THE APPLICATION OF RIVET, HAP, AND ECOTECT PROGRAMS FOR THE ANALYSIS OF BUILDING ENVELOPE PARAMETERS TO OPTIMIZE ENERGY EFFICIENCY AND ENERGY SAVINGS: A CASE OF BAGHDAD-IRAQ

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ABSTRACT

With the growing emphasis on energy conservation and emission reduction in Iraq, there has been a rising focus on the consumption of energy in buildings. This phenomenon is attributable to its substantial contribution to aggregate energy consumption within society. Consequently, the primary focus of energy conservation research has been directed towards this particular domain. There has been a growing emphasis in energy conservation research on public buildings characterized by elevated levels of energy consumption. The examination of energy conservation in expansive public structures carries substantial practical significance and societal value. This study employs a building in Baghdad City - Iraq, as a case study. The research was centred on the execution of experiments pertaining to insulation, the ratio of windows to walls, and the thickness of window glass. A comparative analysis was undertaken through the implementation of simulations that considered the climatic conditions of the Baghdad- Iraq region. In order to evaluate energy efficiency, a variety of software applications were utilized, namely Revit, Ecotect, and Hap. The results showed that when analyzing the climate of Baghdad, it was observed that the total cooling savings ranged from 2.34% to 2.45%. As a result, it was determined that the optimal insulation thickness is 11cm. Additionally, it was observed that the energy savings in cooling remained consistent. The analysis of window-to-wall ratios has shown that the highest level of savings can be achieved by maintaining a window-to-wall ratio of 50%. During the calculation of window glass thickness, it was discovered that in the city of Baghdad, the ideal glass thickness is 2mm. This thickness leads to a 1% reduction in annual energy consumption for cooling purposes. The results of this study are significant as they can significantly contribute to reducing energy consumption. Furthermore, the authors highlight the potential for improving energy efficiency in the buildings situated within the specified study area.

KEYWORDS

Energy Saving Optimization; HAP; Ecotect; Revit; Building Envelope; Sustainable Buildings.

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1. INTRODUCTION

The role of energy is of utmost importance in the social and economic advancement of any given nation [1]. Based on data provided by the International Energy Agency (IEA), the final energy consumption of the worldwide building sector in 2007 amounted to 2,794 million tons of oil equivalent (Mteo). According to [2], the building sector is responsible for approximately 34% of the global final energy consumption, thus establishing itself as the most significant consumer sector. Based on the reference scenario provided by the International Energy Agency (IEA), it is projected that the building sector will continue to be the primary consumer by the year 2030, accounting for a consumption share of 32% (equivalent to 3,639 million tons of oil equivalent). According to [2], the energy demand is projected to increase at an annual average rate of approximately 1.2%, while the overall final energy consumption is expected to grow at a rate of 1.4%.

The demand for indoor environments and comfortable buildings has experienced a gradual increase among individuals as Iraq's economy continues to grow. It is anticipated that there will be a subsequent rise in the energy consumption of residual buildings in the future. The aforementioned rise in energy production poses a significant obstacle to both the preservation of national energy security and the promotion of environmental sustainability. The management and mitigation of energy usage in residual infrastructure play a pivotal role in fostering sustainable development within the context of Iraq.

The main sources of potential energy savings in residual buildings include the energy saved through building envelopes and equipment systems, as well as the energy saved through effective management and behaviour in equipment operation and maintenance [3, 4]. The transfer of heat between buildings and the external environment takes place through the building envelope. The efficiency of the building envelope has a direct impact on the amount of heat exchange that occurs, which in turn affects the overall energy consumption of the building. Therefore, improving the performance of the envelope of a residual building on a large scale is a practical method for increasing the building's energy efficiency ratio.

Numerous studies have examined and evaluated energy-saving schemes by conducting energy consumption simulations. The study conducted by [5] investigated the sensitivities of energy consumption for building heating and refrigeration across four distinct climate zones in Turkey. The researchers also examined the effects of various design parameters on the system, such as the heat transfer coefficient of the building envelope, the orientation of the building, the depth of the structure, the height of each story, and the ratio of windows to walls. The findings of the study prompted the formulation of precise recommendations for each parameter. [6] Utilized DeST's methodology in their study to develop dynamic energy consumption simulations. Yi and Malkawi [7] proposed a methodology with the goal of optimizing the design of building forms. This methodology focuses on the energy consumption related to heating and cooling systems. The goal of the genetic algorithm is to optimize the reduction of heat transfer between indoor and outdoor environments. A windowless hypothetical structure was used to study the use of natural daylight and artificial lighting. In their study, [8] conducted an optimization procedure that failed to take into account the effects of energy and transmitted solar radiation. The purpose of this study was to investigate how building form and urban patterns affect the energy consumption of air-conditioned buildings in different desert environments. In the study conducted by [9], a selection of three innovative insulation materials was made, namely gypsum, vermiculite, and an ethylene-vinyl acetate (EVA) copolymer. Subsequently, an assessment was conducted to gauge the efficacy of said materials in tropical regions of Brazil, with a comparative analysis against traditional envelopes frequently employed within the region. The researchers of the study observed that the novel materials exhibited a reduction in the thermal load of buildings by 38%. [10] Introduced a nondestructive testing technique for assessing the integrity of insulation walls. This methodology entails the quantification of air temperature and humidity levels within both internal and external building environments, as well as the interstitial spaces between insulation panels and walls. A novel instrument has been devised for the purpose of quantifying the thermal and humidity properties of architectural building envelopes. The measurement results that were obtained were subsequently subjected to analysis using mathematical techniques. The study conducted by Yang et al. [11] examined the influence of the window-to-wall ratio (WWR) on the energy consumption for heating and cooling in residential buildings located in the hot summer and cold winter climate zone of China. According to their report, the critical factors in determining the optimal window-to-wall ratio (WWR) include the air conditioning system, window orientation, and the types of glazing used. The study of [12] focused on optimizing energy consumption in buildings by improving the building envelope parameters for a default residential building in Konya- Turkey.

Energy efficiency is widely regarded as the most efficacious strategy for effectively addressing both economic growth and environmental preservation on a global scale. The exponential growth in global fuel demand has substantial implications for elevated international prices and its contribution to the phenomenon of global warming. Therefore, it has become imperative to redirect our attention towards tactics that facilitate fuel conservation and investigate alternative energy sources, all the while embracing innovative technologies that are more compatible with our evolving requirements. At present, there exists a multitude of global advancements that place emphasis on the adoption of policies and strategies with the primary objective of fostering energy utilization efficiency [13]. This study proposes the use of three essential simulation tools, namely Revit, Ecotect, and Hap, to assess energy efficiency and providing optimized solutions for insulation, window-to-wall ratio, and window glass thickness specifically tailored for the city of Baghdad.

There exists a discrepancy between energy-efficient design and program design within the realm of architectural design. Architects typically formulate the program for a given project by drawing upon their professional acumen and established principles of energy efficiency. Frequently, the examination of energy consumption is deferred to

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a subsequent phase within the design process. The efficacy of energy-saving design as a fundamental principle in program design is called into question due to the irreversible nature of the design process. Furthermore, the predominant focus of research in the field of energy-efficient design for residential buildings has been on multi-story and high-rise structures situated in urban and suburban regions. Conversely, there exists a dearth of scholarly investigations pertaining to energy-efficient design methodologies tailored specifically for rural structures. Residential structures account for a significant amount of energy consumption in urban areas.

Residential structures necessitate a consistent supply of energy to fulfil a range of functions, including illumination, temperature regulation, and the facilitation of various operational processes and activities. Residential buildings account for the majority of energy demand in Iraq. In the city of Baghdad, the energy consumption attributed to residential buildings constitutes approximately 48% of the overall energy usage. Industrial buildings are responsible for 29% of overall consumption, whereas office buildings constitute 13% of the total. According to [14], the energy consumption of commercial buildings accounts for 6% of the total, while agricultural buildings contribute 4%.In the city of Baghdad, residential buildings allocate 69% of their total annual energy consumption towards cooling activities, with an additional 26% dedicated to heating purposes. The aforementioned rates exhibit a notable disparity in magnitude when juxtaposed with the energy requirements for illumination, household appliances, and other domestic necessities, which merely constitute 5% of the aggregate annual energy consumption in residential dwellings, as stated by [15].

The objective of this study is to examine the quantitative relationship between the envelope structure, and the energy consumption of buildings in the urban area of Baghdad- Iraq during periods characterized by very hot summers and cold winters. The rationale for adopting this approach was to support the construction of residential buildings in urban areas that experience high temperatures during summers and low temperatures during winters. The aim was to reduce energy consumption throughout the duration of the year.

The manuscript is organized in the following structure: The following section of this report provides a thorough overview of the subject area being examined and discusses the datasets that were used. The demonstration highlighted the various processes and analyses that can be performed using Revit, HAP, and Ecotect Techniques. The third section succinctly outlines the key findings derived from our research. The fourth section will discuss the outcomes of the processing and analysis conducted on the study area regarding energy conservation and consumption. The fifth section presents a thorough analysis and interpretation of the findings.

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2. MATERIALS AND METHODS

2.1. MATERIALS

Baghdad city is 33° 19' N, 44° 25' E, part of the Middle East region. Its climate is classified as hot and dry in summer and cold and humid in winter [16]. The present study employed a residential building with a total area of 80 square meters, as illustrated in Figure 1. The building's design was implemented by employing appropriate software to optimize several parameters, such as the ratio of windows to walls within the building envelope, Revit software was used to design it. Table 1 presents the structural parameters of the building in the study area, along with comprehensive information regarding the selected properties of the windows and walls.

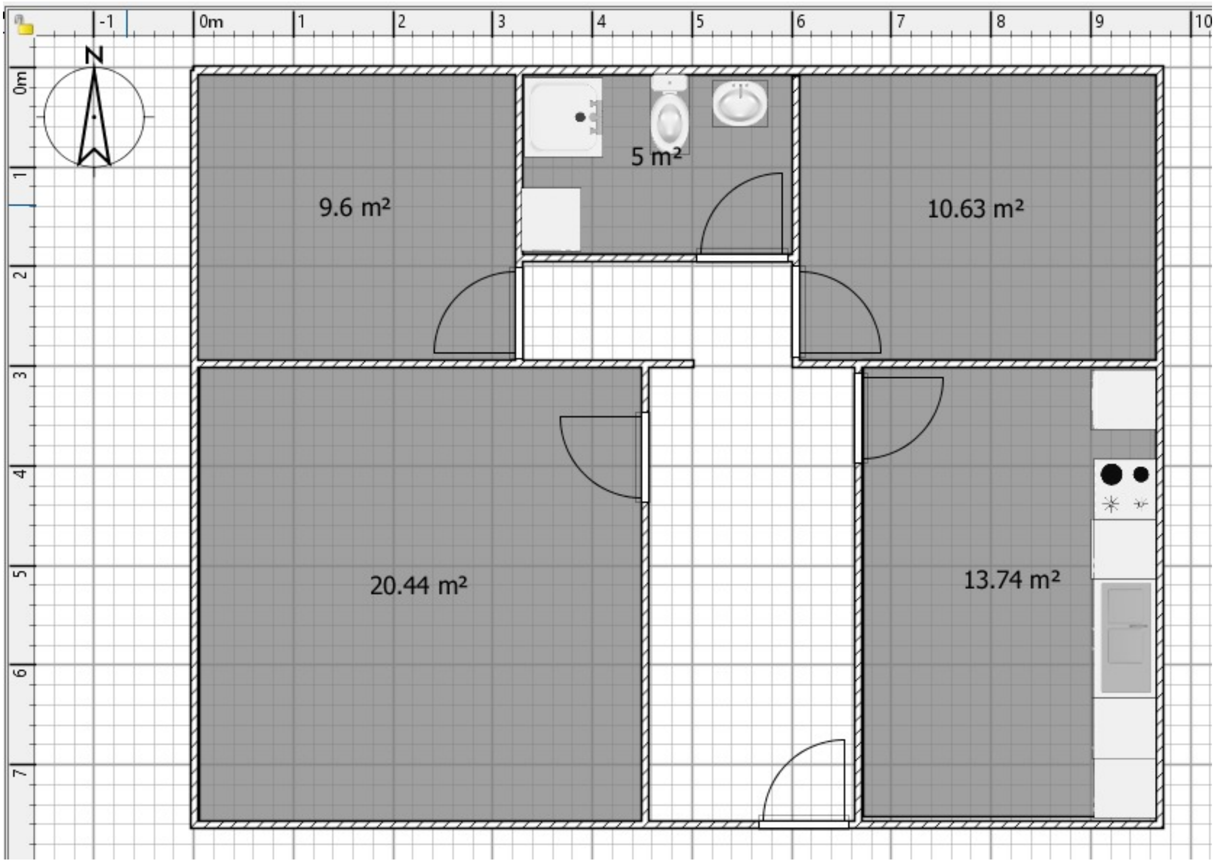

Figure 1. Plan of the default building [12]

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Table 1. Details of the inputs of the used building

Building Features	Value
The total area of the building	80 m^2, It was chosen because the aspect ratio of the building is very close to 1:1, and it is the smallest and most suitable area in single house building designs in Turkey.
Building height	3 m
Total exterior wall area	107.28 m^2
Window/wall ratio	North/ South %30 East %50 West %10
The volume of the building	240 m^3 1:1.5 aspect ratio
Total window area	15 m^2
Number of floors	1 floor

2.2. METHODS

To investigate the impact of residential building envelope parameters on energy consumption in hot climates, it is necessary to conduct a thorough analysis and assessment of commonly accepted assumptions. Furthermore, it involves quantifying the effects of building envelope parameters on energy consumption to determine their validity. The research inquiry focuses on investigating how residential building envelope parameters affects energy consumption in hot climates, specifically in the city of Baghdad as a case study. The building sectors are widely recognized as major contributors to global warming and climate change because they consume a substantial amount of energy. In developed nations, the building industry is responsible for both 40% of total energy consumption and 40% of carbon dioxide emissions. Researchers from around the world are currently involved in studying energy management and conservation. They are using simulation software as a tool to develop strategies with the goal of significantly reducing energy consumption in buildings. In order to fulfil the objective, three indispensable simulation tools, specifically Revit, Ecotect, and Hap, were utilized:

2.2.1. REVIT

The Revit software (see Figure 2) is a Building Information Modeling (BIM) software program developed by Autodesk. It incorporates a range of tools specifically designed for conducting energy analysis, enabling users to evaluate the energy efficiency and performance of a building design. This study offers valuable insights into various factors, including heating and cooling loads, energy consumption patterns, and potential strategies for energy conservation. Designers possess the capability to conduct an analysis of various components within a building, including walls, roofs, windows, and HVAC systems, with the aim of enhancing energy efficiency. Revit's

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analysis and simulation capabilities provide designers and engineers with the tools they need to make informed decisions, optimize designs, and improve the performance and sustainability of buildings. By identifying potential issues proactively during the design process, individuals and organizations can take the opportunity to reduce costs, minimize energy consumption, and create environments that are both comfortable and sustainable. Revit also offers a range of tools specifically designed for simulating and analyzing heating, ventilation, and air conditioning (HVAC) systems.

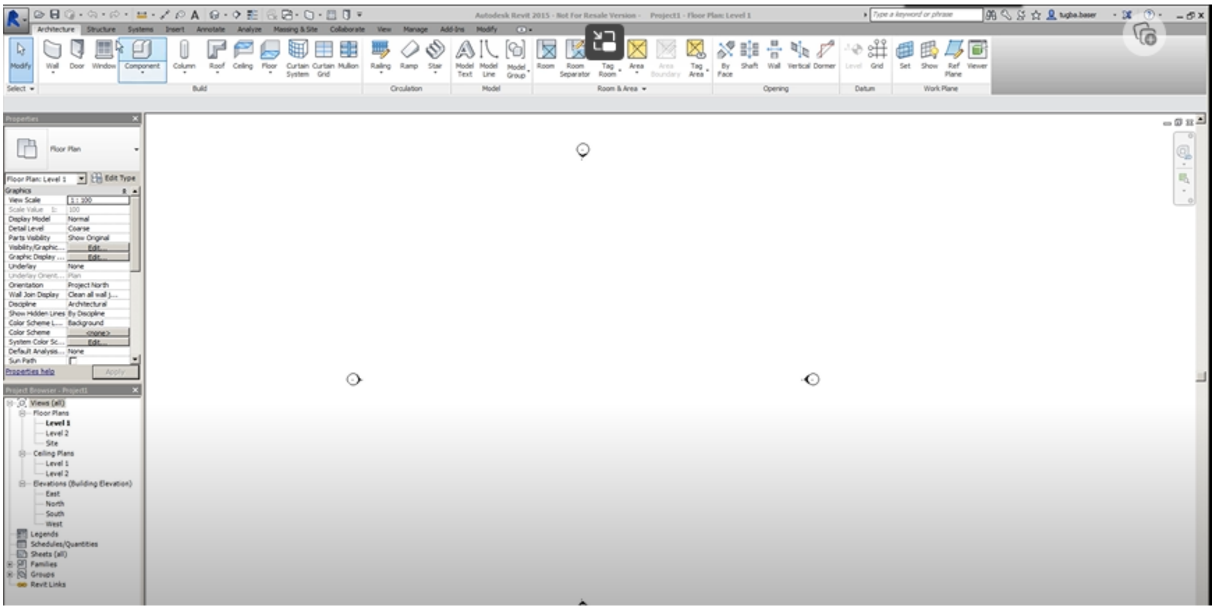

Figure 2. The view of the Revit software

2.2.2. ECOTECT

The Ecotect energy simulation software offers the ability to create geometric models and perform thermal and lighting analysis within the same program. It is designed to be user-friendly and intuitive, making it easy to use. It is a proprietary application developed and maintained by Autodesk, a leading company in the field. The Ecotect program is a highly efficient computer-based application that offers various features for accurately assessing the thermal performance of a building. It also boasts a user-friendly interface that is particularly well-suited for architects [17]. Ecotect is a powerful tool used for simulating and analyzing the energy efficiency of buildings and their surrounding environment. It provides comprehensive simulations for various climatic conditions, including solar radiation, daylighting, and thermal comfort [18]. An Ecotect analysis (see Figure 3) was performed to simulate and evaluate the performance of the building, with the aim of assessing the effects of reduced energy consumption and the utilization of sustainable power sources. The task at hand encompassed the coordination and optimization of the existing energy conservation technology systems within the building.

It has the capability to function in conjunction with other building energy analysis software applications. The program has the capability to incorporate intricate threedimensional computer-aided design (CAD) models, albeit in a simplified representation. Additionally, it has the capability to serve as input data for 3DS and DXF files. The analysis results have the capability to be stored in various formats such as Meta, Bitmaps, and visual animations or can be visually represented. Even with a rudimentary model, it is possible to conduct a fundamental energy analysis, which can provide guidance to users during the initial phases of the design process. The utilization of detailed modelling in the final stages of design facilitates decision-making for users in complex system solutions. One of the program's limitations is that it requires the user to possess a proficient understanding of its intricate software. Without such expertise, the outcomes produced by the program may potentially misguide the designer [19].

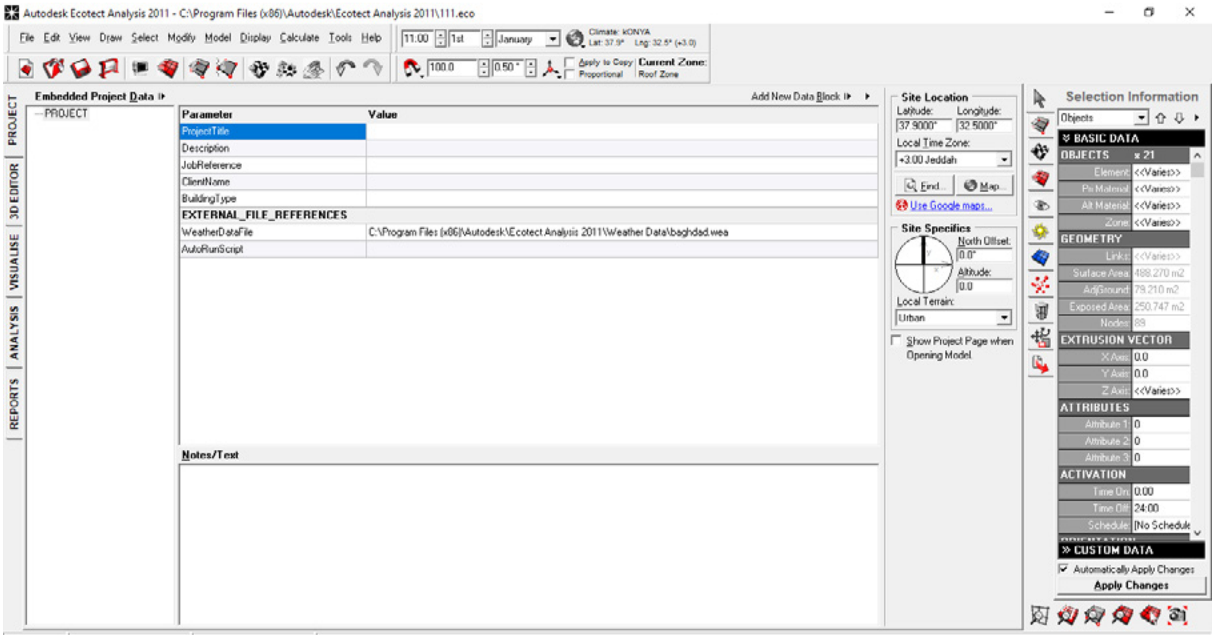

Figure 3. The main interface of the ECOTECT software

2.2.3. HAP

The Hourly Analysis Program (HAP) is a computer software application developed by Carrier, a renowned company specializing in providing comprehensive solutions for air conditioning, heating, and refrigeration systems. The objective of this program is to provide support to engineers in the process of designing HVAC systems tailored explicitly for commercial buildings. The tool integrates two primary functions, namely load estimation and system design, alongside energy use simulation and computation of energy costs. The program can be categorized into two main components: HAP system design features and HAP Energy Analysis Features, as described in [20].

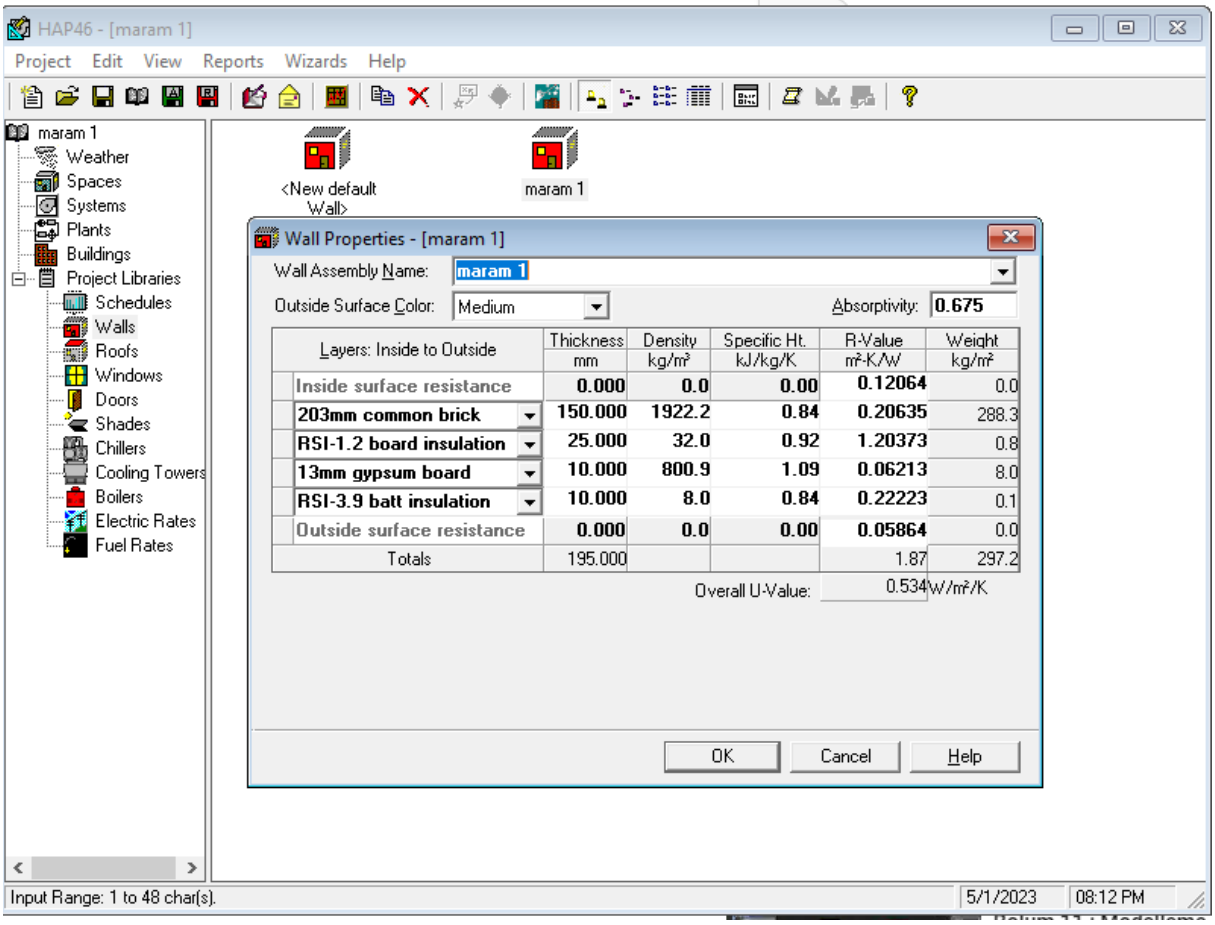

Figure 4. The main screen of the HAP air conditioning calculation program

The aforementioned calculation methods are made according to ASHRAE's standards.

2.2.4. MODELS APPLICATION AND THE MOST SUITABLE PROGRAM

We considered a residential building located in the Baghdad region- Iraq. This building is known for its property and dimensions, measuring 8.9 x 8.9 meters, resulting in a total area of 80 square meters. After identifying all the relevant information in the program, the calculation table is prepared. The amount of solar energy was calculated by taking into account various factors, including wall thickness, window/wall ratio, and window glass thickness. The collected information was used to make these calculations. Once all the required data was entered into the program, the chart was utilized to calculate the annual thermal energy. The obtained result provides information about the total amount of heat loss. Therefore, a comparison was conducted among the programs that were used, and the most appropriate one was selected for the optimization procedure.

Hence, the Ecotect software was chosen as the most similar program. Upon comparing the outcomes derived from the Revit software with those of the Ecotect software, it becomes apparent that the Revit program exhibits a notable augmentation

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of approximately 22%. Conversely, the observed increment in the Ecotect program is minimal, with a maximum value of 1%. The Hap program produced a result that exhibits a significant divergence. Based on comprehensive comparisons, it has been ascertained that the Ecotect program is the most appropriate choice for the intended objectives. This is due to its capacity to yield the most precise outcomes in the context of thermal regulation. The thesis conducted at Yıldız Technical University elucidates the utilization of a cooling program, which enables the attainment of the aforementioned conclusion. This is accomplished through a comparative analysis of the calculations performed in the Antalya and Diyarbakır regions of Turkey. The selection of the Ecotect program was based on its specific design to deliver precise outcomes utilizing the cooling load factor (CLF), as exemplified in Table 2.

Table 2. Outcome of the used programs

ECOTECT max heating W	**Revit max heating W**	**HAP max heating W**
49,196	77,759	11,700
ECOTECT max cooling W	**Revit Max cooling W**	**HAP max cooling W**
31,314	62,982	4600
ECOTECT Total Max load W	**Revit Total Max load W**	**HAP Total Max load W**
71,039	140,741	16,300

After the Baghdad climate file was imported into the Ecotect program, the chosen building underwent necessary preparations for subsequent analysis. The utilization of the drawing tools within the Ecotect drawing interface facilitated the completion of this task, as depicted in Figure 5 and Figure 6.

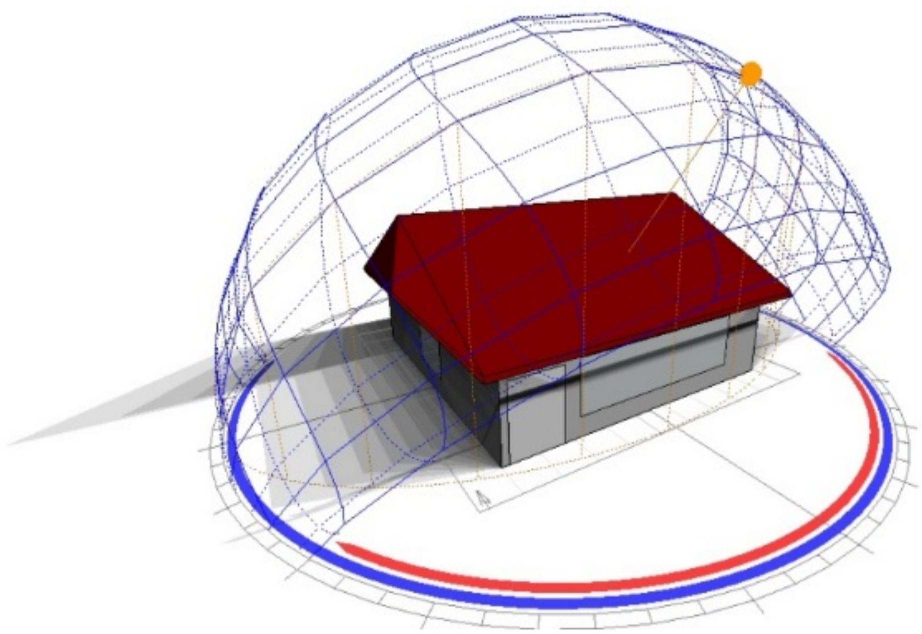

Figure 5. View of the study building using ECOTECT software

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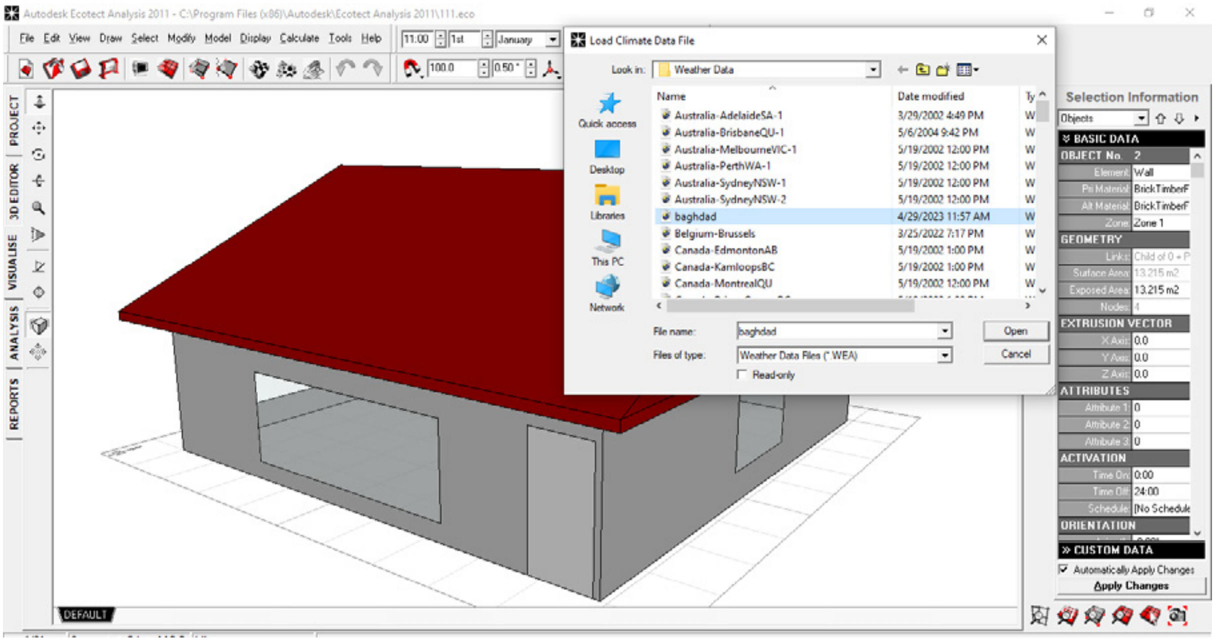

Figure 6. Display of Baghdad climate file uploading

2.2.5. BUILDING ENVELOPE PARAMETERS

After determining that the Ecotect program produced the most favourable results in the experiments mentioned earlier, a thorough analysis of the parameters was conducted, dividing them into three separate groups. The main focus of this analysis was to optimize the building envelope. The table shows the optimum trials and measurements conducted on selected parameters.

Table 3. Ideal tests and measurements conducted on each used parameters

Trials	Shell element	Parameter Types	Measurements
1-	Wall insulation thickness	TSE-825 Proper insulation	1cm, 2cm, 3cm, 4cm
2-	Window glass measurement	Glass/Wall ratio	%25, %50, %75, %100
3-	Window glass thickness	Pure-glass SHGC %80	2mm, 4mm, 6mm, 8mm

Wall Insulation Thickness

Proper insulation of a building's envelope is crucial. Inadequately insulated walls, roofs, or foundations, as well as drafts and low-quality doors and windows, can lead to significant heat loss. Specifically, poorly insulated walls can account for 40% of total heat loss, while roofs and foundations can contribute to 25% and 30% of heat loss, respectively. The existing walls of the building exhibit inadequate or nonexistent insulation. The XPS insulation with thicknesses ranging from 1 to 15 cm was chosen for testing purposes based on its cost-effectiveness and low thermal conductivity factor (K factor). Following the creation of the initial building envelope through the

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utilization of the Ecotect software, an assessment was undertaken to evaluate the energy efficiency of the insulation envelope within the specific climatic conditions of Baghdad. The Ecotect Weather program format was used to load the annual hourly climate files of Baghdad for experimental purposes. After the completion of the climate file preparation, the thickness of the wall insulation in the building shell was altered in each experimental trial. This was achieved by substituting the initial uninsulated shell with 15 different shells, as illustrated in Figure 7, which can be accessed via the wall-window properties. Prior to conducting an energy analysis using the software, the thermal properties panel was utilized to specify a building that is fully air-conditioned. The temperature settings for the air conditioning system in Baghdad city were selected to encompass a set point range of 22-24°C, taking into consideration the hot climate prevalent in the region.

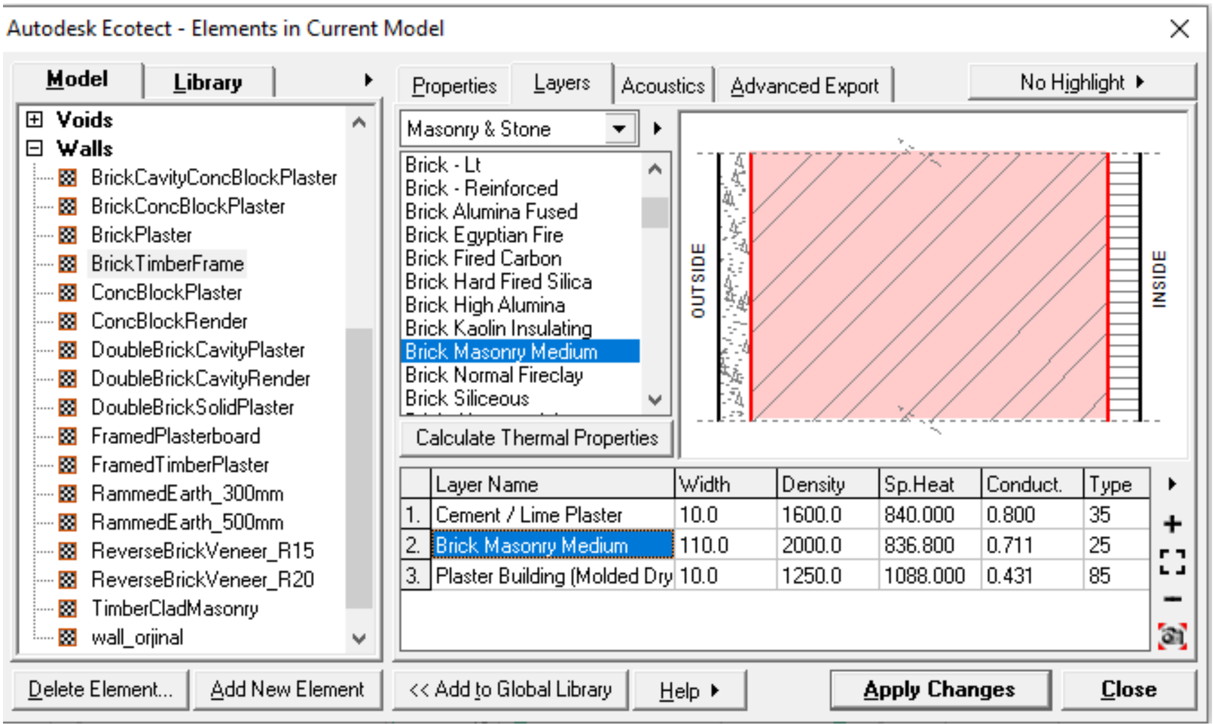

Figure7. Materials of the building original wall

Window/ Wall Ratio

This examination encompassed ratios of 25%, 50%, 75%, and 100% and was conducted for all orientations of the building in Baghdad. The objective of this analysis was to attain an optimal outcome. The window-to-wall ratios (WWR) for each of the four facades of the building were determined by quantifying the total area of windows in relation to the total area of walls. This information is presented in Table 4. The values depicted in Table 5 were obtained through the utilization of Equation 1. Subsequently, the aforementioned values were employed in the optimization experiments conducted for the purpose of window design. To ensure accurate calculations for the southern window area, adjustments were made in the dimensions shown in Table 5. This was done by reducing the ratio to account for the presence of a door on the southern facade.

$$WWR = \frac{\text{Area of Window}}{\text{Area of Wall}} \quad (1)$$

The aforementioned equation was employed to determine the proportion of windows in the structure in relation to the walls of the building. The calculation was performed on each individual room within the building to ascertain the proportion of windows that were being utilized.

Table 4. Window/Wall ratios, area and measurements

Direction	Area(m²)	Measurement (m)
North	0.3 x 889 x 3 = 8.01	5.34 x 1.5
South	8.01 – 2 = 6.01	4 x 1.5
East	0.5 x 8.9 x 3 = 13.35	8.9 x 1.5
West	0.1 x 8.9 x 3 = 2.67	1.78 x 1.5

Table 5. Window/Wall ratio details on the southern facade

WWR	area(m²)	Dimension (m)
25 %	6-675	4.45 x 1.5
50 %	13-35	8.9 x 1.5
75 %	20-025	2.5 x 8.01
100 %	267	3 x 8.9

Window Glass Thickness

The study involved conducting simulations on windows that are frequently employed in building envelopes, varying in thickness from 2 mm to 8 mm. The objective of the study was to evaluate the potential of the subject under investigation in terms of attaining the utmost level of energy efficiency see Figure 8 and Table 6.

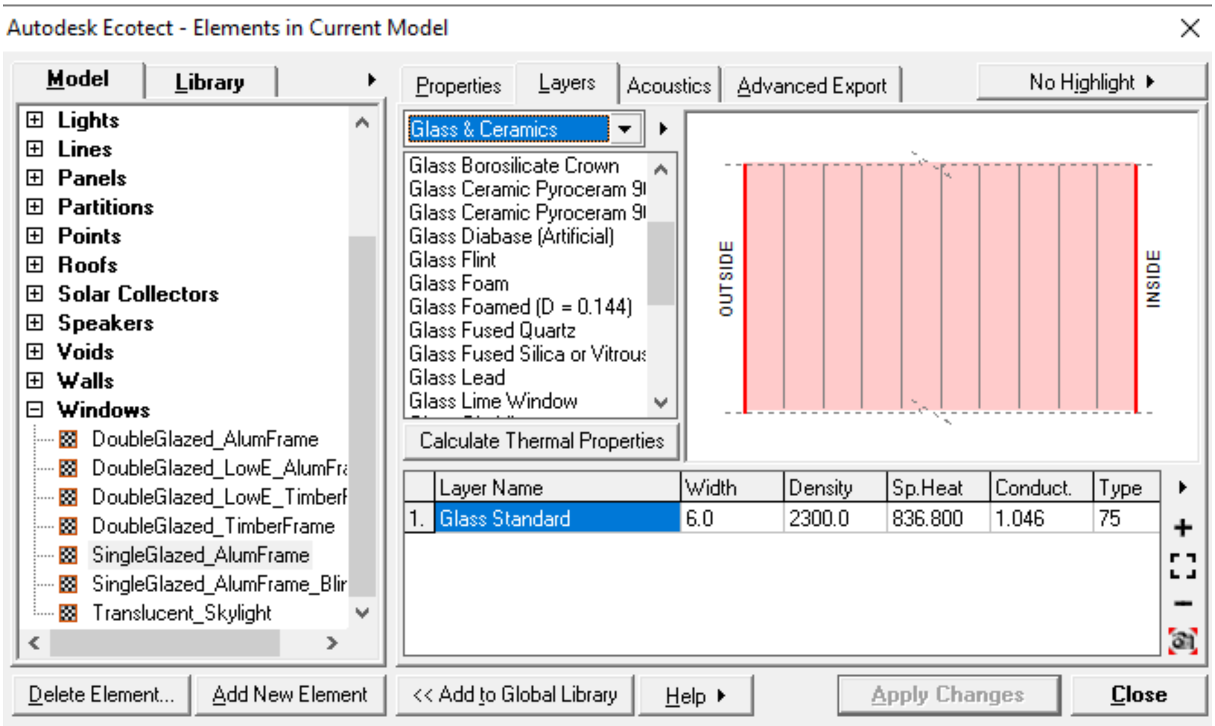

Figure 8. Display of the window glass thickness optimization process

Table 6. Window Features

Structural Element	Material	Thickness	U value (W/m² K)	SHGC	SHGC
Window system	Ordinary glass, Aluminum joinery	Glass 4mm, The air gap is 16mm, Glass 4mm	2,73	0,60	80 %

3. RESULTS

Before conducting experiments in this specific section, a comprehensive analysis was performed on the outcomes obtained from each of the three programs (HAP, ECOTECT, and Revit). The study objectives led to the conclusion that Ecotect is the most suitable program. The heating and cooling energy consumption of the building was calculated by considering the annual meteorological data of Baghdad, Iraq, and taking into account the ASHRAE limit values. Three optimization parameters were taken into consideration, and the resulting outcomes are presented below:

3.1. OPTIMIZATION OF WALL INSULATION THICKNESS

This study aimed to assess the thermal insulation properties of various wall materials within a representative building through a series of experimental tests. The insulation levels exhibited a range of minimal to nonexistent, with the thickness of the insulation varying between 1 and 15 cm. The results of our observations indicate a

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positive correlation between the thickness of insulation and energy savings across various energy conditioning loads, such as heating, cooling, and overall energy consumption.

After conducting an analysis focused on Baghdad, Iraq, a region characterized by high temperatures, it was observed that the energy savings achieved in heating loads were more substantial than those in cooling loads. The cooling load determined in Baghdad was found to be approximately three times greater than the corresponding heating load. The observed variation in the total savings in cooling load was approximately (2.34 - 2.45) per cent, as determined through our calculations. Interestingly, the magnitude of these savings was found to be greater than that observed in the heating load.

In contrast, our analysis also revealed that the heating load in Baghdad is relatively low, amounting to approximately 4.65% at the optimal thickness. In conclusion, upon examining the overall annual energy conservation achieved through air-conditioning in the urban area of Baghdad, it is evident that employing insulation with a thickness ranging from 1 to 15 cm results in a reduction in energy consumption by approximately 2.92% to 3.067%, as shown in Figure 9.

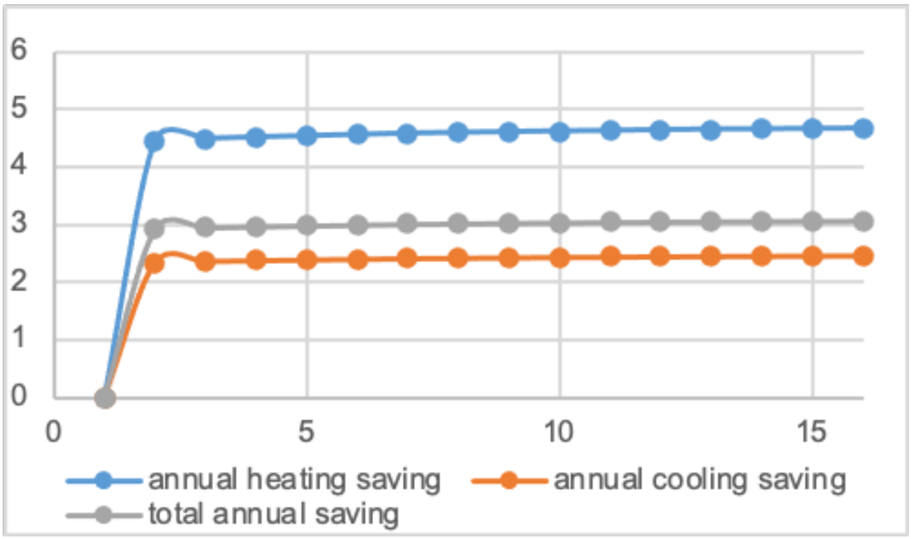

Figure 9. The relationship between the thickness of wall insulation and the rate of energy savings in air conditioning within a building

3.2. WINDOW/WALL RATIO OPTIMIZATION

The building envelope was examined with four distinct window-to-wall ratios: 25%, 50%, 75%, and 100%. Modifications were made to all four facades, and the air conditioning loads were calculated using the Ecotect program (see Figure 10). The analysis of the climate data for Baghdad revealed a direct correlation between the window-wall ratio and energy consumption in buildings. As the window-wall ratio increased, there was a corresponding increase in overall energy consumption and cooling energy requirements. This observation can be attributed to the high temperatures in the Baghdad region, which necessitate more significant energy expenditure for cooling purposes.

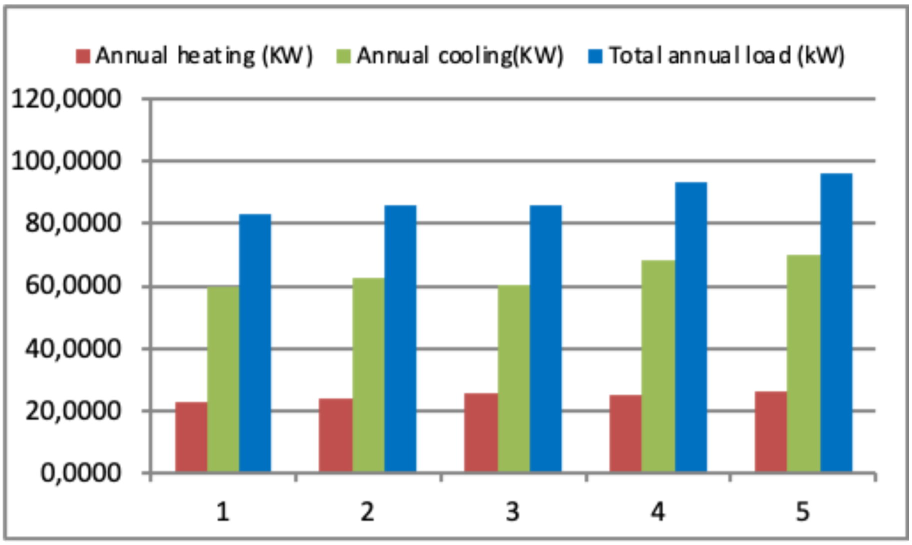

Figure 10. The energy loads associated with air conditioning in the climate of Baghdad were examined for four distinct window-to-wall ratios that were employed

3.3. WINDOW GLASS THICKNESS OPTIMIZATION

Different results are obtained when conducting analyses on the thickness of glass in the climate of Baghdad. Due to its location in a hot region, Baghdad experiences a cooling load 2.5 to 3 times greater than its heating load. One of the most significant energy savings observed is the reduction in total cooling requirements. After considering the climatic conditions in Baghdad, it was observed that increasing the glass thickness from 4mm to 6mm and 8mm led to higher annual cooling savings within the building. The savings reached 1.2% and 1.344%, respectively, as shown in Figure 11. The impact of reducing the glass thickness from 4mm to 2mm is illustrated in Figure 12. Surprisingly, it was observed that this reduction in glass thickness led to a slight decrease in savings and energy consumption. The cooling savings achieved from 4mm to 2mm glass thickness was approximately 1%. This finding suggests that thinner glass may compromise insulation properties, leading to higher cooling energy requirements in the hot climate of Baghdad.

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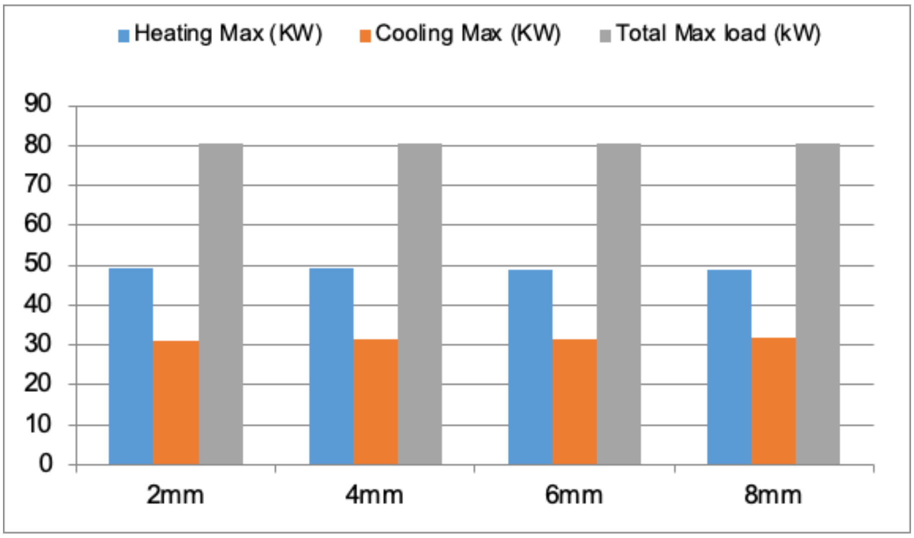

Figure 11. Window glass thickness and energy consumption in Baghdad climate

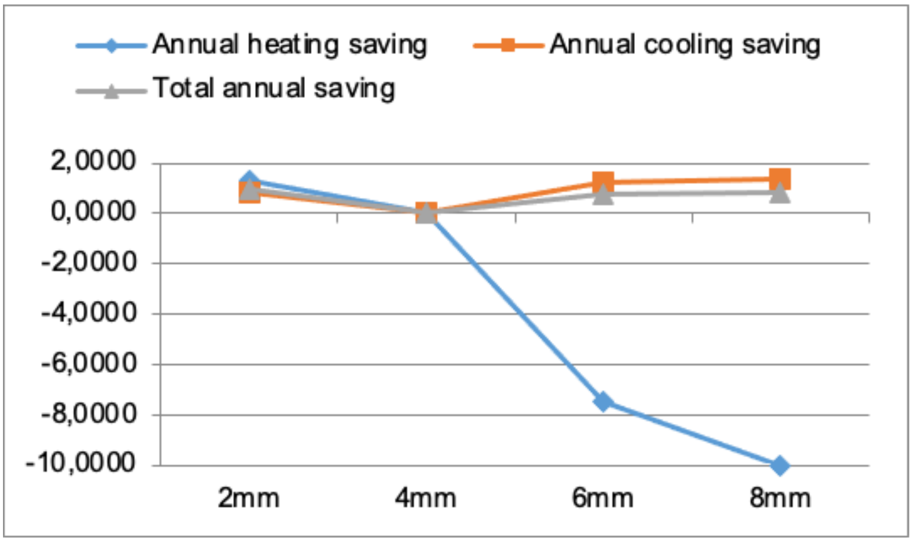

Figure 12. Window glass thickness and energy saving in Baghdad climate

Additionally, it was observed that as the thickness of the glass increased in Iraq, there was a decrease in heating savings, which was opposite to the yearly reduction in cooling expenses. Studies have shown a direct relationship between reducing the thickness of glass in a building and the resulting increase in annual savings on air conditioning energy consumption.

4. DISCUSSION

Our research findings show that increasing the thickness of wall insulation is an effective method for energy conservation in heating and cooling needs. This discovery aligns with the existing research on the correlation between building insulation and its impact on energy consumption. A consistent pattern of energy savings in both heating and cooling loads was observed in the Baghdad region as the insulation thickness increased from minimal to 13 cm. The reason for the improved energy efficiency in

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heating loads in Baghdad, despite the predominantly warm climate, can be attributed to several factors. One possible hypothesis suggests that having insulated walls during colder months helps to keep heat inside the building, reducing the need for energy consumption for heating.

On the other hand, during high temperatures, the insulation acts as an obstacle, reducing the heat transfer from the outside to the inside of the space. As a result, this leads to a relatively minor decrease in the cooling load. The study's findings emphasize the significance of adequate insulation in hot climate regions like Baghdad. They demonstrate a significant increase in cooling load savings when the wall thickness reaches 13 cm. Based on the analysis, it is evident that a thickness of 13 cm provides an ideal level of insulation. This thickness offers substantial energy savings for both heating and cooling needs. Figure 13 illustrates the relationship between wall thickness and energy savings. It highlights that the most significant energy savings in both cooling and heating loads were observed at a wall thickness of 13 centimeters. This figure is a valuable reference for architects, engineers, and policymakers when designing and constructing buildings in similar climatic conditions.

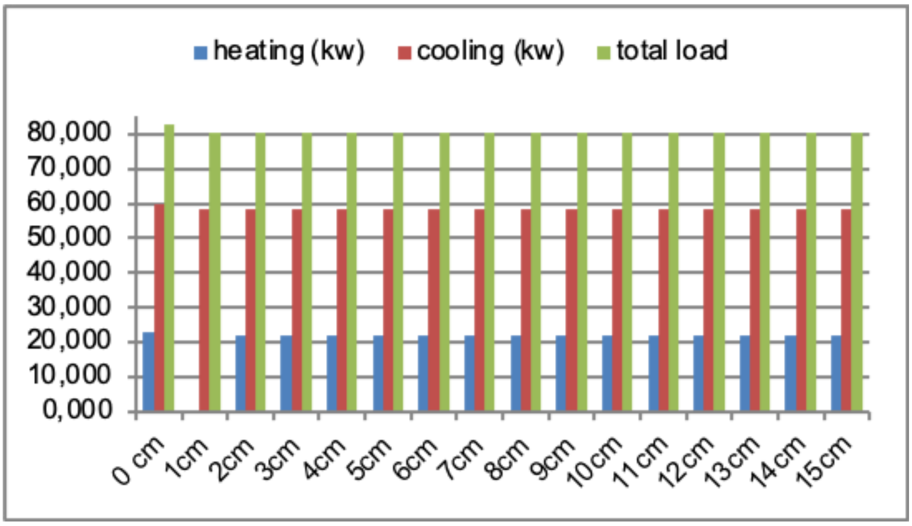

Figure 13. The diagram illustrates the energy consumption of the building as influenced by the insulation present on its walls

The window-to-wall ratio also significantly determines the energy consumption and cooling energy requirements of buildings in the Baghdad region. An increase in the window-to-wall ratio results in a greater influx of solar heat into the building, necessitating an increase in cooling loads to sustain a desirable indoor temperature. This phenomenon is notable in areas characterized by high temperatures, such as Baghdad. Our analysis determined that a window-to-wall ratio of 100% yielded the most significant overall energy consumption and cooling energy demands. This discovery suggests that an entire glass exterior in a building would result in a notable rise in heat absorption, consequently necessitating a higher demand for cooling energy. Nevertheless, the cooling energy requirements were significantly lower when employing a window-to-wall ratio of 25% due to its effective reduction of solar heat

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gain. Nevertheless, it is crucial to acknowledge that this ratio could potentially lead to increased heating energy consumption in colder periods.

The optimal equilibrium between natural lighting, solar heat gain, and energy efficiency was determined to be a window-to-wall ratio of 50%. The energy consumption for both cooling and heating exhibited a more equitable distribution at this particular ratio, rendering it the most appropriate choice for architectural structures in Baghdad. The data presented in Figure 14 demonstrates that the window-to-wall ratio of 50% corresponds to the threshold at which energy performance is optimized.

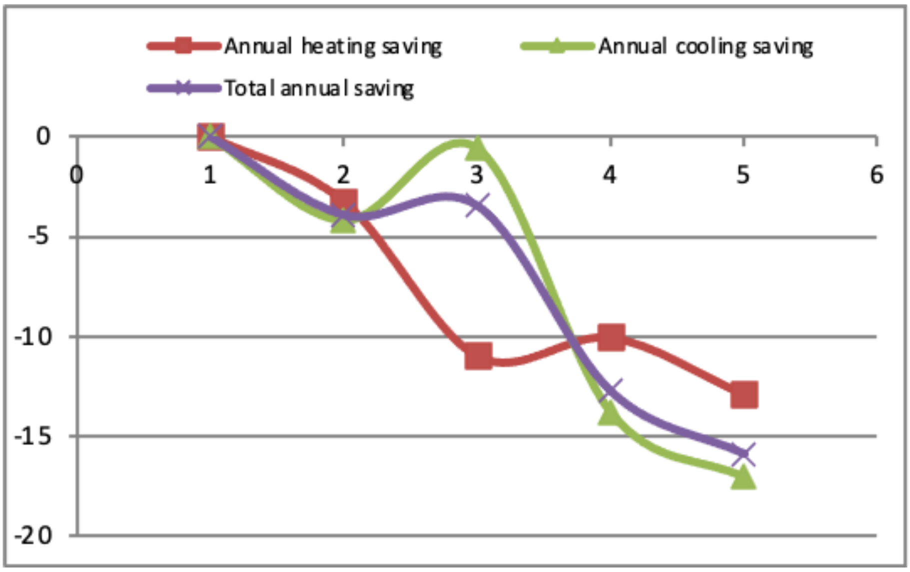

Figure 14. The correlation between the varying ratios of window-to-wall and the resulting increase in energy consumption saving

Moreover, a notable energy-conservation strategy that was observed involved the augmentation of glass thickness. As the thickness of the glass increased from 4mm to 6mm and 8mm, significant reductions in annual cooling requirements were observed, leading to cooling savings of 1.2% and 1.344%, respectively. Thicker glass exhibits enhanced insulation characteristics, thereby diminishing the transmission of heat from the external environment to the internal space. As a result, the demand for cooling energy is reduced. In contrast, a marginal decline in cooling savings and energy efficiency was noted upon reducing the glass thickness from 4mm to 2mm. This discovery suggests that thinner glass may not offer sufficient insulation, resulting in increased energy consumption for cooling purposes. Hence, the selection of an optimal glass thickness holds significant importance in order to enhance energy efficiency and optimize cooling performance within the context of Baghdad's high-temperature climate.

The results obtained from this study hold significant potential value for professionals in architecture, engineering, and building ownership, particularly in regions characterized by high temperatures, such as Baghdad and other similar areas. Through the careful selection of appropriate glass thickness, it is possible to

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optimize energy efficiency, mitigate cooling demands, and diminish overall energy usage, thereby fostering the development of sustainable and ecologically conscious architectural structures.

5. CONCLUSION

Energy is a vital resource that serves society and industry, providing quality and cost-effective solutions. It is an essential requirement for human life, enhancing the overall quality of community living, improving people's comfort levels through reduced energy consumption, and creating healthier environments. Energy consumption also plays a crucial role in facilitating economic and social development, as highlighted in this review. In recent times, the topic of energy efficiency has garnered significant significance as a result of the depletion of energy reserves and the adverse environmental consequences associated with primary energy sources. In this context, it is imperative to optimize the utilization and allocation of energy in binaural applications in order to achieve maximum cost efficiency. The adoption of energy-efficient practices in the construction sector is becoming more prevalent on a global scale. Nations consistently engage in the transfer of technological advancements to energy systems with the aim of mitigating costs and minimizing environmental harm, particularly in relation to the phenomenon of global warming.

The research focused on improving energy efficiency and was conducted in an 80 m2 residential building. The objective of this study was to analyze the energy performance of buildings and determine the most suitable optimization programmes. In order to accomplish this, a variety of simulation software was used, such as Ecotect, Revit, and Hap. The design of the building took into account various architectural parameters such as the total area, height, window-to-wall ratio, and building volume. Various factors influence the properties of building components, including windows, roofs, walls, and floors. These factors include the type of material used, the thickness of the components, the U-values (which measure thermal conductivity), and the solar heat gain coefficient (SHGC). The investigation utilized specific software programmes to simulate and analyze the energy performance of buildings. The climate data for the Baghdad region was obtained from the Ecotect Weather programmes. The annual energy consumption for heating, cooling, and total loads was determined using modelling techniques in the Ecotect and Revit software applications. A comparative analysis was conducted to evaluate the outcomes of different programmes. The analysis determined that Ecotect is the most suitable programme for accurately estimating heating and cooling loads.

After selecting the most suitable programmes, optimization tests were conducted on three specific parameters: wall thickness, window-to-wall ratio, and window thickness. The evaluation of the energy efficiency of the building envelope required adjusting the insulation thickness of the walls. The window-to-wall ratio has been adjusted for different facades to achieve the best possible results. In addition, a thorough examination has been conducted to assess the energy efficiency potential of

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various window thicknesses commonly used in building envelopes. The study has focused primarily on the energy performance of the building, explicitly examining optimized parameters. The effectiveness of the optimization procedure was evaluated by comparing the annual energy consumption for heating, cooling, and overall loads.

In addition, it is crucial to evaluate the effectiveness of passive building designs in the city of Baghdad and their impact on the overall cost, as shown in the invoice. Evaluating passive designs can play a significant role in constructing sustainable buildings and promoting energy efficiency. The purpose of these recommendations is to clearly identify the specific areas that should be given priority for future research and scholarly investigations. In the field of building design, it is crucial to prioritize the optimization of building elements, the improvement of energy efficiency, and the implementation of necessary measures for sustainable structures.

The investigation findings have emphasized the importance of optimizing building components to enhance the energy efficiency of the building envelope. Optimizing parameters such as wall thickness, window-to-wall ratio, and window glass thickness can significantly enhance energy savings and overall energy performance. The findings mentioned above emphasize the importance of considering the characteristics of building components in addition to architectural entrances when designing a building.

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