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Using Building Information Modeling Technology as an Aid Tool for Sustainable Office Building Design.

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Using Building Information Modeling Technology as an aid Tool for Sustainable Office Building Design

استخدام تكنولوجيا نمذجة معلومات المبانى كأداة مساعدة في تصميم مبانى ادارية مستدامة

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KEYWORDS:
Building information modeling; sustainable buildings; Revit Architecture; energy consumption; Office buildings.

الملخص العربي:- **إن المباني الخضراء و نمذجة معلومات المباني يعدان اثنين من الاتجاهات الرئيسية في مجال الهندسة المعمارية والبناء والتشييد. لذلك، لتحقيق كفاءة استهلاك الطاقة في مباني المكاتب، والتي تستهلك كمية كبيرة من الطاقة مقارنة بأنواع المباني الأخري، فإن المباني المستدامة هي الخيار الأفضل.**
يهدف هذا البحث إلى تحديد العديد من التصاميم المستدامة التي يمكنها تحسين أداء الطاقة في المبانى الاداريه باستخدام برامج مثل Revit Architecture 2018 and Green Building Studio . تم اختيار المبنى الإداري لكلية الهندسة بجامعة المنصورة ليكون بمثابة دراسة حالة توضح أي من المواد التي تساعد في تقليل استخدام الطاقة للمبنى. في النهاية، تم اقتراح بعض التصاميم البديلة والمستدامة للمساعدة على توفير المزيد الطاقة.

***Abstract*—Building information modeling (BIM) and green building are currently two major trends in the architecture, engineering and construction (AEC) industry, so, to achieve the efficient energy consumption in Office buildings, which consume a large amount of energy compared to other building types, Sustainable buildings are the best choice. This research aims to identify several sustainable designs that can improving the energy performance of office building by using simulation programs (BIM) such as Revit Architecture 2018, Green Building Studio. Administrative building of Faculty of engineering at Mansoura is chosen to be the case study to demonstrate which materials have helped in reducing the energy use of the building. At the end, alternative, sustainable designs suggested for more energy savings.**

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I. INTRODUCTION

AS we are currently fully aware about energy crisis, climate change, the direct impact of building design on human health and the previously mentioned dynamics, there are current trends to green buildings and sustainable design. Green buildings sometimes include measures to decrease energy consumption – both the embodied energy used to extract, transport, process and install building materials as well as the operational energy, such as heating, cooling, and providing power for equipment. To reduce the thermal effects of energy consumption during the operational stage, high-efficiency windows and isolation in walls, floors, and ceilings help to increase the efficiency of the building.

Workspace is the container of people, process, and tools. Without being configured and well designed; it may have a negative impact on its occupants. People, processes, and tools are vital to accommodate workspace, which, when brought together in an appropriate way, enable organizations to operate business [(1)].

Building Information Modeling (BIM) is an evolving technology, continuous research and software development that offers opportunities to address current problems and improve the process. Although BIM technology is still relatively new, those who have used it have indicated that the creation of a 3D model with associated information reduces design errors, improves design quality, shortens construction time, and reduces construction costs significantly [2]Since 2007, the U.S. General Services Administration (GSA) has required the use of BIM on all major projects, and, although not required at this time, GSA is encouraging ‘‘exact energy estimates in the design process’’ [3]. With the rising cost of energy and growing environmental concerns, the demand for sustainable building facilities with minimal environmental impact is increasing. The most effective decisions regarding sustainability in a building facility are made in the early design and pre-construction stages. Fig 1 shows sustainable strategies in NOAA Southwest Fisheries Science Center [4]. In this context, Building Information Modeling (BIM) can help to analyze the performance of the complex buildings to ensure an optimized sustainable buildings design [5].

The research focuses on BIM concepts in achieving sustainable office building and arriving to reduce the amount of energy consumed by buildings

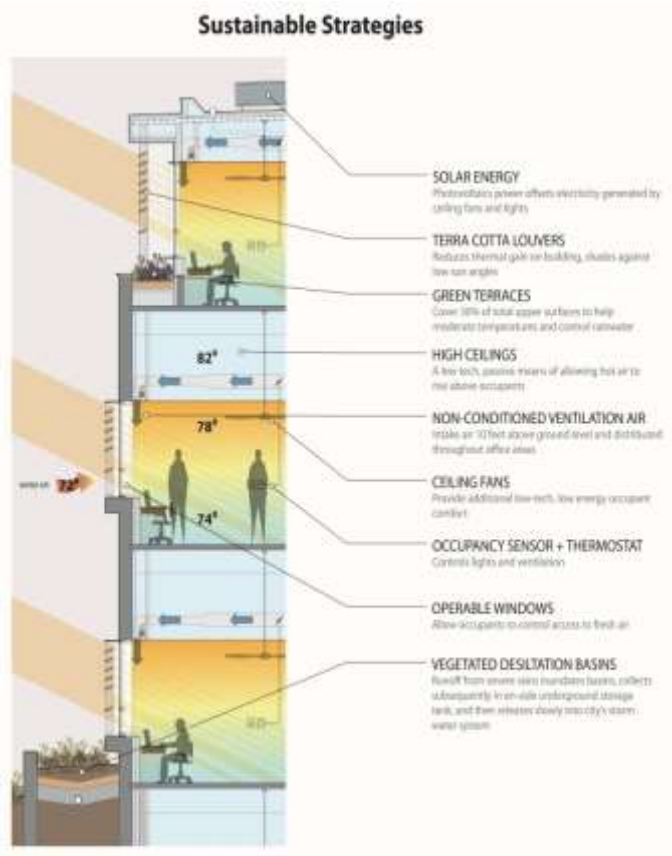


Fig.1: Sustainable Strategies

It is worth mentioning that many previous studies have confirmed the benefits of using BIM in the design process and focused on the promotion of energy efficiency in buildings. For example, Peippo et al. [6] used a numerical optimization procedure to determine the best building-design variables that would result in decreasing lifecycle cost for given certain project specifications and an energy consumption target. Fang et al. 2014 [7] tested the effect of wall isolation on the thermal performance of two types of test rooms in the hot climate in China. Reviewing all current studies, there is strong evidence that appropriate treatment of the building envelope is essential for comfortable both living and working environments, as well as decreasing the energy consumption.

A. Characteristics of Building Information Models

Building information models operates on digital representations of building components (objects) which contain computable graphic and data attributes identifying them to software applications to stores them in the form of digital databases [8]. Fig. 2 shows the Characteristics of BIM.

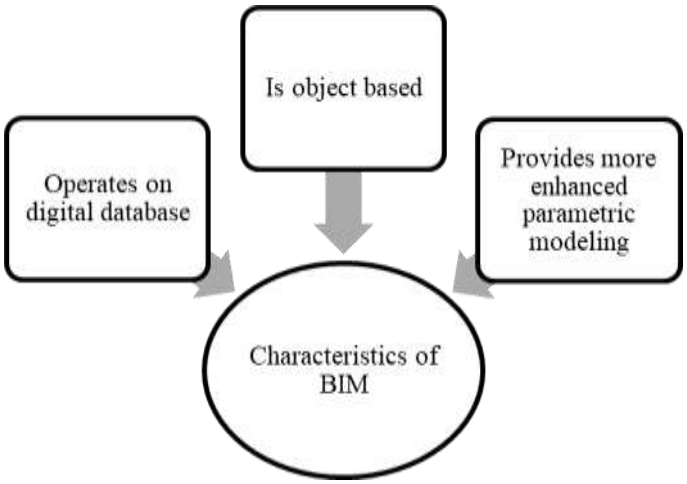


Fig.2: Characteristics of BIM

B. BIM applications

Some are well established applications used extensively in professional practice; others are still in academic research stages "[9].

The applications are:

- ✓ Programming and space planning
- ✓ Form exploration
- ✓ Documents production
- ✓ Design coordination
- ✓ Design review and visualization
- ✓ Sustainable design
- ✓ Scheduling (4D Modeling)
- ✓ Cost estimation
- ✓ Design and code checking

C. BIM Tools

Building information modeling is not considered as a particular software; it is a system of process. In this system the different project participators effectively collaborate and communicate by sharing design data to all each other to help reducing errors and increasing productivity. Table 1 shows BIM Software [10].

TABLE 1
BIM TOOLS

BIM Tools(Software)	Autodesk BIM Tools	Autodesk Revit Architecture Autodesk Revit Structure Autodesk Revit MEP AutoCAD Civil 3D
	Graphisoft BIM Tools	ArchiCAD ArchiCAD MEP Modeler Eco Designer Artlantis Virtual Building Explorer
	Energy modeling applications	IES<VE> Integrated Environment Solution Ecotect eQUEST Design Builder Green Building Studio
	Vico BIM Solution	
	Tekla BIM Solution	
	Other BIM solutions	Bentley BIM Solution Solibri Model Checker Nemetscheck BIM Solution

II. THE PROBLEM

Building performance analyses are typically performed after the architectural design and construction documents have been produced. This shortens of continuous sustainability analysis during the design process results in an inefficient Process of retroactive modification to the design to achieve a set of Performance criteria.

Office buildings in Egypt, consume a large amount of energy compared to other building types. For that reason, was the purpose of this study to use BIM to reduce energy consumption in office buildings.

III. THE AIM OF RESEARCH

This research aims to identify several sustainable designs that can improving the energy performance of office building by using simulation tools (BIM) and suggested alternative materials to determine those that have the greatest impacts on building performance by reducing the annual usage of operational energy.

IV. METHODOLOGY

The research's methodology based on simulation study strategy that tries to modify some aspect of the physical environment in one of the variety modes, from a digital simulation software to a real scale status imitation [11]. This study tests the energy performance and cooling loads of office spaces of faculty of engineering – Mansoura University with proposed design alternatives of wall materials using a digital building performance simulation software. The alternative materials suggested in the mentioned components of the case study building were tested to evaluate their efficiency in reducing the building's annual operational energy use. Fig.2 illustrates the hierarchy of the research.

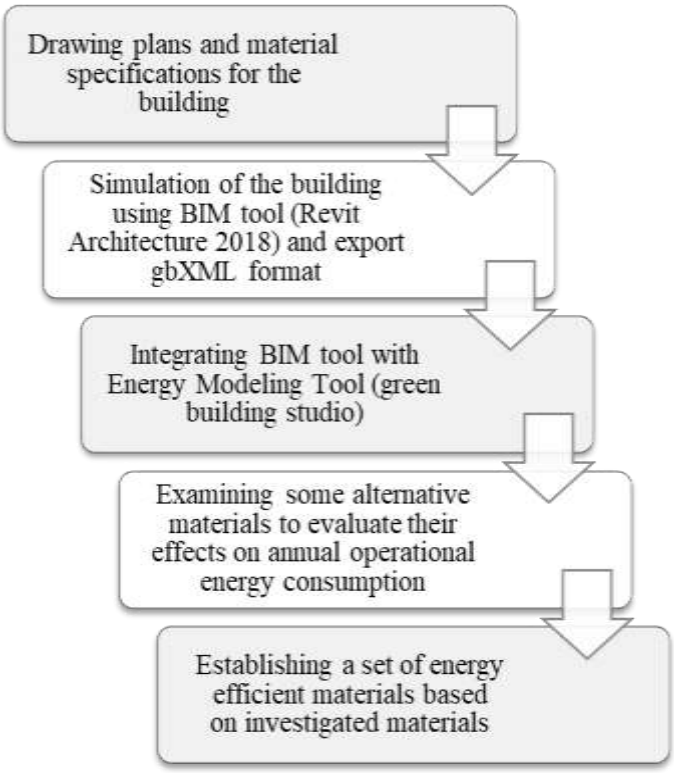


Fig. 3: The Hierarchy of the research

A. *Case Study Information*

Administrative building of Faculty of engineering at Mansoura is chosen to be the case study as Dakahlia Governorate Mediates provinces of northern and it's a sample of the biggest learning community in our country.fig.3 shows the Administrative Building of Faculty of Engineering. And fig 4 shows Satellite Map of Mansoura University.

- ✓ **Project Title**: Administrative Building of Faculty of Engineering.
- ✓ **Location**: Mansoura city, Al-Dakahlia Governorate, Egypt.
- ✓ **Climate**: Similar to Cairo and the Delta.
- ✓ **Type**: Office Building.
- ✓ **Site Area**: 1652 m^2
- ✓ **Floor Area**: 914 m^2

Fig. 4: Administrative Building of Faculty of Engineering

Fig .5: Satellite Map of Case Study

B. *The Climatic Data Used in Simulation*

A large number of researches classifying Egypt into several climatic zones depending on geographical and climatically base. The case study simulation will be applied at Mansoura city which related to Cairo and Delta Region. Fig 6 shows screenshot for model climate date and fig. 7 &8 shows the weather data.

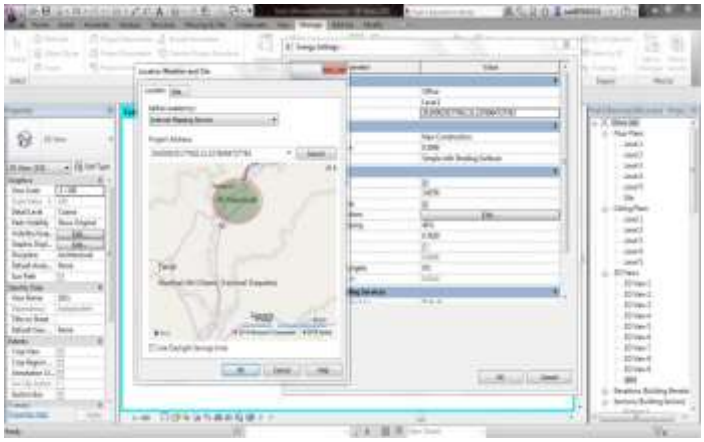


Fig.6: Web-based model Climate Data

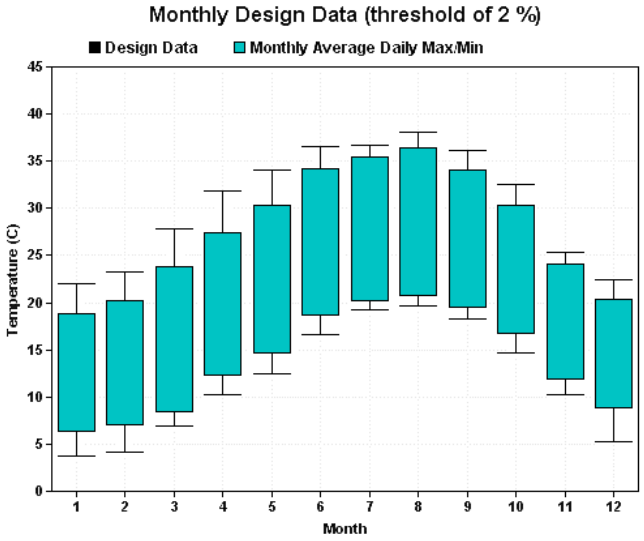
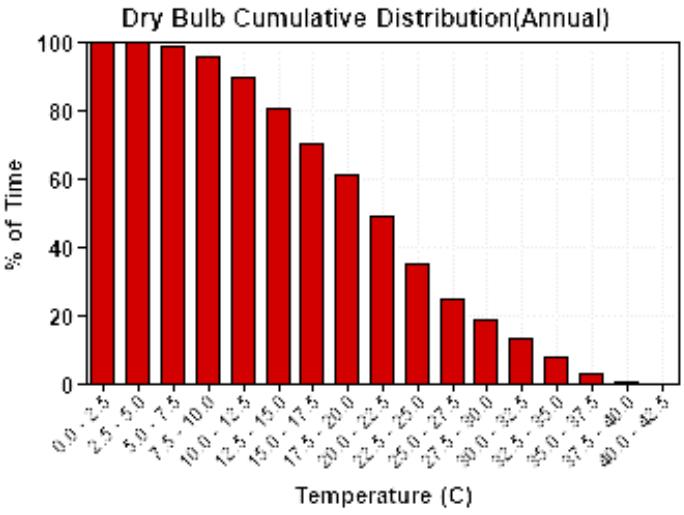


Fig.7: Monthly Design data generated by Revit (BIM Software) and Green Building Studio



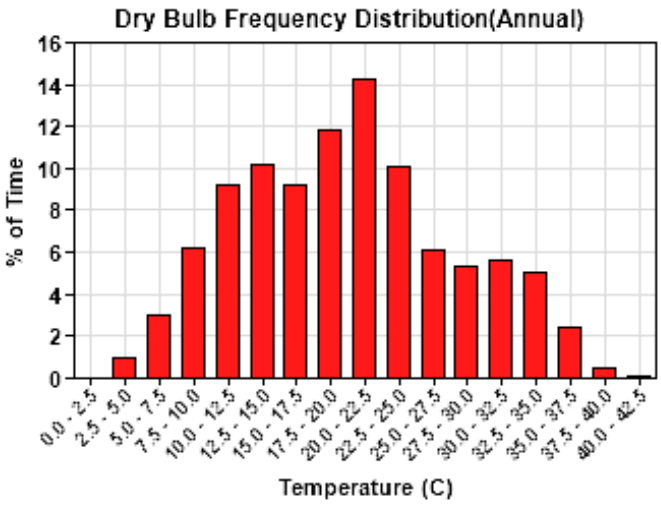


Fig. 8: Annual Temperature bins generated by Revit (BIM Software) and Green Building Studio

C. Modeling and Design the Case Study

Initially, all the building components specifications were simulated in Revit architecture software. As one of BIM tools, Revit architecture software can develop higher-quality architectural designs [12]. Fig. 9 shows the perspective and 3D views of the case-study building simulated in Autodesk Revit architecture.

Revit architecture software groups the building components by types, categories and families. The category is a group of elements which utilize the model or documents a building design, and the families are the classes of elements in the category. Fig.10 shows elements categories, the family classifies elements with a common parameter, identical use, and similar graphical representation [13]. After modeling, the results from Revit must be exported to Green Building Studio software. Component types of material used in the current phase shown in table 2. Fig. 11&12 show plans for case study.

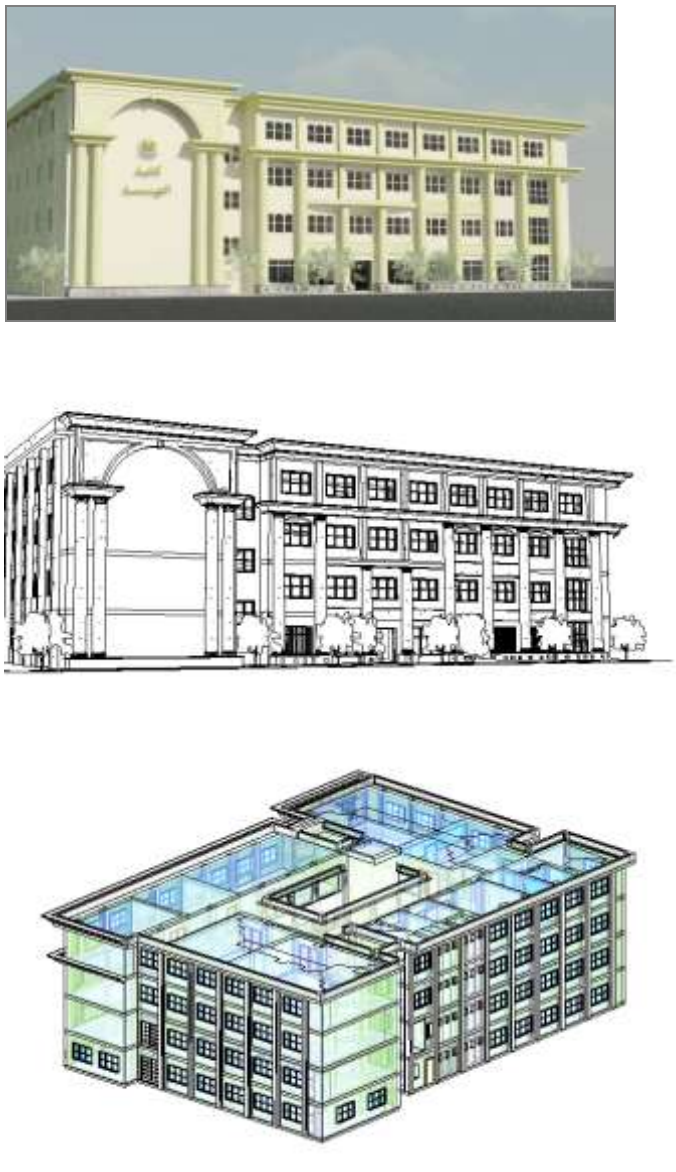


Fig. 9 Case study modeling presented by Revit (BIM Software)

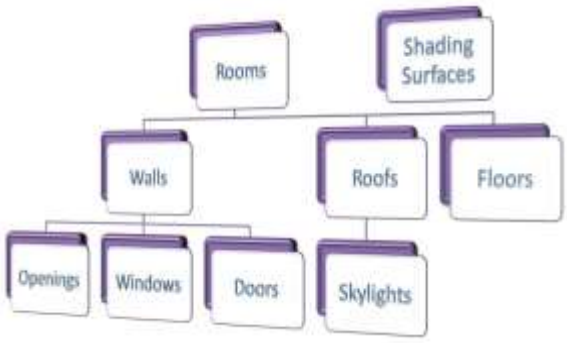


Fig. 10: Elements Categories

TABLE 2
COMPONENT TYPE OF MATERIALS

Walls	Burnt Clay Brick with 25 cm thickness, 2 cm mortar from both sides and finishing with plastic paints.
Ceiling	Reinforced concrete and finishing with plastic paints.
Floors	Reinforced concrete with Mosaic floor tiles.
Windows	6mm single glass Without shading device.
Doors	Hollow core plywood.

1. Walls Materials

Walls consists of burnt clay brick with 25 cm thickness and two layers of mortar. Thermal properties of wall layers for base case shown in table 3.

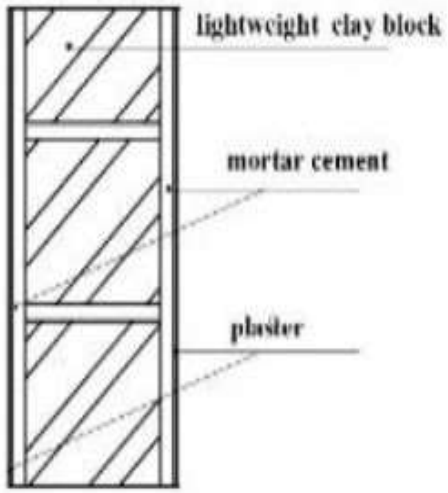


TABLE 3:
THERMAL PROPERTIES OF WALL LAYER

Wall layers	Thickness (cm)	Resistance (m^2.k/w)	Conductivity (w/m.k)
Plastic Paint	0.5	0.022	0.51
Mortar	2	0.033	0.72
burnt clay brick	25	0.64	0.27
Mortar	2	0.033	0.72
Plastic Paint	0.5	0.022	0.51

2. Windows

The glass used in case study is a single type glass with thickness 6mm, table 2 shows the optical and physical properties of glass.

TABLE 4
THE OPTICAL PROPERTIES OF GLASS

Type Of Glass	U -Value	VT	SHGC
single glass	6.7	0.88	0.81

1. Floors

The floor used in case study is Reinforced concrete (Thermal conductivity 6.7 w/m.k) with Mosaic floor tiles.

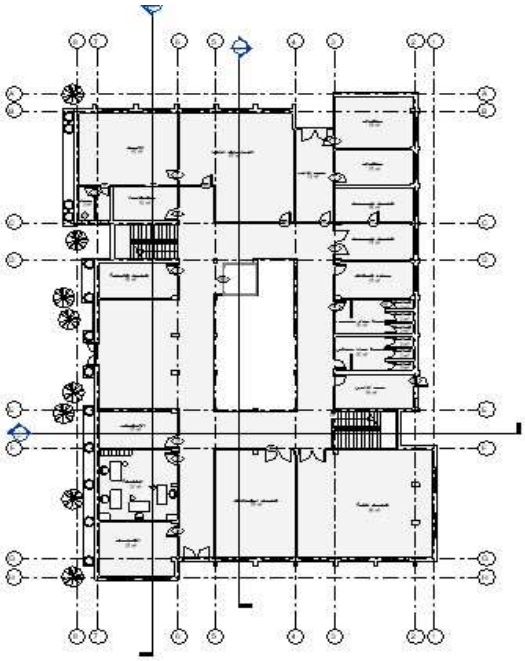


Fig.11: ground floor plan

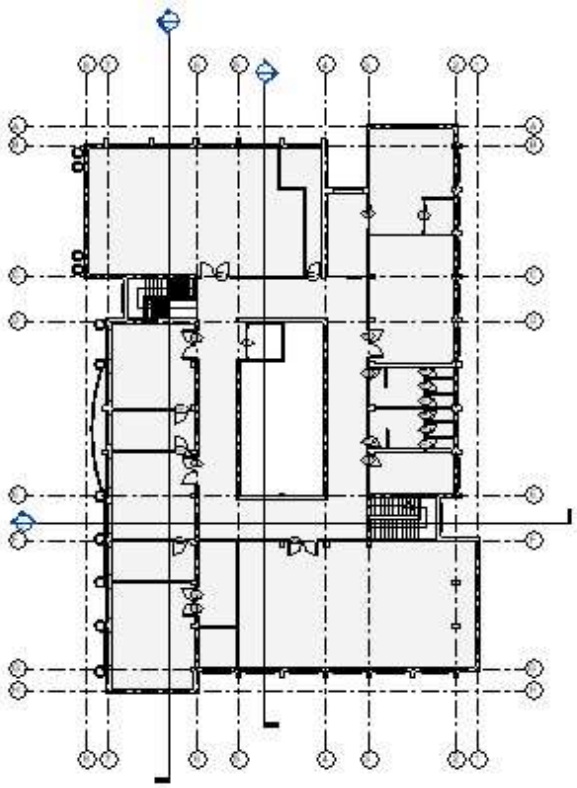
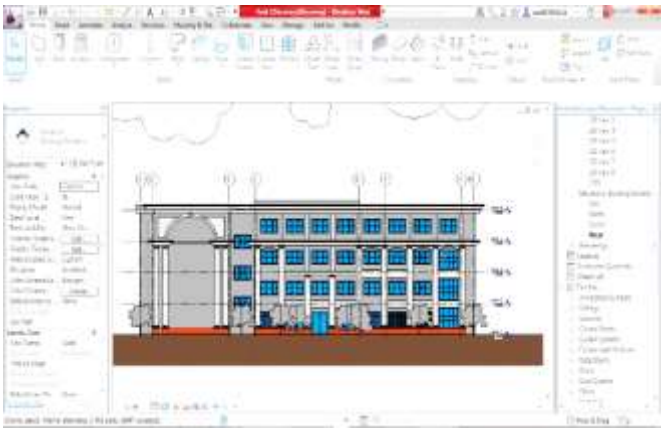


Fig.12: Third floor plan

There is one way of imports to Green building studio, which are gbXML-based exports from Revit architecture software. The gbXML depends on space-based concerns, like solar radiation, thermal performance, and energy demands. According to the study and the type of analysis that is to be performed, gbXML-based export should be chosen to import the simulated file from Revit architecture to Green building studio. Before performing the export process, zones must be produced. The location and types of the building must also be defined in addition to room setting within BIM before exporting the energy model, because they are significant factors in energy consumption and can affect the amount of energy used. Fig. 11 shows elevations screenshot of Revit architecture 2018.



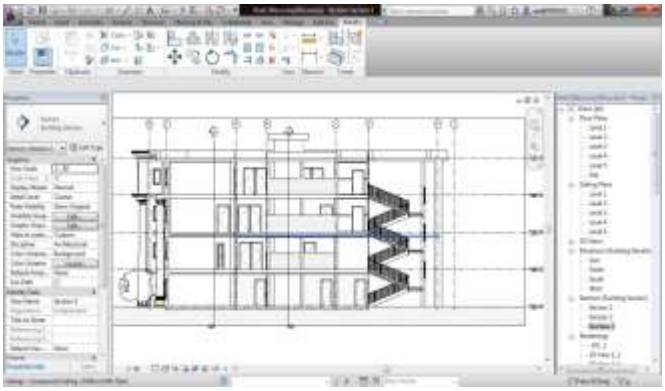


Fig.11: Case Study Elevations

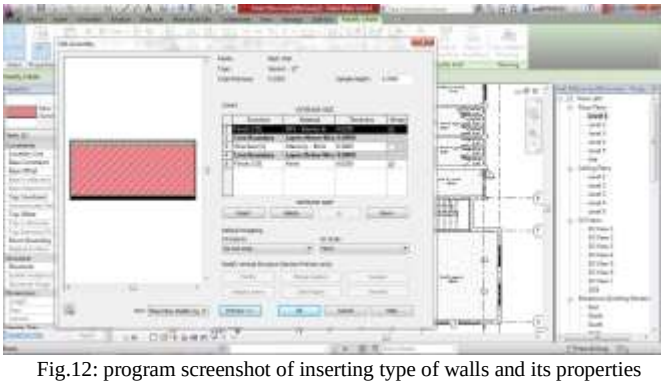


Fig.12: program screenshot of inserting type of walls and its properties

Fig.13: program screenshot of inserting type of windows and its properties

D. Case study alternative

Simulation of energy consumption of Office building of Mansoura University are conducted using alternatives of external wall material and windows.

1. Using Light weight burnt clay block

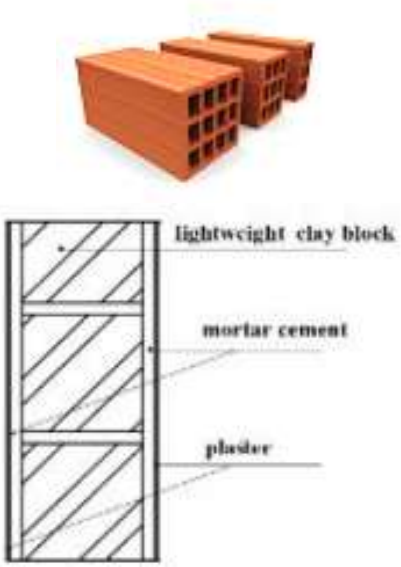


Fig.14: section of Light weight burnt clay block

TABLE 5
THERMAL PROPERTIES OF WALL LAYER

Wall layers	Thickness (cm)	Resistance (m^2.k/w)	Conductivity (w/m.k)
Marble	3	0.022	2.9
Mortar	2	0.033	0.72
Light weight burnt clay block	20	0.88	0.27
Mortar	2	0.033	0.72
Plastic Paint	0.5	0.022	0.51

2. Appling double glass

Using Double glass with thickness6 mm. the thermal and optical properties of glass.

TABLE 6
THE OPTICAL PROPERTIES OF GLASS

TYPE OF GLASS	U -Value	VT	SHGC
Double glass	2.7	0.78	0.69

After the essential data required for the simulation had been gathered and after importing the data from Autodesk Revit Architecture to the energy analysis software, the building was simulated using the BIM tool (Green Building Studio), and the annual energy consumption of the building was estimated. The modifications included the walls and windows. Fig. 15 shows solar studies presented by Revit (BIM software).

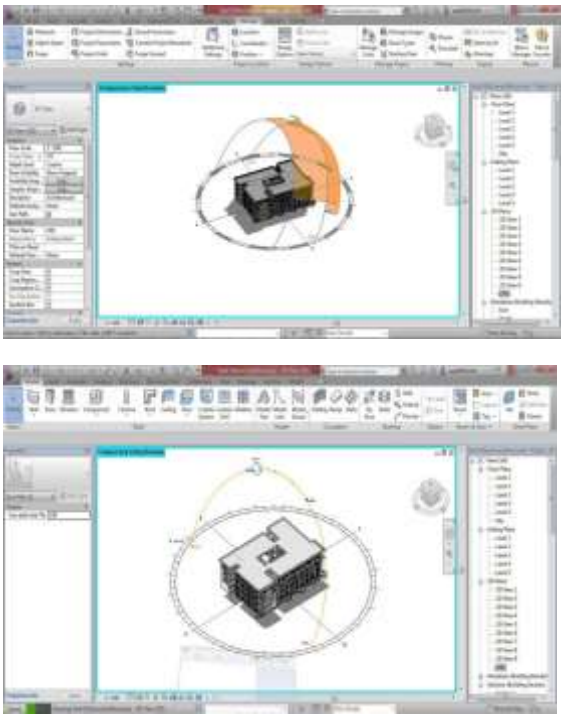


Fig. 15 Revit Solar Studies

V. RESULTS

- *BASE CASE RESULTS*

To improve energy use in office building of Mansoura university needs specific design, so some sustainable improvement has been added to building envelope material to achieve energy efficiency.

Base case results could be shown in the next figures.

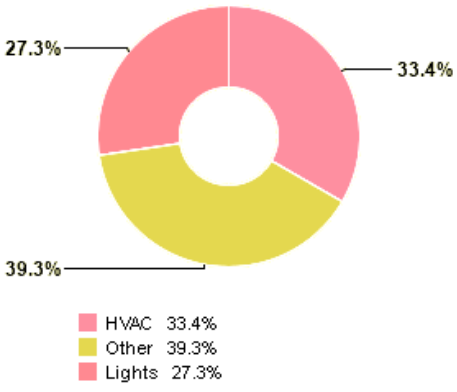


Fig. 16 Energy Use Electricity

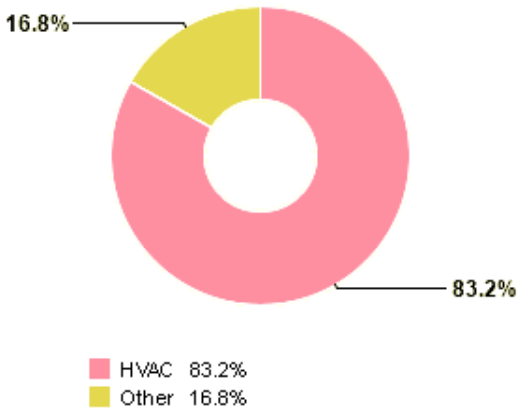


Fig. 17 Energy Use Fuel

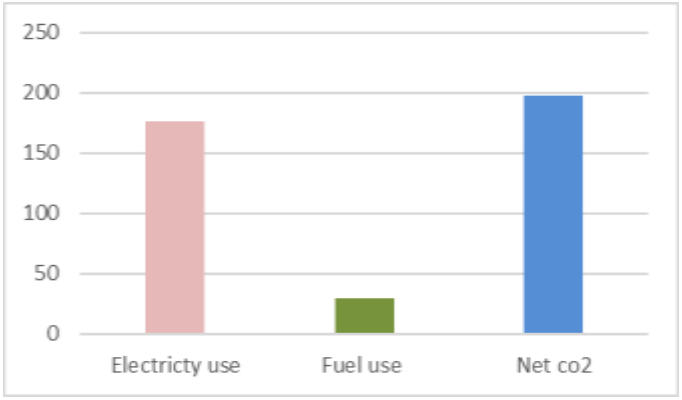


Fig. 18 Annual Carbon emissions

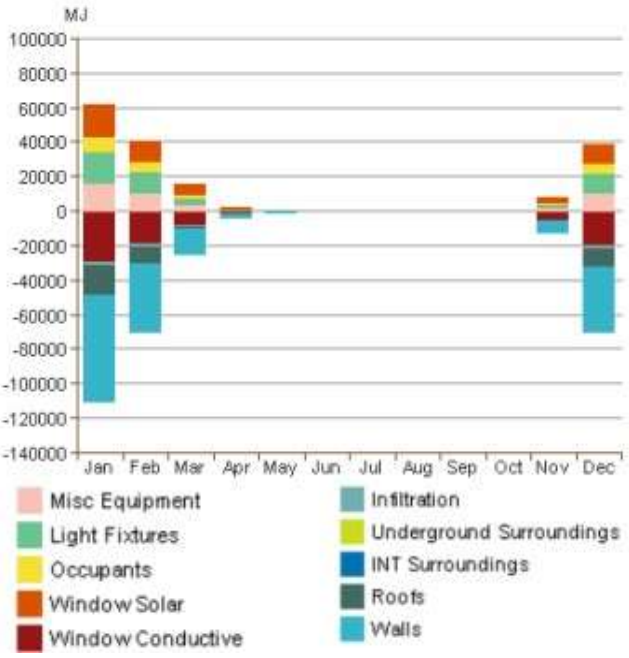


Fig. 19 Monthly Heating Loads

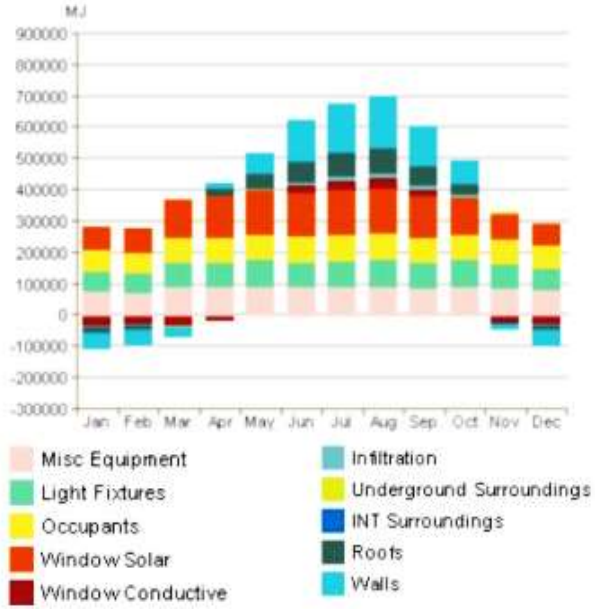


Fig. 20 Monthly Cooling Loads

Because of The largest heating and cooling value, we need to examine another alternative building envelope material, alternative materials to determine the material which achieve most energy efficiency. The largest cumulative cooling loads occur in August and the largest heating value occur in January.

- *Results of using alternative materials*

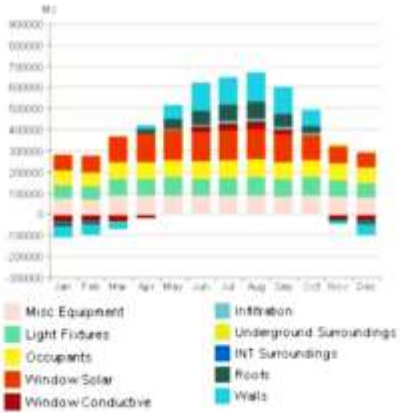


Fig. 21 Monthly Cooling Loads

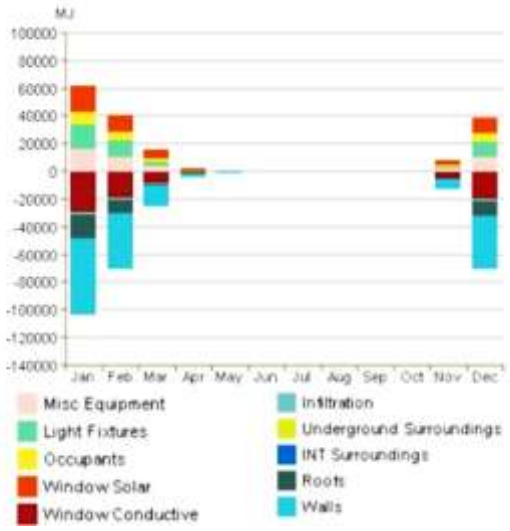


Fig. 22 Monthly Heating Loads

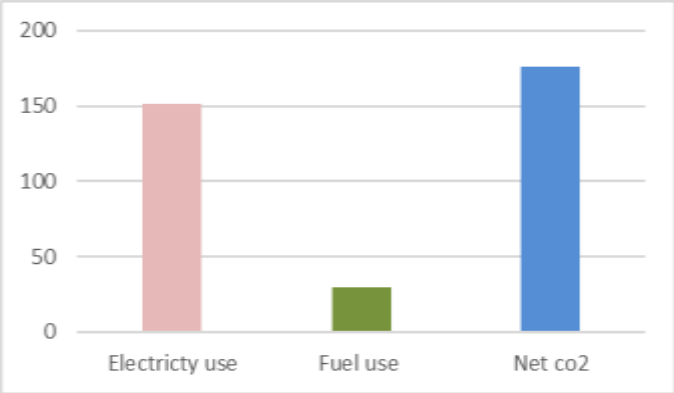


Fig. 23 Annual Carbon emissions

From simulation with Green building studio Using this alternatives material reduced energy consumption in this building from 1213 to 1090 kw.h with 11% decreasing ratio.

VI. Conclusion and Recommendations

The integration of the BIM concept into the design stage can and be used to select the best green building designs and reduce the need for later design modifications.

This research recommended to:

✓ Study office buildings envelope requirement for the selected site to determine the proper technique for this building without effect in environment.

✓ Simulation study in early stage design is essential to support using of integrated approach on designing.

✓ Window shading system is recommended to reducing energy.

Using marble or stone which fixed mechanical with thermal insulation having also a positive effect on energy efficiency of tasted building and have less carbon emission comparing with other building materials.

The results of the Research will be useful to architects and building designers using the BIM concept to develop more energy-efficient buildings in the future with achieving sustainable development for society and determining the best building orientations and designs.

Efforts to prevent adverse environmental impacts and minimize energy costs are beginning to show beneficial effects. In terms of more efficient and sustainable building designs, improved building performance.

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