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The Effectiveness of Thermal Insulation of the Exterior Composite Walls of Buildings in Iraq Based on Different Materials and Climate Regions using Engineering Applications

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Abstract :U-value, or thermal efficiency, is a measure of the thermal characteristics of a building envelope and an essential criterion for assessing heat loss via building elements due to heat transfer. It is calculable based on the thermal qualities of the construction materials. By enhancing their thermal qualities, composite walls could help buildings meet stringent energy and environmental performance standards, such as those for practically zero-energy buildings (nZEB). Composite walls are preferable to traditional building methods due to their superiority in several areas, including durability, efficiency, cost, and the well-being of construction workers. Despite the benefits of this construction method, thermal bridges may arise in wall elements due to the high thermal conductivity of structural materials. Adding thermal insulation layers to composite walls is the focus of this research. To this end, four climatic regions in Iraq are used to conduct tests on various composite wall types. To calculate thermal transmittance, all that is needed are the indoor and outdoor air temperatures and the characteristics of the wall material. Exhaustive statistical research shows how Iraq's climate directly impacts the building's heat load and the effectiveness variations between insulating materials.

***Keywords**: Thermal efficiency, insolation materials, thermal properties*

1. Introduction

An integral part of any building life cycle analysis is deciding what materials to use. Materials used in construction are a significant factor in determining how much energy a building uses and how much damage it does to the environment, significantly affecting the buildings' sustainability [1]. The construction industry consumes many of the world's raw resources and energy. Common construction materials such as steel, concrete, aluminum, and glass are all examples of high-energy materials [2]. Concrete is a widely used material in the building trades. Studies show that while the initial energy consumption of concrete components is minimal, the total energy consumption of construction is significantly high due to the large amount of concrete utilized in structures [3]. Studies have shown that low-energy materials are more important than the running energy of a building. Thus, it's clear that material choice is crucial. Selecting materials with a high energy footprint increases the number of greenhouse gases released during the first production phase [4]. However, considering environmental factors like building materials and construction technologies makes choosing sustainable building materials more demanding and challenging. In addition, there are many unknowns and variables in the field of environmental impact assessment and the development of construction materials [5]. It is essential to do market research and prepare for using sustainable building materials at the outset of the design process [6]. Oil, which includes polymers; ores, which include metals and ceramics; and biomass, which includes wood, make up the three main groups of traditional construction materials. The criteria listed below constitute sustainable building materials design standards. To begin, sustainable building materials are typically made from renewable resources, require little in the way of upkeep, can be readily deconstructed and recycled after destruction, and have a low overall energy footprint [7]. Second, throughout their life

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cycle, sustainable materials should not emit toxins or other emissions that negatively impact human health and comfort [8]. Pollutant-containing materials may cause problems at every stage of the product's life cycle, from production to use to recycling and disposal [9]. Thus, sustainable construction materials have zero or negligible adverse effects on the building and its surrounding natural environment, such as low or nonexistent emissions of carcinogens, renewing toxic compounds, or irritants [10]. Furthermore, sustainable construction materials are typically sourced from renewable energy rather than fossil fuels. Not only should they be environmentally friendly, but their production process should also be low-impact on the environment.

Building Energy Efficiency

The creation of an ecologically sustainable building material requires a focus on energy efficiency. Reducing the amount of generated energy needed to transport materials to a construction site is the ultimate goal of using energy-efficient materials. A building's long-term energy costs are heavily influenced by the materials with which it was constructed. You can evaluate the energy efficiency of a building resource using several different metrics, such as the R-value, shading coefficient, luminous efficiency, and fuel efficiency. Materials that impede heat transfer through a building's skin are preferred because they lessen the load on the boiler and the cooling system.

The efficiency of construction material can be quantified to help evaluate alternatives and determine whether or not it will function well in a particular setting [4].

The R-value is a standard metric for evaluating the insulation performance of building envelopes. Insulation performance is enhanced using materials that meet or exceed the R-value requirements. Applying it in thicker layers is required when trying to achieve the same amount of insulation with a lower R-value. Measurements of individual materials (such as insulation, siding, wood wainscoting, and brick) can be made before calculating R-values for composite physical components (e.g., roofing, walls, floors, and windows). Insulating materials range from carbon-based cellulose derived from recycled paper to bubbles made from petrochemicals [11].

Background of the Study

According to a recent study Xiaoqiu [2], Due to their many positive effects on human health, environmental quality, and structural integrity, "green" building materials have seen widespread application in recent years. However, it is necessary to improve the efficiency and organization of green building materials because construction projects can be complex and time-consuming, and there are often too many stakeholders involved in supply chains [2], [12]. High construction costs and a general lack of knowledge are just two of the many challenges the Malaysian construction industry faces on the path to long-term success. Standardization, economic, awareness, and environmental strategies were all separated using EFA. This guidance will help academics, policymakers, and practitioners evaluate the scope of their research [12]-[13]. Consumers and designers are constantly worried about a sustainable project's energy footprint. This research presents a hypothetical BIM-based model that can recover the post-tenancy review process and meet industry criteria for sustainable buildings [13]. As reported by a group of researchers led by Hanjong [14], new practical procedures that may support the data of particular objects and guarantee the activation of green buildings in compliance with green building standards need to be developed. In order to create structures that deliver on their eco-friendliness promise, studies that account for this criterion should be conducted from the earliest stages of design onward. The complexity of many work operations could have improved the in-depth study of substances, identifying information needs, and effectively applying knowledge [14]. According to Giama & Papadopoulos [15], To address the issues of incommensurability and complexity in environmental legislation and regulatory frameworks, practical and relevant evaluation tools and methodologies are required for the construction of maintainable management [15] in a study [16], green and eco-friendly buildings are trending across India, not just in the western genre. According to the study, the process is more comprehensive than employing sustainable materials once sustainability is included in every step of construction practice. [16]. According to Hussein [17], the most advanced small molecule and protein-protein docking methods cannot predict how flexible polypeptides will bind to proteins, despite their importance According to Urban Persson [18], STURE's verification reveals that with some help from the client's environmental management system, construction projects may be tracked in advance to determine whether or not they are headed toward sustainable, partially sustainable, or non-sustainable growth. An example of a non-prejudicial assessment that refrains from generalization [18]. According to study Neyestani Behnam [19], the world is confronting numerous challenges and issues, and climate change and global warming are among them. Several scientific investigations have linked specific commercial sectors to the emergence of this disease [19]. According to T. Häkkinen et al. [20], the importance of regular building maintenance cannot be overstated in the context of green building. Maintenance helps reduce the need for material inputs and propels the development of more effective energy usage. Along with preserving the built environment, its monetary value, and the cultural history it represents, this is possible because of this [20]. Tobias Kraschewski et al. [21] Global weather protection agreements can be strengthened using sustainable building practices [21]. Izzet Yüksek and lker Karadag [22] stated that the rising energy consumption can be attributed to advancements in digital technology and rising incomes. While fossil fuels still account for most energy usage, renewables are slowly but surely making their way into the picture. Despite the widespread adoption of renewable energy sources, environmental damage and climate change have only worsened [22]-[25]. This research uses BIM-based energy consumption analysis to precisely evaluate building energy consumption and spot the building energy consumption problem in advance (Building Info Modeling). This guideline encourages evaluating energy use at different points throughout a building's lifespan (NAİMİ and HRİZİ, 2019). Based on previous work by Aesha Bhat et al. [5], you may save money and energy with the lime building concept. Good ventilation and clay walls not only help to increase the amount of natural light but also help to chill the interior naturally. Also, rainwater collection sustains the clay wall's moisture level [5].

1. Methodology

New HASP/ACLD-b is utilized to determine the heat loads of various structures in this study. New HASP/ACLD-b is a popular simulation application that is used to do the same kinds of things in the United Kingdom that EnergyPlus does in the United States. To evaluate the efficiency of air conditioning systems, it is necessary to calculate the indoor temperature, humidity, and thermal loads of buildings. The parameters of the New HASP/ACLD-b calculation program was readily rebuilt. This included the building walls' structure and the air conditioning's working state. The following calculation period input data is required for the New HASP/ACLD-b method of calculating building thermal loads:

- Temperature, humidity, solar intensity, cloud cover, wind direction, wind speed, and other meteorological parameters are recorded every hour.
- Factors such as the building's latitude and longitude, the height of the ground, the solar reflectivity of the ground, the solar radiation absorption and long-wave emissivity of the outer walls, the structure and materials of the outer and inner walls, the ceiling height, the distance to and height of neighboring buildings (not used here), the schedule of activities and occupancy inside the building, etc.

Building input variables include surface reflectivity of exterior walls and insulation thickness of outside walls in this research. Hourly, daily, monthly, and annual analyses of the building's thermal loads are all possible using the data that is generated.

Cost analysis: The cost of the HR or RR building envelope material and the insulating material, the cost of the annual thermal loads of the building, the coefficient of performance (COP) of the heating and cooling systems, the building envelope's lifetime, etc. all factor into determining the optimal combination of surface reflectivity and insulation thickness. Increasing the insulation thickness or reflectivity of the building envelope often reduces yearly thermal loads. The price of insulation rises proportionally to its thickness.

There are four widely available commercial materials, and HR or RR is assumed to cost the same as one of them. The total cost per unit area of exterior wall Ct is given by the following Equation.

$$C_t = C_{ins} + C_{ref} + C_{ene} = L_{ins}.c_i + C_{ref} + c_e.PWF$$

where C_{ins} is the cost of the insulation material, C_{ref} is the cost of reflective material of building envelope, C_{ene} is the cost of energy consumption over the building envelope lifetime, L_{ins} is the insulation thickness, c_i is the cost of insulation material per unit volume, c_e is the current annual total lifetime cost of energy and PWF is the present worth factor.

2. Result and Discussion

In order to construct buildings that are both environmentally friendly and economical, thorough research is essential. Reaching the project's financial goals is crucial to the project's overall success. In addition, the use of energy and natural materials and their effect on the environment are considered in environmentally responsible design. It is essential to make the most use of money and time by picking the right supplies for the job. Increasing numbers of people, in line with the rising tide of public environmental consciousness, are looking for sustainable materials to construct their homes and businesses. Materials that can either create energy or help remove the need for energy are typically considered by those interested in sustainability. Five eco-friendly materials were evaluated for their potential usage as thermal insulators in Iraqi building walls. Hollow blocks, clay bricks, white blocks, lightweight concrete, and multilayer concrete were some of the materials considered. Various insulations readily available in the area will be used in the experiments. According to table 1, insolation features include:

Table 1. Characteristics of insolation used in this research

insulation material	Thermal Conductivity (W/m.K)	availability	weight(kg/m3)	life of product	heat transfer	production flexibility
Polystyrene (expanded)	0.0374	high	16.5	long	18.67	medium
Glass Fiber	0.05	high	70	long	24.63	low
Glass Wool	0.051	high	75	long	25.10	low
Perlite	0.035	medium	160	long	17.52	medium
Polystyrene (extruded)	0.0288	high	27	medium	14.51	medium
Polyurethane	0.026	medium	41.5	medium	13.14	medium
Light Weight Concrete	0.065	high	400	long	16.60	high

Table 2. Results of thermal resistance of insolation with different materials

insulation material	thermal resistance of composite wall (k/w)	thermal resistance of block (k/w)	thermal resistance of brick (k/w)	thermal resistance of white block (k/w)	thermal resistance of light concrete (k/w)
Polystyrene (expanded)	1.39	2.25	1.81	2.77	4.41
Glass Fiber	1.06	1.91	1.47	2.43	4.08
Glass Wool	**1.04**	1.89	1.45	2.41	4.06
Perlite	1.48	2.34	1.90	2.86	4.51
Polystyrene (extruded)	1.79	2.65	2.21	3.16	4.81
Polyurethane	1.98	1.68	1.24	3.35	5.00

This study aims to find the heat load originating from the ambient temperature by combining the traditional wall materials with insulations and measuring the heat load in the buildings when replacing the wall materials. Figures 1–4 represent the results of some calculations.

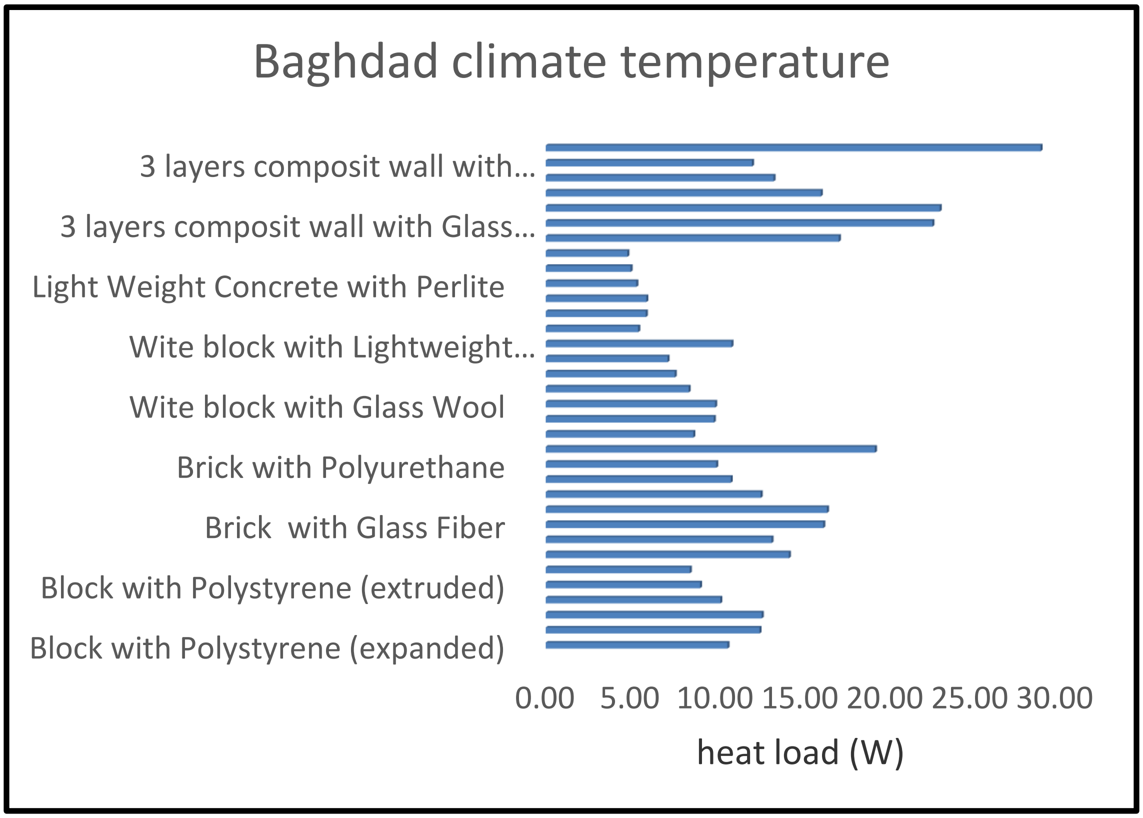

Fig 1. The heat load results in Baghdad city based on different types of composite materials

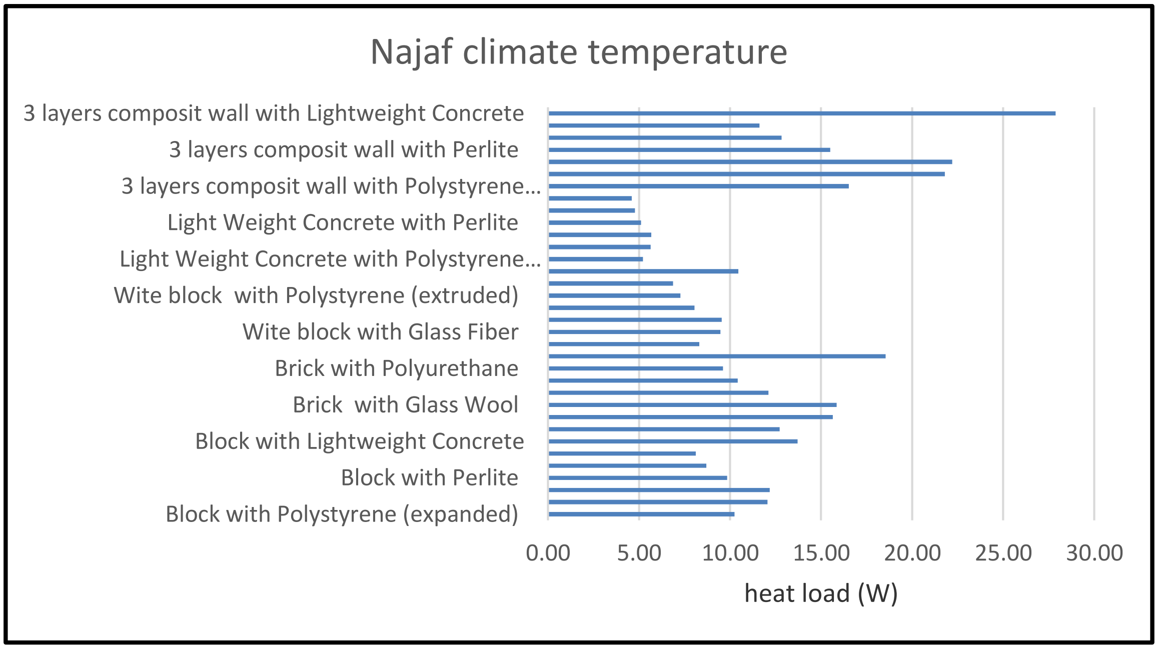

Fig 2. The heat load results in Basra city based on different types of composite materials

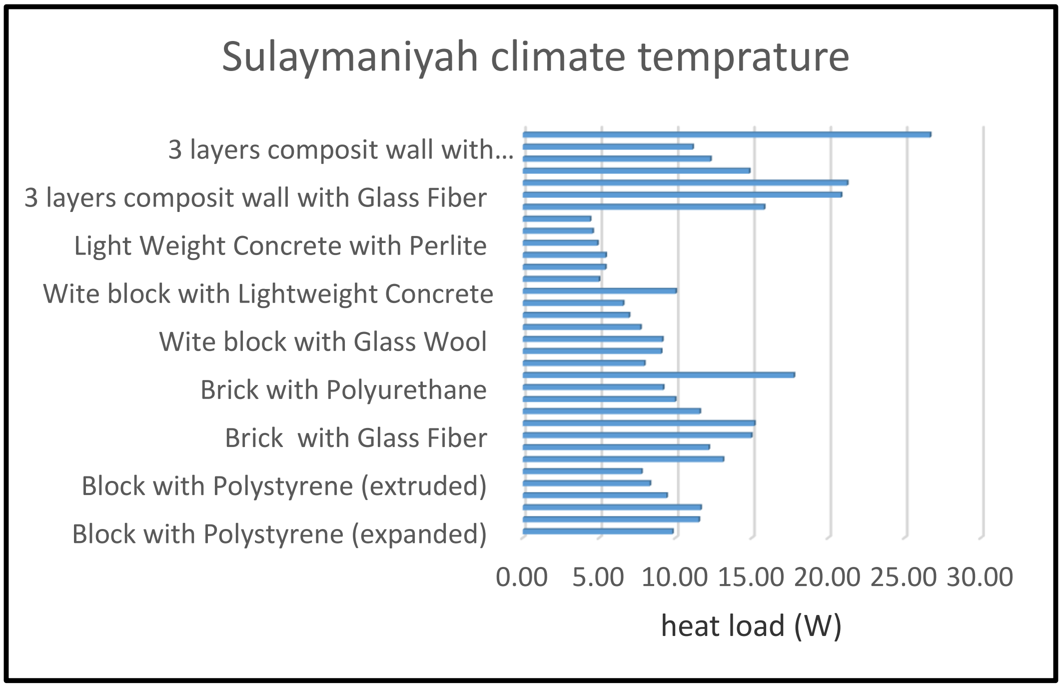

Fig 3. The heat load results in Najaf city based on different types of composite materials

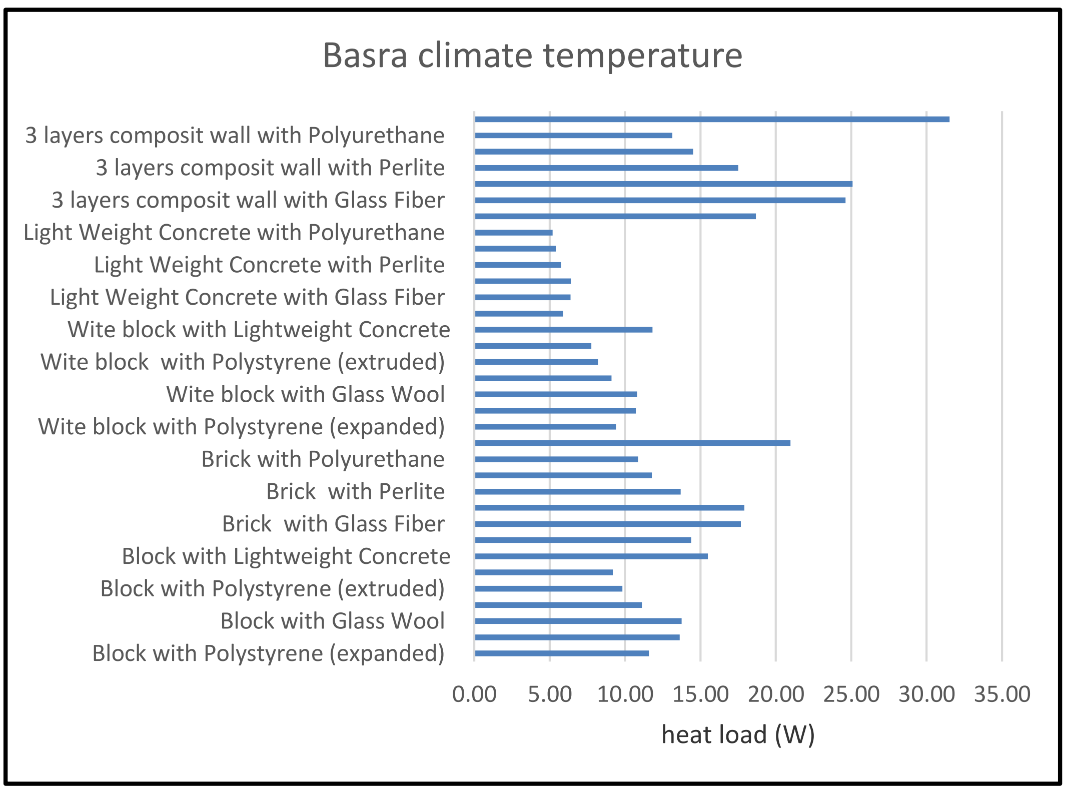

Fig 4. The heat load results in Sulaymaniyah city based on different types of composites materials

These figures summarize the study's findings on the various types of wall insulation used. The difference between the walls' U-values is presented beside the walls' individual U-values. The analysis results show how the heat load of composite walls could change depending on the insulation used. Differences in thermal insulating properties of materials account for these differences. When the temperature is high, increasing the continuous thermal insulation has the opposite effect, increasing both U-values. Using this structural strategy, the full potential of the insulation can be realized. Reduced ambient heat loads of 4.80 (W) are achieved by all types of Polyurethane-infused Light Weight Concrete, improving the overall thermal performance of these materials (U-value). Brick and block walls achieved 7.7 and 9.1 (W) and 11.1 (W) for the same thermal insulation with different wall thicknesses, respectively, while the composite wall exceeded even these values (W). The composite wall benefited from being lighter in weight.

5. Conclusion

Searches based on sustainability might yield encouraging and motivational results while evaluating the building material features of different projects. However, due to civil engineering's heavy concentration on this area, a few adjustments will need to be made to this method. However, the results of this study showed that isolation materials would be heavily evaluated in the construction sector and future studies. The ability to recover energy from generated heat following the materials used is an essential factor that should be considered when estimating building costs. Any company involved in the construction process should have a solid grasp of this. This new cost estimation method should be given more weight to take advantage of the substantial potential for using readily available sustainable resources in the construction industry.

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