of thermal comfort for users.
- The necessity of moving towards benefiting from modern technologies in designing high-rise glass facades to achieve environmental compatibility in Egyptian architecture.
- High-rise glass facades must achieve the required utilitarian and aesthetic goals such as social, architectural, constructional and environmental goals, which are represented in benefiting from natural lighting by choosing the appropriate degree of transparency, and climatic comfort by controlling (heat, ventilation and humidity).
- Continuous development of glass manufacturing processes to find new types, and obtain functional and aesthetic performance in the external and internal architectural fields while being compatible with the environment.
- Choosing appropriate construction solutions for facade divisions and loads to which the elements of the design facades are exposed, while studying the sectors that can be used while maintaining the required architectural form.
- Increasing interest in specialized studies in the fields of environment and design.

Conflicts of interest

The authors declare no conflicts of interest.

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