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Sustainable Building Blocks Impacts on Cost, Productivity, Time, and Insulation

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Abstract

This research evaluates four sustainable masonry block options used in Iraq and examines their impact on insulation performance, construction productivity, building time, and total cost. Also, it assesses the sustainability of four common masonry block types in Iraq—conventional concrete, pumice-based blocks, clay hollow blocks, and Izocrete (EPS-based) blocks—by thoroughly comparing their thermal performance, construction efficiency, environmental footprint, and long-term economic viability. A quantitative approach is used, including calculations of thermal transmittance (U-value), heat-load modelling, yearly energy cost estimates, and life-cycle cost analysis (LCCA) over 50 years. Results indicate that pumice and Izocrete blocks have much lower U-values (0.108 and 0.078 W/m²·K, respectively) compared to conventional concrete blocks (2.39 W/m²·Kleading to major reductions in cooling loads. Annual energy savings amount to $300.55 for pumice, $266.14 for clay, and $304.34 for Izocrete blocks, compared with $935.71 in annual cooling costs for conventional concrete walls. Productivity analysis shows that lightweight blocks improve construction efficiency by about 20%, shortening project duration by roughly two workdays and saving up to $1,760 in labor costs per unit. Environmental analysis reveals pumice and clay blocks emit the least embodied CO_2 due to their natural materials and lower manufacturing energy. A 50-year present value (PV) analysis demonstrates strong long-term financial benefits, with Izocrete attaining the highest net present value (over $390,000), closely followed by pumice. Overall, the results emphasize the economic and ecological benefits of using lightweight, thermally insulating blocks in Iraq's residential building sector. Future research should explore actual thermal performance under different climate conditions and develop policies to promote the widespread adoption of sustainable wall systems.

Keywords: *Cost, Productivity, Time, Insulation.*

Introduction

Concrete remains one of the most widely used construction materials worldwide. However, a major drawback of traditional concrete systems is their poor thermal insulation, which is especially problematic in regions with extreme climate conditions. For example, in Iraq, electricity consumption during summer nearly doubles compared to winter, mainly due to the extensive use of air conditioning. This high demand is primarily caused by the insufficient thermal resistance of external walls and roofs [1].

Within the context of sustainable housing, reducing energy consumption has become a primary goal. Using thermally insulating masonry blocks can substantially decrease cooling loads in residential buildings by reducing heat transfer through the building envelope. One of the key factors affecting a building's energy efficiency is the effectiveness of its thermal insulation.

Besides thermal performance, the choice of construction materials also directly impacts labor productivity, project duration, and operational costs. While conventional heavy concrete blocks are often chosen for their lower initial costs, alternative materials—such as lightweight pumice blocks and hollow clay blocks provide significant advantages, including better insulation and quicker installation.

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This study aims to evaluate and compare four common block types used in Iraq—conventional concrete, pumice-based, clay, and Izocrete blocks—by examining their influence on construction speed, thermal performance, and energy consumption. Additionally, it assesses broader sustainability factors such as embodied energy, carbon footprint, and material resource efficiency to offer a comprehensive review of these masonry options.

Literature Review

Sustainability is a growing concern in construction due to the environmental impact of building materials and energy consumption. Researchers emphasize the importance of energy-efficient and cost-effective materials to reduce carbon footprints and long-term operational costs [2].

Sustainability and Thermal Insulation

Thermal insulation refers to materials and systems designed to reduce heat transfer between indoor and outdoor environments, enhancing indoor comfort and energy efficiency. Effective insulation depends on factors such as low thermal conductivity, increased thermal capacity, and reflective properties [1].

Cabeza et al. (2014) noted that material selection impacts not only construction time and costs but also long-term energy performance and maintenance[3]. After years, Al-Hafith et al. (2019) demonstrated that thermally efficient materials significantly reduce energy demand for cooling and heating[1].

Adebayo & Akinyemi (2020) found that lightweight and pumice-based concrete blocks exhibit lower thermal conductivity than conventional ones, leading to better thermal resistance and reduced indoor temperature fluctuation [4].

A comparison of different insulating materials found that lightweight concrete blocks and pumice-based blocks exhibit lower thermal conductivity than conventional concrete blocks, improving thermal resistance and reducing indoor temperature fluctuations [4].

Thermal Insulation, U-Value Behaviour, and Energy Efficiency in Iraq

Research on thermal insulation and wall performance in Iraq has advanced considerably over the past decade. Earlier work at the University of Technology – Iraq (UoT) primarily focused on experimental assessments of masonry walls, while more recent studies incorporate advanced materials, numerical simulations, and energy consumption modelling. The following chronological overview highlights this progression.

The earliest relevant UoT study is by Mahmood et al. (2019), which provided foundational experimental evidence on the effect of local insulation materials placed between brick layers. Using ASHRAE heat transfer equations, the researchers calculated U-values and wall heat gain under real Baghdad conditions. Their results showed that adding low-conductivity fillers such as cork grains or sawdust significantly reduced heat flow and indoor temperatures. Although predating recent developments, this study established the methodological basis for U-value calculation and heat flow modelling that continues to underpin current research in Iraq[5].

Progressing to newer research, Nsaif et al. (2024) reviewed the application of phase change materials (PCM) within glazing systems and insulated façades. Their analysis demonstrated that PCM-enhanced window systems can lessen indoor temperature fluctuations and decrease cooling energy use by up to 46%, especially when combined with night ventilation. This work expanded the field from simple insulation layers to dynamic, latent-heat storage materials, reflecting a shift towards high-performance building-envelope technologies[6].

Shortly after, Alwan and Jalghaf (2024) conducted numerical simulations of multilayer PCM-based walls under Baghdad weather conditions. Their MATLAB-based model calculated hourly heat flux, internal wall temperatures, and annual energy cost reductions for different PCM thicknesses. Their findings identified optimal PCM thicknesses (approximately 0.05–0.07 m) that greatly reduce annual cooling demand. Along with Nsaif et al., their work highlights a growing interest in thermally responsive wall systems within UoT literature[7].

Also in 2024, Hussein et al. performed one of the most comprehensive UoT simulations, using TRNSYS to analyse how insulation thickness and window-to-wall ratio (WWR) influence cooling loads in typical Iraqi houses. Their study showed that applying 5 cm of insulation to walls and roofs reduces annual thermal load by roughly 49%, while optimized WWR values further improve energy efficiency. Their work provides solid evidence for using Q = U × A × ΔT models to evaluate wall systems, directly supporting quantitative heat load methods used in current research[8].

Moving to the most recent material-focused studies, Abd et al. (2025) investigated rubberized, fiber-reinforced foamed concrete as a lightweight alternative for roof tiles. Although their research targets roof systems rather than wall blocks, their results confirmed that lower-density cementitious materials offer improved thermal insulation, sound reduction, and sustainability benefits due to waste-rubber use. This aligns with the broader shift towards lightweight, thermally efficient construction materials in Iraqi housing[9].

Finally, Karoon and Ibraheem (2025) broadened the perspective by examining the role of smart, energy-efficient building envelopes as part of climate-responsive design strategies. Their study highlights that HVAC systems account for over one-third of building energy use in Iraq, making improvements to the envelope—such as insulation, optimized U-values, and advanced glazing—crucial for cost reduction and environmental performance. Their conceptual analysis links passive envelope improvements with active, smart technologies, framing insulation as part of an integrated sustainability approach[10].

Across these chronological developments, it is clear that UoT research has evolved from basic insulation experiments (2019) to advanced materials and envelope optimization (2024–2025). However, despite meaningful progress, current studies do not offer a multi-dimensional comparison of the four main masonry block types used in Iraq (normal concrete, pumice, clay hollow, and EPS/Izocrete), while also considering construction productivity, costs, annual cooling electricity consumption, and 50-year life-cycle financial performance. Addressing this gap, the present study provides a comprehensive evaluation that links thermal behavior to economic and environmental sustainability in residential construction.

Thermal Insulation Material Properties

Thermal insulating materials are evaluated not only by their thermal performance but also by their mechanical and environmental properties. Thermal insulating blocks are evaluated not only for their ability to reduce heat transfer, but also for their structural performance, environmental impact, and durability. Key thermal properties such as low thermal conductivity and high thermal resistance directly influence how well a block limits heat flow across building envelopes, which is essential in reducing energy demand for cooling or heating [3].

Several critical factors influence the selection and performance of thermal insulation materials in block form:

- Thermal Performance: Lower thermal conductivity values enhance the block's ability to minimize heat gain or loss. Some surfaces may also incorporate reflective layers to reduce radiant heat transmission.
- Mechanical Strength: Certain insulating blocks, such as EPS-based Izocrete, offer a balance between thermal efficiency and sufficient compressive strength for non-load-bearing or partially load-bearing applications [11].
- Moisture Resistance: Resistance to water absorption is vital, as excessive moisture can degrade insulating properties and structural integrity.
- Health and Safety: The use of non-toxic, low-emission materials is important during manufacturing, installation, and long-term use.
- Acoustic Properties: Some thermal blocks also contribute to noise reduction, which improves indoor comfort in dense urban environments.

Lightweight blocks such as pumice-based and EPS (Izocrete) blocks generally have lower thermal conductivity compared to traditional concrete, enhancing insulation and helping to regulate indoor temperatures [3]. From a mechanical standpoint, although some insulating materials like clay blocks may provide moderate compressive strength, others like concrete or Izocrete can be optimized to achieve a balance between load-bearing capacity and insulation performance [11]. Environmentally, insulating blocks with low embodied energy and recyclable components—such as pumice or clay fired using renewable energy—can greatly lower a building's carbon footprint over its life cycle [12]. Moreover, moisture resistance, fire safety, and acoustic insulation are becoming increasingly important for assessing block material performance in real-world conditions, especially in harsh climates like Iraq's [13].

Block Types and Thermal Conductivity

The economic feasibility of using alternative construction materials relies on factors such as material cost, labor productivity, and execution time. According to González & Navarro (2006), lightweight concrete blocks enhance productivity due to their ease of handling and quicker installation compared to conventional concrete blocks [12]. A comparative study on bricklaying productivity indicated that lightweight blocks decrease construction time by 20-30%, resulting in labor cost savings [14].

There are several types of blocks that are widely used in construction as follows:

A. Conventional Concrete Blocks

Concrete block construction has gained importance and has become a viable alternative to fired clay bricks. The main ingredients of concrete are cement, aggregate (sand, gravel), and water. Concrete blocks are produced in a wide variety of shapes and sizes, and they can be manufactured manually or by machines [15].

Figure 1: Normal block shape

The most commonly used sizes are:

Length: 40cm (half blocks: 20cm)

Height: 20cm

Width: 8/10/15/20cm

Conventional blocks are divided into two main types:

i. Solid blocks have no cavities or, according to US standards, do not have voids exceeding 25% of the total cross-sectional area.

ii. Hollow blocks are the most common type of concrete blocks, featuring one or more holes open on both sides. The total void area can be up to 50% of the gross cross-sectional area.

B. Pumice Block:

Pumice blocks are easy to work with, allowing for various architectural designs while contributing to an energy-efficient and cost-effective construction system. Unlike regular concrete, they are primarily used for insulation and lightweight construction. Their natural volcanic origin makes them resilient, earthquake-resistant, and highly fire-resistant.

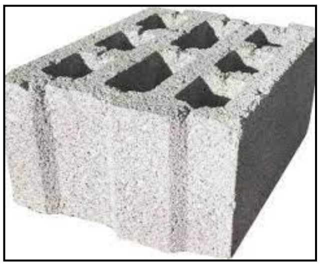

Figure 2: Pumice Block Shape

Pumice stone, a naturally occurring lightweight aggregate, has been widely studied for its insulation properties and structural performance. Research highlights that pumice-based blocks provide better thermal resistance than traditional heavy concrete blocks, making them suitable for sustainable constructionm[11].

In addition to their insulating benefits, pumice blocks contribute to reducing dead load on structures, enhancing earthquake resistance, and lowering material transport costs [16].

C. Clay Block :

Clay hollow blocks, also known as hollow clay bricks, are increasingly favored in modern construction due to their numerous advantages over traditional solid bricks .

One of the primary benefits is their exceptional thermal insulation; the hollow cavities within these blocks reduce heat transfer, maintaining cooler interiors in summer and warmer environments in winter, thereby enhancing energy efficiency .

Additionally, their lightweight nature, approximately 50-60% lighter than standard clay bricks, facilitates easier handling and faster construction, reducing labor costs and shortening project timelines. Moreover, clay hollow blocks are eco-friendly as they are made from natural materials and often incorporate industrial waste products like fly ash, contributing to environmental sustainability .

Figure 3: Clay block shape

Their inherent fire resistance and sound insulation properties further enhance building safety and comfort. However, it's essential to consider that while they offer these benefits, clay hollow blocks have a lower compressive strength compared to solid bricks, which may limit their use in certain load-bearing applications [17].

D. Izocrete Block:

Izocrete blocks are manufactured by using Expanded Polystyrene (EPS) concrete, a composite of cement and EPS beads, which results in a significant weight reduction and enhanced thermal insulation.

These blocks offer advantages such as ease of handling, high thermal efficiency, and good fire resistance, making them suitable for walls, floors, and roof applications.

The use of EPS concrete aligns with modern sustainable construction practices by improving energy performance and reducing structural loads [18].

The inclusion of such innovative materials contributes to achieving lightweight, energy-efficient, and cost-effective building systems in residential and commercial projects [18].

Figure 4: Izocrete block shape

Environmental Impact of Insulating Materials

Sustainability assessments of construction materials involve analyzing embodied energy, carbon footprint, and recyclability. Thermal insulating blocks, especially those made from pumice stone or lightweight aggregates, have been found to reduce CO2 emissions due to their lower energy-intensive manufacturing process [11]. Moreover, their increased durability and reduced maintenance contribute to sustainable urban development.

To further evaluate the sustainability of selected construction materials, it is essential to assess the embodied carbon emissions (CO_2) associated with producing each block type. Embodied carbon includes emissions from raw material extraction, manufacturing, transportation, and construction. Among the four types of block.

Table (1) summarizes the estimated embodied CO_2 emissions associated with producing 1 m² of wall for each block type, highlighting the differences in carbon intensity based on manufacturing processes and material composition.

Table (1): Approx. CO_2 Emissions Per M² Of Wall of Different Types of Block [11] .

Block Type	Approx. CO_2 Emissions per m² of Wall	Key Emission Source
Normal Concrete Block	100–150 kg CO_2/m²	Cement production
Clay Block (fossil kiln)	80–140 kg CO_2/m²	Kiln firing with fossil fuels
Clay Block (renewable kiln)	40–70 kg CO_2/m²	Biomass or solar-powered kilns
Izocrete Block	70–120 kg CO_2/m²	EPS manufacturing + cement usage
Pumice Block	60–90 kg CO_2/m²	Natural pumice + minimal cement use

Using renewable energy in clay block production can reduce CO_2 emissions by up to 50%, making it competitive with pumice and EPS-based blocks.

Energy Savings and Life Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) is a critical tool for evaluating the long-term financial viability of sustainable materials. Cabeza et al. (2014) assert that while thermally efficient blocks may entail higher upfront costs, they lead to substantial reductions in operational energy expenditures.

A simulation study by Al-Hafith et al. (2019) in Iraq revealed that replacing traditional concrete blocks with thermal insulating alternatives can reduce energy demand for cooling by 30–50%. These findings confirm the potential for such materials to contribute significantly to long-term economic and environmental sustainability [1].

Methodology

This section outlines the approach used to evaluate the performance of different block types based on thermal insulation, construction cost, productivity, and energy savings. The study employs a quantitative comparative method incorporating thermal calculations, life-cycle cost analysis, and energy modeling.

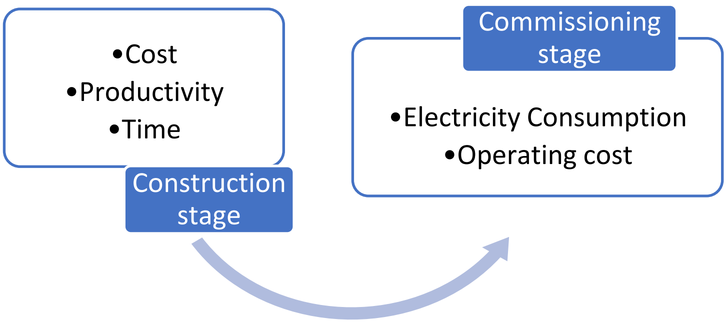

Figure 5: Research Methodology

Usually, in horizontal residential projects, several construction systems are used, some of which are traditional systems using load-bearing walls (load-bearing bricks), and some of which are pre-cast systems such as shear walls and pre-cast hollow Slabs, while the most common systems to achieve continuity in production are structural systems using Columns and slabs with non-load-bearing walls.

A case study of horizontal units has been taken to apply the calculations to this model. An outer wall should comply with the specifications of thermal insulation

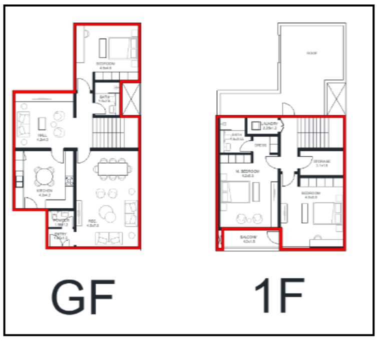

Figure 6: Case study plan

Understanding U-Value and Its Impact

The U-value measures the rate of heat transfer through a material or structure. When the U-values is Lower, that indicates better insulation and less heat gain/loss. heat transfer coefficients (U-value) for each block type can be computed using the formula [13]:

U = 1 / R …… Equation - 1

Where R-value is the Thermal resistance of the wall layers, derived from material thickness and thermal conductivity (λ).

The effectiveness of insulation is measured by the thermal conductivity (k) of the material and the thickness of the insulating layer. The relationship is given by:

U = k / thickness **…….Equation No - 2**

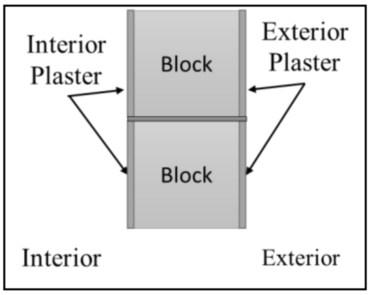

Figure 7: Wall Section Details.

For each block type, including conventional concrete, pumice, clay, and Izocret (EPS-based) blocks, thermal conductivity values were collected from manufacturer specifications and scientific literature. Material layers included interior and exterior plaster, the block core, and surface resistances.

By applying the data for each type as follows in Table (2) presents the step-by-step calculation of the thermal transmittance (U-value) for a standard 20-cm normal concrete block wall, including layer thicknesses, thermal conductivities (λ), thermal resistances (R), and surface resistances based on ASHRAE procedures.

Table (2): Calculation Of U-Value for Normal Wall [19].

20 cm - Norma block					
Material	Thickness (m)	λ (W/mc°)	R (m2. c°/W)	Temp. gradient (c°)	K
Exterior surface resistance	0.001848667	0.042992261	0.043	0.45	10.465116
External Plaster	0.02	0.8	0.025	0.26	10.4
block Type	0.2	0.96	0.208	2.17	10.416
Internal Plaster	0.015	0.8	0.019	0.19	10.133333
Interior surface resistance	0.015110565	0.122850123	0.123	1.28	10.406504
R			0.418		
U=1/R			2.392		

Using the same methodology applied to the normal concrete block wall, the U-values of the other wall types were calculated by summing the thermal resistances of all layers, including surface films, plaster, and the core block material. This allows for a direct comparison of the thermal performance of each wall system.

Table (3) provides a comparative summary of the calculated U-values for the remaining wall types, using the same thermal-resistance procedure applied to the normal block wall to evaluate differences in heat-transfer performance among the selected materials.

Table (3): Calculation of U-Value for Other Types of Walls.

20 cm - Pumice block					
Material	Thickness (m)	λ (W/mc°)	R (m2. c°/W)	Temp. gradient (c°)	K
block Type	0.2	0.022	9.090909091	2.17	0.2387
R			9.301		
U=1/R			0.108		
20 cm - Clay Block					
Material	Thickness (m)	λ (W/mc°)	R (m2. c°/W)	Temp. gradient (c°)	K
block Type	0.2	0.08	2.5	2.17	0.868
R			2.710		
U=1/R			0.369		
20 cm - Izocret Block					

Material	Thickness (m)	λ (W/mcº)	R (m2. cº/W)	Temp. gradient (cº)	K
block Type	0.2	0.016	12.5	2.17	0.1736
R			12.70975		
U=1/R			0.078		

Heat Load and Energy Cost Modeling

In sustainable housing projects, reducing energy consumption is crucial. One of the key factors affecting energy efficiency is the thermal insulation of buildings. Using insulating blocks can significantly decrease the required cooling load (tonnage) for residential units by reducing heat gain through walls.

The resulting U-values were then applied in heat load equations to estimate the monthly and annual energy savings [20]:

$Q = U \times A \times \Delta T$ …… Equation -3

Where:

- Q is the heat load (W)
- A is the wall surface area (m²)
- ΔT is the temperature gradient (°C)

The energy load reduction is calculated using the equation[14]:

$\Delta Q = (U_a - U_i) \times A \times \Delta T$ …… Equation -4

Where:

- U_a: U-value of conventional block (2.39 W/m²·K)
- U_i: U-value of insulated block (e.g., 0.11 W/m²·K for pumice)
- A: Wall surface area (m²)
- ΔT: Monthly average temperature difference

These results were integrated into a cost model for estimating electricity consumption and savings over different operational months in the Iraqi climate.

Electricity cost savings are estimated using:

Cost Savings = $((U_a - U_i) \times A \times \Delta T / COP) \times H \times C$ …. Equation -5

Table (4): Calculation of U-Value for normal wall.

Month	Avg. Max Temp (°C)	Avg. Min Temp (°C)	Avg. Outside Temp (°C)
Jan	15.2	3.5	9.35
Feb	18.3	5.7	12
Mar	23.9	10.5	17.2
Apr	30.2	15.8	23
May	37.8	21.4	29.6
Jun	43.2	26.4	34.8
Jul	45.6	28.4	37
Aug	45.1	27.8	36.45
Sep	41.1	24	32.55
Oct	33.5	17.6	25.55
Nov	23.3	10	16.65
Dec	16.6	5.1	10.85

Monthly values for temperature gradient and system operation hours were taken from typical climatic patterns in central Iraq. This is especially crucial in hot climates like Iraq, where efficient insulation reduces cooling loads and energy consumption

During 2024 year a temperature records has been taken in calculation as a reference to get the average temperature as shown in table [21] :

To determine the cost of electricity consumption for a residential unit, several models of houses operating on both the main electricity line and generators were examined, and the amount of electricity consumed was calculated. It was found that a residential unit similar to the model to be studied, with the same contents, reaches a 1.5 kWh/M monthly income. To estimate the cost, it is done according to the pricing of the Iraqi Ministry of Electricity [22].

This estimation shows the largest portion of electricity, accounting for 60%, is consumed by cooling and heating systems, highlighting their significant energy demand. Kitchen appliances follow, using 15% of the total energy, while lighting and other miscellaneous uses each account for 10%. Entertainment devices consume the least, at only 5%. This distribution emphasizes the high energy requirements of climate control compared to other household uses [22].

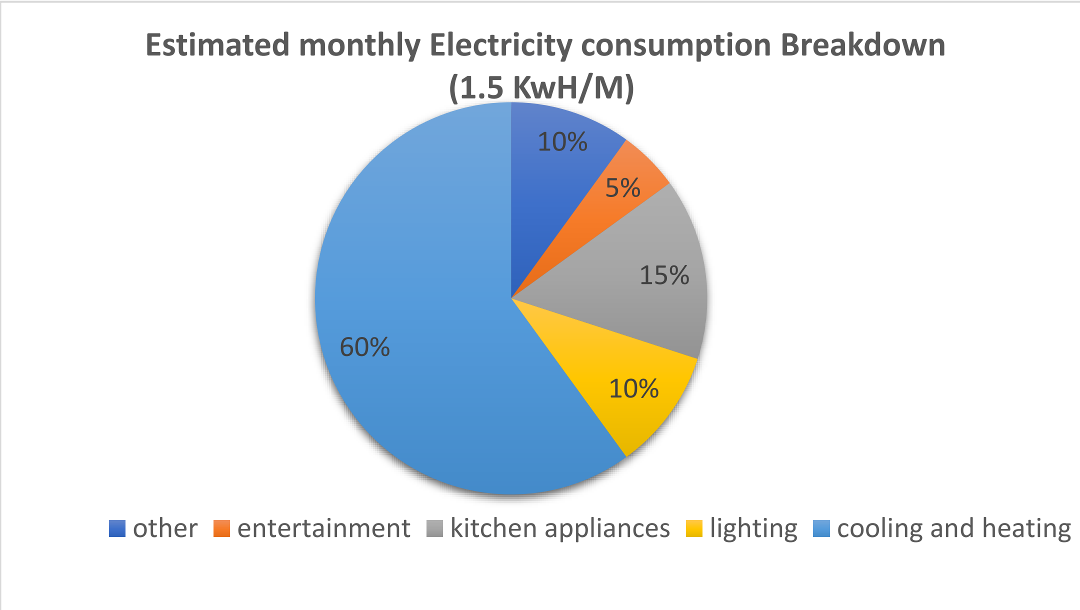

Figure 8: Estimated monthly Electricity consumption Breakdown

The number of hours the machine operates at 60% of the total electricity consumption is consumed by cooling and heating systems, which can be taken from the data survey for different houses, as shown in Table 5:

Table (5): Number of Hours Per Month for Cooling and Heating

Number Of Hours Per Month For Cooling And Heating					
Month	Avg. Cooling Hours/Day	Avg. Heating Hours/Day	Notes	Total Machine Working	Number Of Hours Per Month
January	0	6–10	Winter – Strong Heating Needed	10	300
February	0	4–8	Winter	8	240
March	0–2	1–3	Mild Spring	5	150
April	2–4	0	Start Of Warm Weather	4	120

May	6–8	0	Hot Begins	8	240
June	10–14	0	Hot	14	420
July	14–18	0	Very Hot	18	540
August	14–18	0	Very Hot	18	540
September	6–8	0	Hot	8	240
October	2–4	0	Mild Autumn	4	120
November	0	4–6	Cooler Weather	6	180
December	0	6–10	Winter – Strong Heating Needed	10	300

The price of a consumption unit can be obtained from the Table 6 as shown below:

Table (6): Electricity Consumption Price Per Unit.

Price according to the Ministry of Electricity		
KW/hr.	IQD	per month
	60	43,200.00 IQD
	$	
	$ 0.045	$ 32.73

The analysis demonstrates that switching to thermally insulated blocks yields notable energy savings.

Cost Calculations:

This section evaluates construction productivity, cost savings, and thermal efficiency through a comparative analysis by estimating monthly energy consumption and the corresponding annual cost savings for each block type. The analysis relies on average monthly temperature differences (ΔT), cooling system efficiency (Coefficient of Performance – COP)[20], operating hours (H), and unit electricity cost (C).

The block types differ in prices as mentioned in the table below:

Table (7): Block Type Prices in the Local Market of Iraq.

Size	**Prices**			
	normal	**pumice**	**clay**	**izocret**
20*20*40 cm	$ 0.68	$ 0.98	$ 1.06	$ 1.11
15*20*40 cm	$ 0.60	$ 0.83	$ 0.99	$ 0.83
10*20*40 cm	$ 0.52	$ 0.70	$ 0.97	$ 0.55

For the case study table shows the information and estimation of material cost for each type:

Table (8): Case Study Information and Material Cost Estimation.

Activity Description	Activity Unit	Activity Quantity
Outer Brick Wall for Ground and 1st Floor 20*20*40 cm	M2	250
Block type	Activity Unit Price	Activity Price
normal	$ 23.45	$ 5,862.93
pumice	$ 27.28	$ 6,819.96
clay	$ 28.22	$ 7,056.11
Izocret	$ 28.86	$ 7,215.00

Compared to normal blocks, pumice blocks cost $957.03 more, clay blocks $1,193.18 more, and Izocret blocks $1,352.07 more, reflecting the added investment for improved thermal insulation. This difference is only for block material. So, for working and construction, the one team, productivity per day is [14]:

- Heavy Blocks: 2.1 m²/hr per team * 8 hours per day = 16.8 the Productivity in m²/day

- Lightweight Blocks and clayey:

2.5 m²/hr per team* 8 hours per day = 20 the Productivity in m²/day

Workdays Required for Wall Construction per Unit:

- Heavy Blocks=250/16.8=14.88~15
- Other types of block = 250/2.0 =12.5~13

The difference in time ~ 2 days.

Labor Cost Savings calculated by estimating the cost of the difference in time of construction among blocks :

- Daily labor team cost:
- Skilled worker: $55/day
- Two assistants: 2 × $22.5 = $45/day
- Total cost per day: $55 + $45 = $100/day for one team
- Indirect cost saving (10% Direct cost)
- Total Saving =800+800*0.1=880 $, For 2 days will be 880*2=1760 $**.**

Net differences in cost among block types :

Table (9): Difference in cost between Normal and other types.

Block type	Difference in cost between Normal and other types	Net Difference of cost
Normal	$ -	0
Pumice	=6819.96-582.93=957.03 $	=957.03-1760 =-802.97 $
Clay	$ 1,193.18	$ -566.82 $
Izocret	$ 1,352.07	$ -407.93 $

Heat load and energy saving calculation done by applying equation (5) by using the collected data to achieve the monthly cost savings by using different thermally insulated block types compared to normal concrete blocks, under consistent conditions, as shown in tables 10 and 11.

Table (10): Input data used in equation (5).

Month	Avg. Outside-Temp	T inside	Delta-T	U befor	U after	Area of wall	COP	H
Jan	9.35	25	15.65	2.39	To be used according to the block type From tables no. (2) and (3)	250	3	Operation hours in the month, according to the table (5)
Feb	12	25	13	2.39		250	3	
Mar	17.2	25	7.8	2.39		250	3	
Apr	23	25	2	2.39		250	3	
May	29.6	25	4.6	2.39		250	3	
Jun	34.8	25	9.8	2.39		250	3	
Jul	37	25	12	2.39		250	3	
Aug	36.45	25	11.45	2.39		250	3	
Sep	32.55	25	7.55	2.39		250	3	
Oct	25.55	25	0.55	2.39		250	3	

Nov	16.65	25	8.35	2.39		250	3	
Dec	10.85	25	14.15	2.39		250	3	

Table (11): Saving calculation in electricity for each block type:

Saving calculation					
Month	Cost	Cost saving for a normal block	Cost saving for Pumice block	Cost saving for Clay block	Cost saving for Izocret block
Jan	$ 0.045	$ -	$ 40.63	$ 35.97	$ 41.14
Feb	$ 0.045	$ -	$ 27.00	$ 23.91	$ 27.34
Mar	$ 0.045	$ -	$ 10.12	$ 8.96	$ 10.25
Apr	$ 0.045	$ -	$ 2.08	$ 1.84	$ 2.10
May	$ 0.045	$ -	$ 9.55	$ 8.46	$ 9.67
Jun	$ 0.045	$ -	$ 35.62	$ 31.54	$ 36.06
Jul	$ 0.045	$ -	$ 56.07	$ 49.65	$ 56.78
Aug	$ 0.045	$ -	$ 53.50	$ 47.38	$ 54.18
Sep	$ 0.045	$ -	$ 15.68	$ 13.88	$ 15.88
Oct	$ 0.045	$ -	$ 0.57	$ 0.51	$ 0.58
Nov	$ 0.045	$ -	$ 13.01	$ 11.52	$ 13.17
Dec	$ 0.045	$ -	$ 36.73	$ 32.53	$ 37.20
Total		$ -	$ 300.55	$ 266.14	$ 304.34

These monthly savings are aggregated to compute total annual and multi-year financial returns, which support the investment decision in sustainable materials.

Regarding the result, the Consumption of Electricity after cost savings has been achieved is shown in Table 12.

Table (12): Consumption of Electricity after cost saving.

Consumption of Electricity compared with normal block				
Month	Normal block	Pumice block using	Clay block using	Isocret block using
Jan	$72.67	32.0	36.7	31.5
Feb	$76.56	49.6	52.7	49.2
Mar	$71.82	61.7	62.9	61.6
Apr	$73.58	71.5	71.7	71.5
May	$86.26	76.7	77.8	76.6
Jun	$81.68	46.1	50.1	45.6
Jul	$82.41	26.3	32.8	25.6
Aug	$83.14	29.6	35.8	29.0
Sep	$80.33	64.6	66.4	64.4
Oct	$72.30	71.7	71.8	71.7
Nov	$75.73	62.7	64.2	62.6
Dec	$79.23	42.5	46.7	42.0
	$935.71	$635.16	$669.57	$631.37

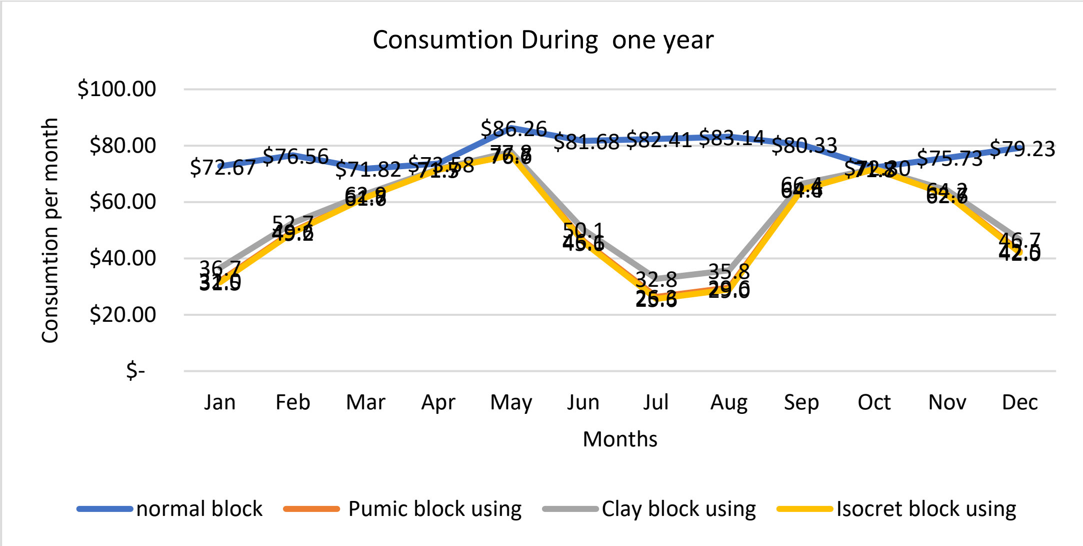

Figure 9: Electricity Consumption During one year of block types Per Month.

Based on the energy savings calculations, the evaluation of financial return on investment over a 50-year project lifespan can be done by computing the consumption of the unit during life cycle (50 years) as shown in table no (11).

Table (13): Consumption per life cycle of the residential unit.

Consumption per life cycle year				
Years	Normal Block	Pumice block using	Clay block using	Isocret block using
0	$-	$-	$-	$-
10	$9,357.09	$6,351.62	$6,695.69	$6,313.67
20	$18,714.18	$12,703.23	$13,391.38	$12,627.34
30	$28,071.27	$19,054.85	$20,087.07	$18,941.01
40	$37,428.36	$25,406.46	$26,782.76	$25,254.69
50	$46,785.45	$31,758.08	$33,478.45	$31,568.36

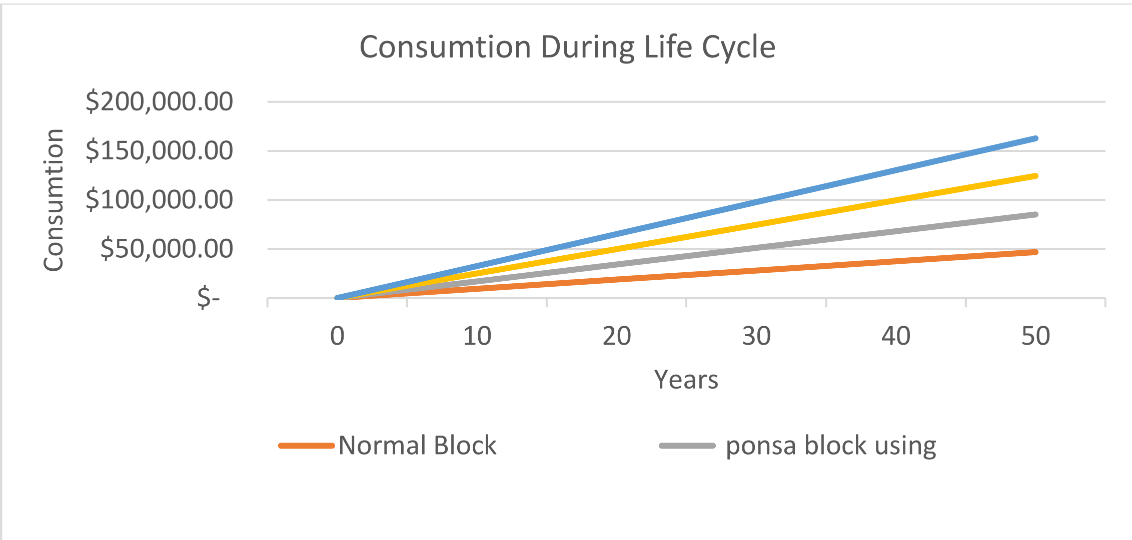

Figure (10): Estimated 50-Year Energy Cost Savings by Block Type

Financial Return and Present Value Assessment

The methodology also incorporated financial calculations using Present Value (PV) formulas to assess long-term cost efficiency by analyzing the financial return of using thermally insulated blocks over a 50-year project lifespan[23].

The key parameters considered include:

-Initial block cost

-Annual energy savings

-Cooling system operating hours

-Electricity tariff

-Present Value (PV) of cumulative savings

The present value of savings over time is calculated using the formula[24]:

PV = A × [{(1 + i)^N – 1} / (i × (1 + i)^N)]…. Equation - 6

$$PV = A \times \left[\frac{(1+i)^N - 1}{i \times (1+i)^N}\right]$$

Where:

- PV: Present value
- A: Annual savings (USD)
- i: Discount rate (e.g., 5%)
- N: Project lifespan (e.g., 50 years)

By using equation no – 6 :

Table (14): 50-Year Savings and Present Value.

50-Year Savings and Present Value				
Block Type	Added Initial Cost (USD)	50-Year Savings (USD)	Present Value (USD)	Net Return (PV - Cost)
Pumice Block	$ 957.03	$ 15,027.38	$ 386,650.89	$ 385,693.86
Clay Block	$ 1,193.18	$ 13,307.00	$ 342,386.04	$ 341,192.86
Izocret Block	$ 1,352.07	$ 15,217.10	$ 391,532.30	$ 390,180.23

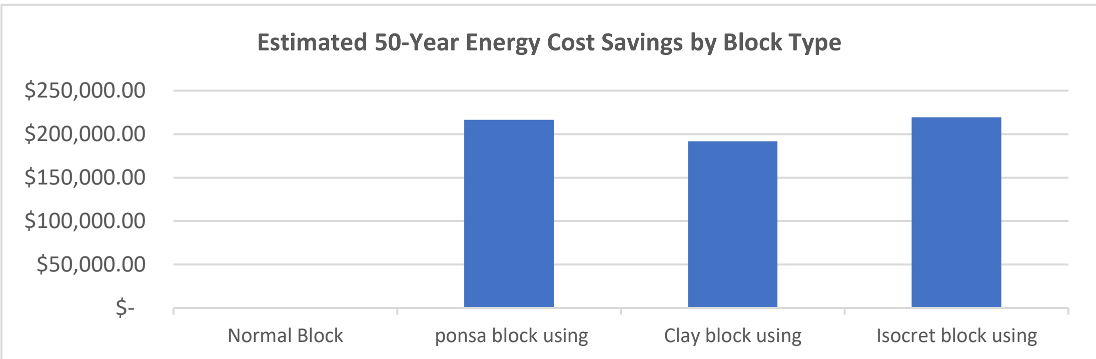

Figure (11): Estimated 50-Year Energy Cost Savings by Block Type.

Results and Discussion

The analysis revealed substantial advantages of using thermally insulated masonry blocks over conventional concrete blocks in residential construction. These benefits encompass energy savings, improved labor productivity, lower environmental impact, and greater financial returns over the building's lifecycle. In the context of Iraq's hot climate, these findings are particularly relevant for promoting sustainable housing strategies. The following subsections detail the key findings.

Thermal Performance and Energy Savings

The thermal conductivity results demonstrated that pumice and Izocrete blocks offer superior insulation with U-values of 0.11 W/m²·K and 0.078 W/m²·K respectively, in contrast to 2.39 W/m²·K for standard concrete blocks. As a result, residential units constructed with insulated blocks experienced a reduction in cooling loads and electricity consumption, with monthly savings ranging between $0.57 and $56.78.

Over a year, Izocrete blocks yielded the highest total energy cost savings at $304.34, followed closely by pumice blocks at $300.55, and clay blocks at $266.42. These savings are particularly impactful in Iraq, where cooling represents a major component of household energy demand.

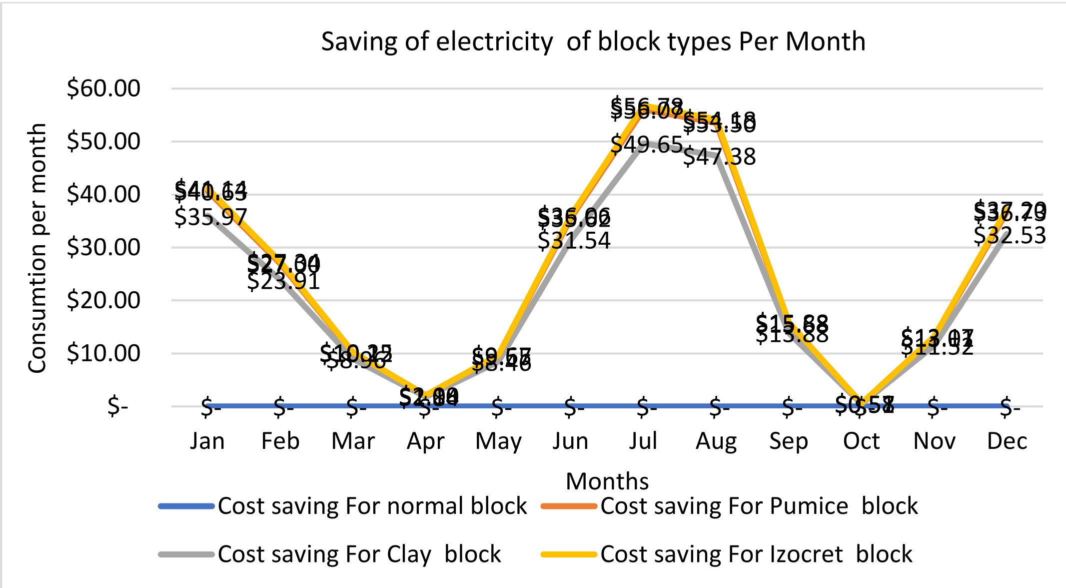

Figure 12: Saving of electricity of block types Per Month.

These savings are critical in Iraq's climate where cooling loads dominate residential energy consumption.

Construction Cost and Labor Productivity

While thermally insulating blocks have higher material costs, their light weight and ease of installation contribute to improved productivity. Lightweight blocks achieved a productivity rate of 20 m²/day per team, compared to 16.8 m²/day for conventional concrete blocks. This resulted in a reduction of approximately 2 working days per residential unit, translating into labor cost savings of up to $1,760. When offsetting the increased material costs, the net savings per unit reached $802.97 for pumice, $566.82 for clay, and $407.93 for Izocrete blocks, demonstrating economic advantages even in the short term.

Environmental Impact

From an environmental standpoint, pumice and clay blocks exhibited the lowest embodied CO_2 emissions due to their natural composition and lower energy requirements in production. Izocrete blocks also performed well owing to the reduced cement content and the lightweight EPS filler. When clay is fired using renewable energy, its emissions further decrease, making it a highly sustainable option. These findings underscore the importance of material selection in reducing the carbon footprint of residential buildings.

Life Cycle Cost and Financial Return

Despite the higher initial investment, all three types of insulating blocks offer substantial financial returns over a 50-year building lifespan. When incorporating energy savings and productivity gains into a discounted cash flow analysis (using a 5% discount rate), the present value (PV) of total savings exceeded $340,000 for each type. Izocrete blocks achieved the highest net financial return, with a PV exceeding $390,180 and a net gain of over $388,000 after accounting for the cost difference. This confirms that insulated blocks not only enhance performance but also ensure long-term economic feasibility, making them a strategic choice for sustainable development in Iraq.

Conclusion and Recommendations

This study has evaluated the sustainability performance of four widely used masonry block types in Iraq—conventional concrete, pumice-based, clay hollow, and Izocrete blocks—across multiple criteria, including thermal insulation efficiency, construction cost, labor productivity, environmental impact, and long-term economic feasibility.

Key conclusions include:

i. Thermal Efficiency:

Pumice and Izocrete blocks significantly outperformed conventional concrete in terms of thermal insulation, achieving U-values as low as 0.078–0.11 W/m²·K compared to 2.39 W/m²·K for standard blocks. This translated into energy savings of $266–$304 annually per unit, confirming their effectiveness in reducing cooling loads in Iraq's hot climate.

ii. Economic Feasibility:

Although insulating blocks incur higher upfront material costs, these are largely offset by reduced labor costs (up to $1,760 per unit) due to higher construction productivity, and by long-term energy savings. Over a 50-year lifespan, the present value (PV) of savings exceeded $340,000 in all insulated cases, with Izocrete yielding the highest net return.

iii. Environmental Benefits:

Pumice and clay blocks, especially those manufactured using renewable energy, demonstrated the lowest embodied carbon emissions. Izocrete blocks also offered environmental benefits due to the lightweight EPS-based material and reduced cement use.

iv. Productivity Gains:

Lightweight blocks enabled 19–20 m²/day installation rates versus 16.8 m²/day for conventional blocks. This reduced project duration and indirect costs, supporting faster and more efficient construction practices.

Recommendations

i. Policy Support for Sustainable Materials:

Government and industry stakeholders should develop incentives and regulatory frameworks to promote the adoption of thermally insulated blocks in residential construction.

ii. Integration in Building Codes:

Thermal performance standards should be integrated into local building codes, encouraging the mandatory use of low-U-value wall assemblies in new developments.

iii. Local Production and Supply Chain Development:

Encouraging domestic production of pumice and EPS-based blocks can reduce costs and enhance availability, making them a viable option for mass housing.

iv. Further Research:

Future studies should assess the real-world thermal performance of these materials under varying climatic conditions in Iraq, and explore hybrid solutions that combine structural and insulation benefits.

v. Capacity Building:

Training programs for engineers, architects, and contractors are needed to increase awareness and technical proficiency in sustainable construction systems.

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