The Effect of Contemporary Construction Materials in Environmental Performance of Building Using Building Information Modeling

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***Abstract* - The principles of environmental design have become the basis of architectural thought, starting from the early stages of the design process and ending with the selection of appropriate building materials in order to achieve sustainable external envelope. Architects began to use new materials in order to reach an environmental design for the building, which led to a qualitative architectural leap that led to the discovery of building materials that contribute to achieving environmental efficiency. This thesis aims to study modern building materials and their environmental impact on the building by achieving thermal comfort by understanding and studying various environmental characteristics. This thesis relies in its methodology on a theoretical study of a group of previous studies in this field, presenting a theoretical study on the environmental performance of the building and the study of modern building materials and their environmental characteristics and their impact on the environmental efficiency of the building, then Building information modeling technology and how to benefit from it in analyzing the environmental performance of the building was studied, then it dealt with an analytical study of global, regional and local experiences to study how to deal with the environmental characteristics of modern building materials. Then an applied study in which the current situation in the case study is monitored, and the current environmental performance of the building is measured using one of the environmental performance analysis programs of the building, then the application of materials with different environmental characteristics and comparing the results.**

Keywords: Contemporary Construction Materials, Environmental Performance, Building Information Modeling, Building Envelope, Glass, Green Building Studio.

I. INTRODUCTION

The evolution of building materials has led to multiple design solutions whether functional or environmental adopted by architects due to the technical revolution that allowed designers to achieve many design ideas especially at the level of building systems and materials; This has led to a multiplicity of methods that make the most of the technological boom in building material characteristics. Access to an indoor environment with adequate environmental performance rates and reduced energy consumption rates remains a key design objective, contributing to the characteristics of the building materials in the largest proportion and selected through the design in a way that depends on the surface knowledge of the materials used without deepening to fully utilize the properties of the materials used, whether based on the characteristics of the building materials themselves or the technology of their design and implementation.

The external envelope of the building represents the transition point between the external environment and the internal spaces, which is the key element in achieving thermal comfort. Through Egypt's global orientation in increasing the environmental performance of buildings and seeking to reduce the energy consumption in buildings, the research seeks to study in detail the characteristics of building materials and how to exploit their properties.

BIM “Building Information Modeling” is one of the most effective design technologies through which the designer can recognize overlaps between different disciplines, proposed design alternatives through which the designer can access the optimal environmental performance of the building through measurability, monitor thermal and environmental performance measurements of the outer envelope and monitor appropriate processing and building material characteristics.

II. Environmental performance of the building and building materials

2.1 Environmental performance of the building

2.1.1 Environmental problems related to buildings in dry hot spots. Buildings in dry hot spots face various environmental problems, including strong solar radiation on the building's outer envelope and high temperature in the internal spaces of the building resulting in thermal discomfort within the building. [1]

2.1.2 Climate Design. The primary objective of climate design is to achieve thermal comfort suitable for vacuum users. This is achieved through several steps through which the site's climate is studied, the initial design of the building is concerned environmentally, and the characteristics of environmental materials are studied. [2]

2.1.3 Building Envelope. The outer shell of any building or urban vacuum is a direct expression of the functional element behind this shell, as well as the structural element used in the building, whether of reinforced concrete, iron, glass or other various construction materials and consists of ceilings, walls, exterior openings and landscape. [3]

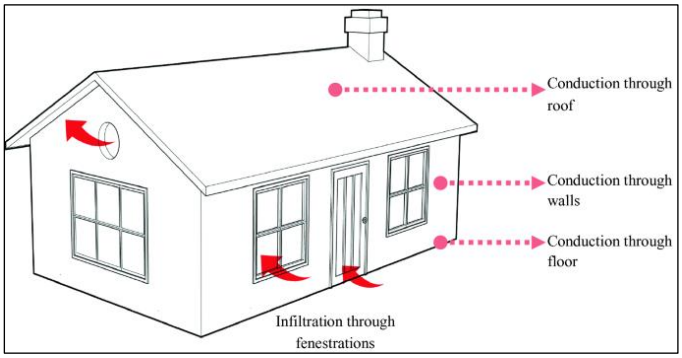

Figure 1: Building Envelope Components

2.1.4 Elements affecting the quality of the building's environmental performance. Indoor environmental quality is an indicator of internal conditions that provide convenience for vacuum users while respecting the determinants of the external location of construction, ventilation agents, natural lighting, wind, energy, the use of ores and environmentally friendly materials and the realization of convenience for vacuum users. [4]

2.1.5 Elements Treatments used to achieve thermal comfort. In dry areas, the need to retain moisture inside the chambers while providing a cold air stream and protecting the chambers from external heat transmission is the basis for the architectural treatments to which the architect has resorted - find the following architectural treatments:

1- The use of outdoor and indoor parachutes and their effective role in alleviating the intensity of heat and sunlight on buildings, thereby protecting the interior spaces of building elements from warming.

2- Use plant elements within courtyards or on the walls and perimeter of the building to reduce the reach of sunlight.

3-Use and inspect heat absorbing building materials at night without allowing them to penetrate the wall.

4-Reduce the number and spaces of external openings and place them in high areas of walls or directed at inside the inner courtyard if any.

5-Use aesthetic and inclined coverings and ceilings that disperse the fallen sun.

6-Use horizontal and vertical sun breakers, beverages and sweatshirts to prevent sunlight reaching the inside of the spaces.

7-Use light colors to paint surfaces and interior and exterior walls.

8-Use air parking to catch air into spaces and use water elements to soften air.

9-Reduce the spaces of external interfaces exposed to external heat.

10-The accumulation and stacking of blocks provides shades and shaded areas and reduces sun-prone spaces.

11-Use double ceilings and walls to allow air movement between them and reduce the effect of sunlight.

2.2 Building Materials

2.2.1 Classification of building materials. Building materials serve as special tools to help care about the environment and make it healthier. Building materials are divided into several types, including smart (modern) building materials that deal with the environment and various environmental factors to achieve the environmental efficiency of the building and are classified as follows:

1- Natural building materials.
2- Manufactured building materials.
3- Blended building materials.
4- Smart building materials.

2.2.2 Properties of building materials. The environmental performance of the building is controlled by knowing and studying the characteristics of different environmental building materials and how to control them to fit the different climatic characteristics of the surrounding environment of the building to achieve the maximum environmental efficiency of the building and one of these thermal properties.

2.2.3 Impact of modern building materials on the environmental performance of the building. Modern building materials change the way construction is done, today's materials are eco-friendly, reliable, durable, airy and lightweight such as:
- Steel and steel are one of the most used materials in modern skyscrapers and office buildings, because of their strength, durability and lightness, steel is used as frames for windows, doors, railings and door handles for many modern buildings.
- Glass is one of the most used materials in contemporary architecture. Over time, glass has been redeveloped as a building material using low thermal insulating glass and lower U value which helps reduce the building's energy requirements, benefiting the environment.
- Plastic can actually offer a smart solution as building materials for most modern buildings. Due to our high levels of plastic production, its recycling and reuse in architecture or bioplastics is becoming increasingly common and has a positive impact on the environment.
- It has high tensile strength, sound absorption and other features such as heat resistance and electrical resistance make it an exceptional material for use in modern architecture.
- Easy transportation and repair and availability of comfortable sizes and a variety of colors and textures make it a popular choice among designers. Today's modern building materials industry works on the concept of recycling in order to achieve sustainability goals.

- Reducing or eliminating health risks is an example of the use of lead in antiquity against steel.
- Longer production life of facilities due to improved physical characteristics and thus increased return on investment.
- For some construction projects, the fastest completion time is a case in point for road projects using fast-drying cement.

2.2.4 Glass. Glass is one of the oldest finishing materials used by the designer in all buildings, whether in exterior openings or the design of entire glass facades. It is the essential element for entering natural lighting inside the buildings and is therefore indispensable in the design of residential, administrative or commercial buildings.

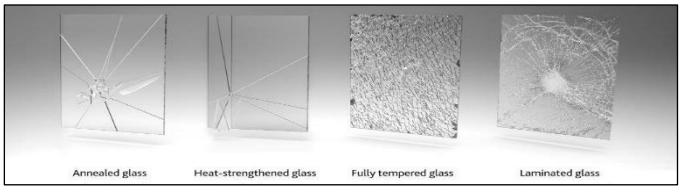

Figure 2: Types of Glass

Glass is the essential element of the outer casing that allows the natural lighting of the building to enter and is directly connected with direct sunlight, so the glass has environmental factors:

1- Thermal permeability (U)
2- Thermal resistance (R)
3- Solar Heat Gaining Coefficient (SHGC)
4- Visual Transmission (VT)

By studying and controlling their values, the maximum environmental efficiency can be reached and the amount of lighting inside the building can be controlled and the temperature of the building's internal spaces controlled.

2.3 BIM

This technology is key to the design and documentation methodology and has changed the designers' and executors' perception of the entire construction process from the initial design phases to the operational drawings phase, to the actual implementation phase, and finally to the post-implementation management phase of the building. [5]

2.3.1 Features of Building Information Modeling. Glass is one of the oldest finishing materials used by the designer in all buildings, whether in exterior openings or the design of entire glass facades. It is the essential element for entering natural lighting inside the buildings and is therefore indispensable in the design of residential, administrative or commercial buildings. [6]

- Fast performance, quality and high productivity

Design and documentation processes (tables, quantity specifications,... etc.) are simultaneously, rather than sequentially, at any stage during the design process any requirement, whether a drawing or a schedule... etc., as well as in the implementation phase, the outlet can extract quantities, prepare cost sheets, even factory instructions regarding the installation and installation of building components.

- Improved design

During the design process, the architectural team needs to track possible design options and alternatives, and the construction information model allows for this through the availability of information and the possibility of developing, studying and comparing multiple design alternatives to choose the optimal solution simultaneously with the model.

- Cost Control

Through the model's ability to provide information, tables and quantities of building components attached to the building database and the calculation of quantities with cost determination, as well as in the implementation phase, the model provides very accurate information that reduces the cost of the building's implementation management process.

- Better coordination at work

The information chain between the task force has many opportunities for poor transition, most information is reproduced abundantly as a way of ascertaining the error, while the construction information model provides the cooperative environment for all the disciplines involved in the project, so we can provide most of the lost efforts and improve the communication process between the task force, focusing more time on improved design and accelerated implementation.

- 3D Simulation

Building information modeling allows a 3D simulation of the building with all its components. This simulation goes beyond showing the systems used in the building to demonstrate the impact of environmental changes on the building's design and on calculating the quantities of materials and estimates of the time of implementation. For example, the simulation enables us to see the effect of sunlight on the building in the middle of the day and illustrate the importance of using sunbeds for the customer.

2.3.2 Role of Building Information Modelling in Sustainability. To improve the overall design of the building, BIM can play a significant role in its ability to provide the necessary information. They provide the perfect benefit for sustainable building design through integrated project delivery (IPD) as well as improved design. [7]

NO.	Sustainability Field	Benefit
1	**Building Orientation**	Determine the best direction to reduce energy costs
2	**Building Mass**	Building Block Analysis for Optimized Outer Cover Construction
3	**Day Lighting Analysis**	Reduce lighting and cooling loads
4	**Water supply**	Reduction of the building's water demand
5	**Energy Modelling**	Reduce energy requirements and analyze renewable energy options to contribute to reducing energy costs
6	**Sustainable Materials**	Reduce material requirements and use recycled materials
7	**Site Management**	Reduction of waste and carbon emissions

2.3.3 BIM 3D Modeling Software. BIM applications have different computer software to support access to the production of accurate, efficient and constructable construction model, BIM software should be able to import and export data seamlessly to allow the sharing of smart data. [8]

2.3.4 BIM 3D Simulation Software. One of the most important environmental performance analysis software for the building is the "Green Building Studio" program is an Autodesk website that makes all environmental building performance analyses and can make different design alternatives without reference to the building's original model and gives comparisons between different alternatives.

2.4 Case study of building used BIM in Materials Selection (Siemens Building). Siemens Building is one of the most energy efficient buildings in the region, based on modeling and simulation where the building's annual power consumption is 109.5 kWh/m2, it is much lower than commercial buildings in Abu Dhabi. [9]

2.4.1 Geographical location of the building and study of its environmental and climatic characteristics. The Siemens building is in the UAE, in one of the most climatic areas with extremely high summer temperatures, limited freshwater and high evaporation rates. [10]

Abu Dhabi has a dry hot climate consisting of sunny weather with rare rainfall. Humid temperature can reach 32 ° C (90° F) while dry temperature often exceeds 40 ° C (104° F) in summer. [11]

Figure 3: Geographical location of Siemens Building

2.4.2 Architectural specifications of the building. The total built-up area of the building is about 24000 square meters, while the net interior area is about 21000 square meters, where the building can accommodate about 1300 tenants and represents approximately 18 m2 per person.

The structure of the building has a highly insulated interior interface and sealed court designed to reduce thermal conductivity and lightweight aluminum external shading system reducing solar heat acquisition while increasing daylight.

2.4.3 Study of materials used in the envelope and their environmental impact on the building. The building's facades are designed to prevent air leakage to reduce heat conductivity. In addition, the outdoor shade is manufactured from lightweight aluminum to reduce heat acquisition from sunlight while providing the greatest amount of external natural light and reducing CO2 emissions.

The building was built from low carbon cement and 84% recycled aluminum in addition to other certified materials that are delivered from the local market.

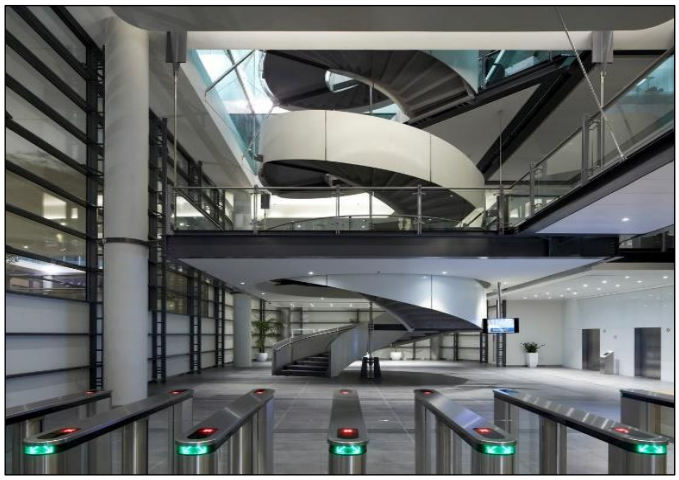

Figure 4: Using recycled materials inside the building

2.4.4 The type of glass used and its environmental impact on the building. The windows are thermally insulated aluminum frames and double glass panels since the glass is fully shaded the glass used does not require the low value of the Solar Heat Gaining Plant (SHGC) to meet the solar control requirements.

By applying BIM technology, double glass was chosen instead of triple glass because triple glass was considered a much more expensive alternative and inert gas was not used among the glass panels due to possible leakage in the future.

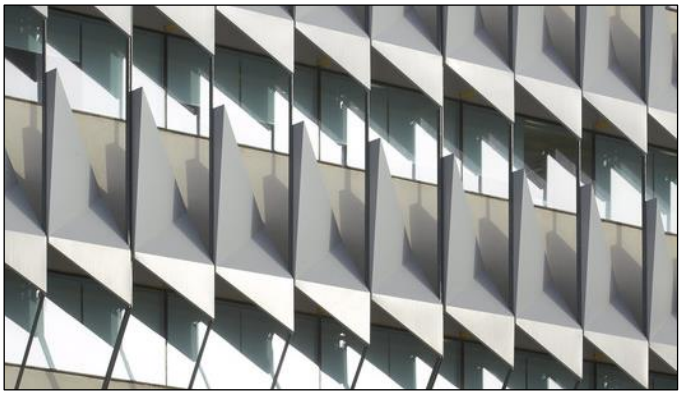

Figure 5: Glass used in building facades

2.4.5 Designer's utilization of modern technology in project design. External shading has been used as one of the most important interventions adopted for the interface design which reaches almost 100% of all glass spaces and external shading elements are not identical in all interfaces but are different for each direction according to the properties of each interface's fallen radiation.

The external material has a very reflective color and light color to increase the penetration of indirect light into the building and reduce heat absorption from direct solar gains.

III. RESULTS AND DISCUSSIONS

1- Buildings in dry hot spots faced various environmental problems as a result of the building's designers' disregard for the environmental and climatic characteristics of the project site resulting in a loss of thermal comfort in the internal spaces of the building.
2- The climate design aimed at achieving the thermal comfort of the vacuum users by following a design methodology that ensures thermal comfort in the initial design stages of the project and taking advantage of the environmental characteristics of the building materials.
3- Monitoring the most important climatic (environmental) characteristics affecting the achievement of thermal comfort in the internal spaces of buildings, and the most important architectural treatments that increase the efficiency of the building's environmental performance.
4- Monitoring the importance of building materials used in the building's outer envelope and their role in enhancing the environmental performance of the building's internal spaces as a link between the external environment and the internal spaces of the building.
5- The glass surfaces in the exterior of the building are the weakest point that allows for rapid thermal transport between the external environment and the internal spaces of the building, so the chapter aimed to study the detailed environmental characteristics of the building material (glass) to reach the best way to control thermal transmission rates for the thermal comfort of the internal spaces of the building.
6- Monitoring the importance of modelling construction information by simulating the 3D building to select the best climate-friendly outer envelope material for the building's environment for maximum environmental efficiency.
7- Monitoring the importance of the building's environmental performance analysis programs and use them to simulate the exterior environment and all the interior and exterior elements of the building to access materials suitable for external climatic conditions to achieve the thermal comfort of the internal spaces of the building.

IV. CONCLUSION

- Using modern building materials and knowing their environmental characteristics and optimizing their exploitation using modern technology such as modeling construction information leads to optimal environmental efficiency of the building and access to appropriate environmental performance of spaces within the building and achieving thermal comfort and reducing the energy used for lighting and ventilation.

REFERENCES

[1] Wafaa, s. and f. Khaled (2019). "A resource-based study that contributes to the use of smart materials to achieve sustainability within the context of contemporary architecture." Journal of Advanced Engineering Trends 38: 1-19.

[2] Abbas, Ah. p. a. Ageing and s. p. Hassan (2019). Climate design has impacted users' thermal comfort, Sudan University of Science and Technology.

[3] Al-Issawi, M. p. a. " (2003). The exterior shell design of the building has an impact on the thermal acquisition and the thermal departure of users. Master's degree in environmental design, Cairo University.

[4] Bakr, p. Rahman, Hussein, S. Mohammed and S. J.M. a. Design (2021). "Standards of the quality of the interior environment of the design halls and their impact on energy consumption." 1(2): 86-111.

[5] Krygiel, E. and B. Nies (2008). Green BIM: successful sustainable design with building information modeling, John Wiley & Sons.

[6] Azhar, S., M. Hein and B. J. B. S. Sketo (2008). "Building Information Modeling (BIM): Benefits, RisNs and Challenges." 18: 11.

[7] Shareef, S. L. and H. Altan (2016). Building sustainability rating systems in the Middle East. Proceedings of the Institution of Civil Engineers-Engineering Sustainability, Thomas Telford Ltd.

[8] Mohamed, A. E. (2019). "The implementation of building information modeling (BIM) towards sustainable construction industry in Egypt" The pre-construction phase".

[9] Abisaab, M. (2014). "High Performance Buildings in Hot Arid Regions-A Case Study for the Siemens Building in Masdar City." Journal of Architecture and Planning 26: 105-120.

[10] St Clair, P. J. E. D. G. (2009). "Low-energy design in the United Arab Emirates–Building design principles." 1-10.

[11] Aspinall, S. J. U. A. E. A. N. P. (2001). "Environmental Development and Protection in the UAE." 278.