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Sustainable Rehabilitation Strategies for Traditional Iraqi Homes: Mitigating Thermal Challenges with Innovative Materials

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ABSTRACT

The rehabilitation of traditional houses in Iraq is very difficult due to outdated construction systems, environmental conditions, and the high costs of maintenance. The present study explores the use of Izocrete blocks as an alternative construction material for sustainability and investigates their potential. There are several benefits, including low weight, high durability, thermal insulation, and economic efficiency of these blocks. Through a case study, it has been shown that Izocrete blocks presented a 7-C reduction in indoor temperature, along with better resistance to environmental factors. Additionally, compared to traditional materials, construction cost was reduced by 30%, while maintenance cost was 50% lower due to the durability of materials. In addition to shedding light on the challenges of Iraq's housing rehabilitation, the findings also tell us much about the potential of this approach in building a more sustainable urban future for Iraq.

1. INTRODUCTION

The traditional houses rehabilitation in Iraq is a cultural need and a technical challenge. Such structures are faced with the critical threat of deteriorating materials, degradation of the environment, and outdated practices in maintaining these homes, compromising the rich architectural heritage and identity of the region [1]. Over decades, the conventional construction practices and materials like brick and cement blocks have not been able to cope up with increasing needs for energy efficiency and cost-effectiveness [2]. In addition, the severe weather in Iraq, including scorching summers, frigid winters, and high humidity, also accelerates the deterioration of construction materials and increases maintenance requirements and costs. These challenges are exacerbating by using of HVAC system to manipulate indoor temperature, that consumes 80% from residential building energy demand and consumed approximately 55% of the total energy demand in Iraq [3] (see Figure 1).

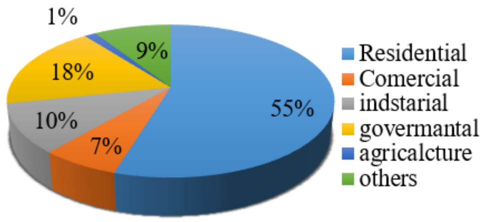

Figure 1. Electrical consumption in Iraq (2023)

The population is still increasing around 2.5% a year. Energy system is still under stress. This further highlights the requirement of new and sustainable solutions which in turn are cost effective and eco-friendly in nature.

The adaptive reuse of heritage buildings had been a focal point of several research emphasizing the balance between preservation, sustainability, and modern functionality [4] where an exhaustive model to assess the adaptive reuse of the Jeddah heritage buildings in terms of maintaining their authenticity, sustainability, and functionality. The model provides a structured metric for assessing architecture, economy, and safety without sacrificing cultural identity. This framework serves as a valuable guide for policymakers and restoration professionals navigating the intricate relationship between heritage preservation and contemporary urban demand. Similarly, the adaptive reuse of heritage buildings in Amman, Jordan [5]. The research highlights how transforming historic structures into functional spaces, such as cultural centers, can preserve their architectural integrity while enhancing socio-economic value. By employing qualitative research methods, including field surveys, interviews, and architectural analysis, the study underscores the significance of adaptive reuse in sustainable urban development [6]. The findings suggest that when modern requirements are integrated while respecting a building's authenticity, it strengthens the connection between communities and their cultural heritage, fostering a deeper sense of identity and continuity. Further expanding on the theme of adaptive reuse, study [7] examined both the preservation efforts and contemporary modifications of historical buildings, using the Rietveld Schröder House as a case study. The study explored how historic structures can be adapted for modern functional needs without undermining their historical significance. By assessing structural preservation, exterior conservation, and interior function modification, the research provided a detailed evaluation of the renovation process using questionnaires and quantitative analysis. Despite initial skepticism and resistance to such large-scale interventions, the findings highlight the necessity of striking a balance between functional modernization and architectural conservation. The study reinforces the critical role of architecture in bridging cultural preservation and contemporary usability, demonstrating how thoughtful interventions can ensure the longevity of heritage structures in a rapidly evolving urban landscape. Heritage as one of the most important expressions of civilization is directly related to the revival of tourist sites based on their historical and archaeological elements.

Some studies focused mainly on the traditional city of Baghdad and especially on Al-Mutanabbi street, determining critical factors which, by creativity, innovation and leadership, can turn heritage sites attractive for tourists [8]. Through an exploration of contemporary urban treatments, this research showcases strategies to improve both local and international tourism while also respecting and safeguarding their cultural identity.

While other studies documented and preserved modern architectural heritage by employing digital techniques with an emphasis on mid-20th-century apartment buildings in Izmir, Turkey [9]. It emphasizes the importance of the digital tools in the maintenance of cultural, social and urban memory and in the enhancement of educational uses and touristic opportunities. The case study will further showcase how 3D modeling / virtual environments and digital archives can be used to document architectural and interior elements from the past with the aim of providing a long-term access to the cultural heritage and to sustainably realize his/her presence there. DIGITAL is the next generation architectural research underlining the potentiality of the digital methods that bridge past and future architectural practices.

Also, there studies exploring the sustainable urban development through adaptive reuse: European historic spa towns negative is the catalyst of adaptive reuse of abandoned heritage buildings and has received growing attention in the field of urban planning since. Importantly, it suggests that integrators of cultural and non-cultural interests should present urban regeneration and territorial cohesion strategies centered on sustainable management of abandoned built heritage that stimulate innovation and sustainable development of regions [10]. Drawing from case studies from towns like Bath, Baden-Baden and Vichy, we know that strategic planning, public-private partnerships and community engagement can do much to meet the social, economic and environmental challenges ahead.

Some studies propose a comprehensive framework for sustainable adaptive reuse, integrating the need for preservation and a vision for modernization. With this model, informed decisions can be made to safeguard heritage structures and meet current requirements as other studies presented the State of Conservation Assessment BIM model that an edition of the damage and conservation data in a dynamic BIM framework. The approach, when implemented in a high-rise residential structure in Spain, leads to improved maintenance, accurate localization of damages, and better decision-making regarding repairs [11].

Social and political changes have led to the fragmentation of its heritage and cultural identity in emphasizing both tangible and intangible heritage and it calls for reconstructing a complete story to maintain descendants' local relationship with the tombs and thus contribute to a paradigm of sustainable conservation [12].

Also, the specific explored values and significance of historical buildings and integrated sustainability principles into their preservation and highlighted the application of green building technologies. It also includes illustrative case studies in domestic and international settings. The article continues this line of thought by providing insights from the author's more than 15 years' experience and humanitarian action for the future of historical building preservation and renovation, as well as examining and summarizing emerging shifts in the development of historical building [13].

The challenge of energy efficiency versus architectural heritage conservation, in unprotected buildings in San Sebastián, Spain. Design Science Research Methodology (DSRM) was utilized to create a replicable prototype for evaluating and steering facade interventions while retaining the site's historical identity. The way of working that encompasses vulnerability analysis, intervention criteria, and case studies aims for sustainable recovery without compromising urban and architectural consistency. The outcomes seek to inform urban and urban development policies and practices that integrate heritage conservation and energy efficiency [14].

A study on the smartening of urban architectural heritage in China was conducted within the context of the Shanghai Federation of Literary and Art Circles [15]. Through a thematic analyses and literature review, it identifies the gap in current practice, and proposes a systematic approach to address such gap emphasizing policy guiding, digitalization, platforms integration and optimization. As a result, smart heritage needs to further evolve in accordance with conservation, cultural inheritance, and urban regeneration and user-oriented multidimensional needs to give priority to smart heritage practices in the new era, addressing different communities, users, and stakeholders.

As it appears in the multidisciplinary research project dedicated to the Castle of Fossa (L'Aquila), a medieval building affected by the 2009 earthquake. The team also performed architectural surveys and archaeological analyses and then created a parametric HBIM model to contribute to its restoration and conservation. The research shows that coordinated, cross-disciplinary approaches can support the safeguarding, conservation and future-use of heritage assets [16].

As for strategies of smart Cities and Cultural Heritage, studied [17] the emerging idea of smart heritage in terms of how it combines smart city and heritage disciplines to tackle local governance challenges. Using the analysis of strategic documents of three Australian local governments, the study derives common themes and discusses an increasing focus on Smart Heritage in the urban policy discourse.

A study was also conducted on strategies for renovation of an Old Buildings and its Balance between Urban Development and reuse problems to the sustainable future and social awareness [18]. It emphasizes characteristics in modern applications, green materials, and earthquake resistance through case studies and literature reviews. The results highlight these dimensions through the respective contributions of policy, social engagement, and innovation, respectively, to enrich urban identity that leads to sustainable development through collaboration.

The aim of this study is to evaluate the use of Izocrete blocks, as engineered lightweight composite material, as the alternative solution for traditional house rehabilitation. Due to their superior thermal insulation, waterproofing properties, durability, etc., Izocrete blocks offer a great solution to overcome the challenges associated with conventional materials. The study examines the use of Izocrete blocks in the retrofitting of a historic house in Baghdad, Iraq, to assess their impact on heat loss, sustainability, and the reduction of maintenance expenses.

The materials may include bricks, concrete blocks, lime sand bricks, and thermostone, depending on the types listed in Iraqi building standards (see Figure 2).

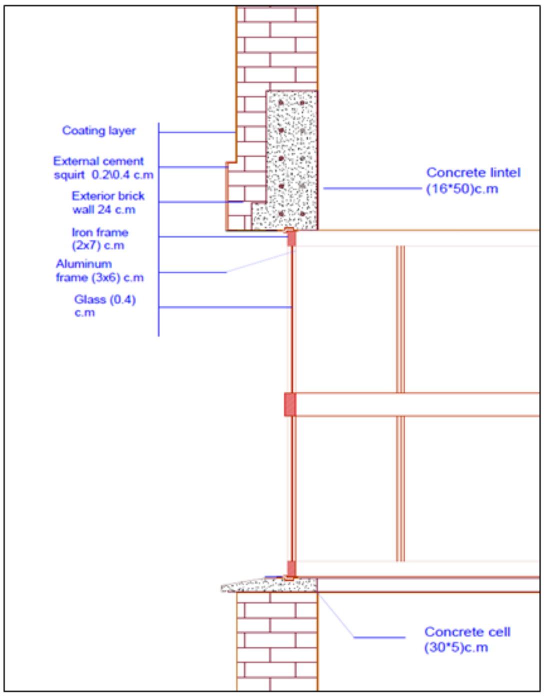

Figure 2. Standard method for constructing wall layers in Iraq

But such materials require skilled labor as well as multiple engineering procedures, details and constructional treatments. Moreover, these materials contribute to the mass of the wall and require regular maintenance, resulting in high renovation costs for traditional houses.

The research proposed a parametric study for common Middle Eastern and Mediterranean house types in response to low-tech rehabilitation and modernization methods [19]. The study relied on a range of methods and tools such as tracking, modeling, quantitative simulation, and infrared cameras. Various construction methods, materials, shapes, and details were employed under the different drying conditions of Middle Eastern climate zones.

Also, the study provided Guidelines for Low-Cost, Energy-Efficient Houses and its key suggestions and an indication that energy consumption can, in some cases [20], be potentially reduced by up to 50% with payback times of two years or less. Some of these actions are excellent at conserving energy, while others can be quite expensive or even harmful to the environment. Of course, there are already other effective safeguards.

In addition, the study provided a sustainable interpretation and analysis of the real facts of vernacular habitats in the efficiency of energy and ecological concepts, considering human settlement patterns, architectural creation and building material uses [21].

Finally, the initial steps towards an alternative modular system for refurbishment leading to zero-energy buildings have been identified [22]. The incorporation of prefabricated insulating panels, advanced HVAC systems, and renewable energy resources are all part of a highly innovative approach. Here, we summarize the limitations and parameters of some of the above-mentioned solutions along with their practical applications. All these weaknesses in encounter together demand for novel methods of the normative techniques of the house treatment that allow for every house to turn out to be as energy effective as feasible whilst minimizing the comparative lengthy phrase upkeep prices. The aim of the study is to assess the feasibility of using Izocrete blocks as an innovative and sustainable option in renovations of passive building envelopes to mitigate heat transfer, energy demand and maintenance of traditional houses prospectively.

2. THEORETICAL BACKGROUND AND CASE STUDY

2.1 Sustainable design principles

Reduce, reuse, recycle are the key aspects correlating to sustainable design, wherein focuses on minimization of depletion of non–renewable resources [23], use of ecological-friendly material and minimum pollution. It also includes natural ventilation, natural lighting, and the use of energy-efficient materials that are responsive to local climatic conditions. It is important to note that the use of Izocrete blocks provides a good solution for the rehabilitation of the traditional Iraqi houses, considering the characteristics of the blocks such as thermal insulation, lightness and no need for maintain [24].

2.2 Material selection

Thermal resistance and durability being ones of their most known properties Why they have been selected: Izocrete blocks are composite made of cement, cork, and lightweight round particles. Izocrete blocks, which are larger than traditional thermostone blocks, provide more insulation and utilize less mortar (see Figure 3).

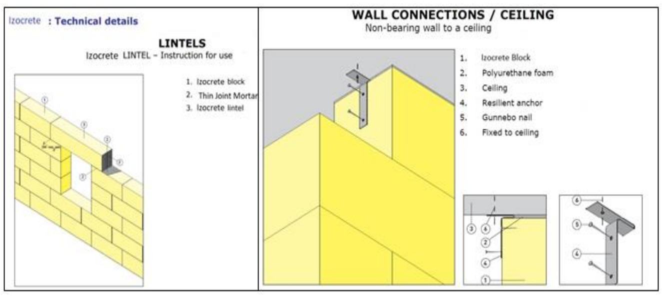

Figure 3. Izocrete blocks for constructing exterior and interior wall layers

2.3 Application process

The following were the steps in the rehabilitation process:

- *Wall construction*: External walls were built of Izocrete blocks.

- *Insulation layer*: To be protected from heat, wind, humidity, and rain, polyurethane foam was applied between the top edges of the wall and ceiling.
- *Structural support*: (Iron Angles (Resilient anchors)) Connect the walls to the ceiling with gunnebo nails.
- *Window lintels*: External and internal Windows were constructed with Izocrete lintel blocks for insulation property.

The concrete layers were thin (1 to 1.5 cm) and thin mortar walls were produced with M-Sand (that is also called manufactured sand, crushed stone sand) and were finished with plastic paint for waterproofing and aesthetic appeal.

2.4 Testing and evaluation

Tests showed Izocrete blocks performing well on thermal insulation, humidity resistance, structural strength and a few other figures. Search for this assessment were performed in controlled lab conditions, as well as realistic environments for precise and academic practicality. The main testing protocols were as follows:

2.4.1 Thermal performance test

Aim: Comparing the thermal insulation of Izocrete blocks with conventional materials.

Methods: Indoor and outdoor temperature sensors were deployed to measure the variability of temperature (by thermocouple with accuracy 5%). Thermal performance was evaluated by measuring internal temperature fluctuations over 24 hours in differential external temperature conditions.in July and the measurement repeated only for one time in March due to limitation to visit of this house).

Control conditions: The chamber was kept under ambient environment humidity and ventilation conditions.

2.4.2 Material durability analysis

- *Aim*: To measure compressive strength, conductivity, and water absorption properties of Izocrete blocks.
- *Compressive strength test*: The maximum load-bearing ability of the blocks was determined by applying increasing pressure using a universal testing machine (UTM).
- *Thermal conductivity testing*: The thermal conductivity of the blocks was confirmed using a guarded hot plate method and verification of insulation property.
- *Test of water absorption*: The blocks were immersed in water for 24 hours, and the amount of water absorbed was measured to assess their performance in preventing moisture ingress.
- *Control conditions*: All testing was conducted under standardized (temperature and humidity) laboratory conditions.

2.4.3 Maintenance appraisal

- *Aim*: The long-term maintenance and replacement feasibility of Izocrete blocks.
- *Methods*: Under simulated conditions of wear-and-tear, we tested the ease of block replacement and reapplication of finishing layers.
- *Results*: Surface finishes were evaluated by adhesion strength, degradation over time, and refurbishment ease.
- *Timeframe*: Blocks were monitored over a period of six months to examine their long-term stability and maintenance requirements.

The results of thermal insulation, durability, and maintenance of Izocrete blocks when compared with the physical properties of conventional blocks were identified using experimental approach, and it was concluded that blocks were efficient as sustainable building material.

2.5 The house of Sheikh Muhammad Reda Al-Shabibi (1889-1965)

This study focuses on the rehabilitation of the house of Sheikh Muham- mad Reda Al-Shabibi (He is Sheikh Muhammad Reda bin Sheikh Jawad bin Muhammad bin Shabib bin Ibrahim bin Saqr Al-Bataihi, known as Al- Shabibi, He is a member of the House of Representatives and its president in one of its sessions. A member of the Senate and its president, a member of the Iraqi Scientific Academy as well as its president, a political activist, a religious intellectual, and a famous poet, and his house represents significant value of Iraqi heritage in Baghdad for the building heritage appearances that stopped from being used and vanished for the English style appearances that have started used after 1970, a historically significant building located on Abu Al-Nawas Street in Baghdad along the Tigris River. Constructed in the early 20th century, the house is a representative example of traditional Iraqi architecture. The Shabibi family is one of the most famous scholarly families in Najaf. They originated from southern Iraq and are a branch of the Bani Asad tribe. Al-Shabibi studied under the most famous scholars of his time, such as Sheikh Muhammad Hassan Al-Muzaffar, Al-Sayyid Mahdi Al-Bahr Al-Uloom, and Al-Sayyid Hussein Al-Hamami (see Figures 4 and 5).

Figure 4. Photos for AL- Shabibi house in Baghdad

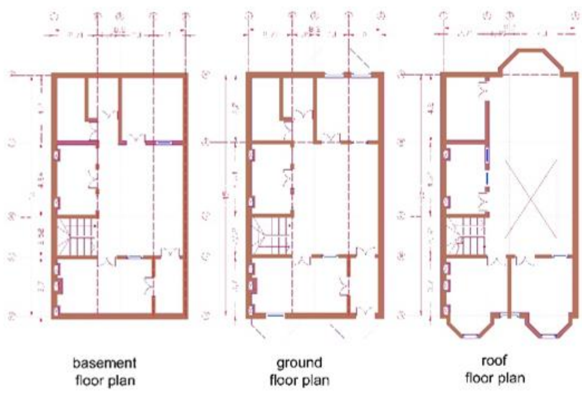

Figure 5. Drawing of AL- Shabibi house in Baghdad

This house is quite ordinary example of the traditional Iraqi architecture, with its thick walls, ornate wooden work and space organization accustom to the harsh climate of the region. Yet, decades of a lack of care and exposure to harsh atmospheric conditions left structural degradation, mainly in the facade walls. This deterioration made it necessary to design a rehabilitation strategy that was sustainable and cost-effective.

This rehabilitation offers not only cultural, but also architectural heritage because it is a case study for how to restore historical buildings using Izocrete blocks while retaining the aesthetic and structural characteristics of the building.

3. RESULTS AND DISCUSSIONS

In light of the results obtained for structural performance, thermal insulation, and maintenance, the Izocrete blocks stand out as a material of choice for buildings similar to the Sheikh Muhammad Reda Al-Shabibi house for rehabilitation purposes. The results below are super useful.

3.1 Thermal performance

Indoor temperatures were significantly cooler than the outdoor temperature measurements taken near the rehabilitated house. These results match the search results [25]. Compared to traditional wall systems, the use of Izocrete blocks lowered the indoor temperature by about 7 C. The fact that this gain better than the material is a good thermal insulator. Improving levels of insulation will reduce the operating hours of heating and cooling systems and, therefore contribute to lowering the peak demand on the electricity grid, an acute problem during ongoing periods of energy shortage in Iraq where these results match the search results [26]. A similar temperature difference in the study was found (see Figure 6).

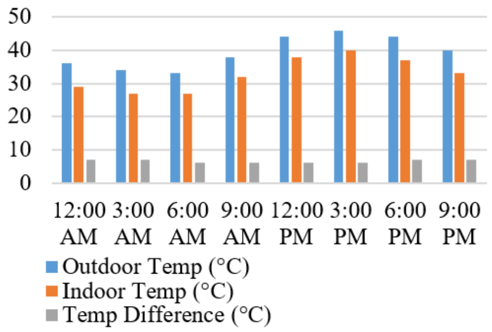

Figure 6. Temperature measurements before and after rehabilitation

3.2 Material properties

Laboratory tests on Izocrete blocks confirmed their suitability for sustainable rehabilitation:

- *Compressive strength*: Average compressive strength of 1.8 N/mm' met the DIN EN 772-1:2011 standard for structural adequacy.
- *Thermal conductivity*: With a thermal conductivity of 0.08 W/mK, the blocks significantly reduced heat transfer.
- *Water absorption*: Capillary water absorption coefficients demonstrated excellent resistance to moisture, enhancing durability and minimizing maintenance needs. (The average capillary water absorption coefficients (Cws) for 10, 30, and 90 minutes were 1.32, 0.54, and 0.23 g/(m^2.s) respectively) .
- *Density*: The lightweight nature of Izocrete blocks (net dry density: 297 kg/m^3) reduced the structural load and facilitated easier handling during construction.

3.3 Cost efficiency

The use of Izocrete blocks resulted in a considerable reduction in construction and maintenance costs. Compared to traditional methods, the material required fewer resources, less skilled labor, and simpler maintenance procedures. Over the 3-year assessment period, the maintenance process primarily involved reapplying a single layer of plastic paint, significantly lowering long-term costs.

3.4 Sustainability and durability

The study showed that Izocrete blocks consider most critical sustainability issues. Environmental Aspects: Resistance to humidity, wind, and rain ensures that the material operates excellently in unstable climates. Longevity: Since Izocrete blocks have very low maintenance requirements, they provide a sustainable option for preserving traditional architecture.

3.5 Comparison with traditional methods

Izocrete blocks performed better than bricks-cement construction in the following areas: Decreased daytime heat gain. Reduced material weight, which reduces stress on the structure. Increased resistance to moisture, protecting against water-based damages We only need one skilled labor to maintain the system (see Table 1).

Table 1. Comparative performance of Izocrete blocks and traditional materials

Metric	Izocrete Blocks	Traditional Materials	Improvement (%)
Thermal Conductivity (W/mK)	0.08	0.15	46%
Compressive Strength (N/mm^2)	1.8	1.2	50%
Net Dry Density (kg/m^3)	297	500	40%
Maintenance Frequency (years)	4-5	2-3	50%

3.6 Limitation of using Izocrete blocks

However, to get a balanced perspective we should also consider limitations. The initial results were promising, but we need to take a closer look before we can implement it broadly. Specifically, the study of the following elements should take place:

Note- Above is why, to understand the real environmental impact of the Izocrete blocks, to go above LCA (Full life cycle assessment). While the product may be helpful for thermal efficiency and energy saving during the operation of the building, the extraction of the raw material, manufacture, transportation, installation, and disappearing (including recycling) should be included in LCA and embodied environmental cost A complete LCA will provide a more macro perspective on Izocrete's impact and how it stacks up against other building materials.

It also must be urged in conclusion that no less than the potential goodwill or otherwise illustrated economic considerations must be scrutinized as social considerations. This means examining how much local employment can be created to assemble the unit, calculating local economic impacts, and grasping how it aligns with objectives for sustainable development." Understanding these larger implications is critical to making informed decisions about what material to select.

4. CONCLUSION

This adaptation demonstrates the importance of undertaking long-term sustainable rehabilitation strategies for traditional houses throughout Iraq, especially considering the extreme environmental temperatures experienced in the region and the high costs of maintenance. By studying the use of Izocrete blocks, this study offers strong support for their use in place of traditional construction material. Key findings include: Izocrete blocks improved thermal comfort by mitigating indoor temperatures by almost 7 C and helping to reduce energy-intensive HVAC usage.

Cost-effectiveness: Izocrete blocks are lightweight and durable, reducing material consumption, labor cost, and maintenance requirements in the long run.

Sustainability: Improved resistance to environmental factors like humidity and rain ensures long-term durability and decreases the ecological footprint of rehabilitation projects.

Sustainable use of materials: Sustainable material use aids in the restoration of culturally significant buildings, thereby promoting the architectural heritage of Iraq.

Additional data: Future monitoring and testing is required to gauge the material's performance in real-world conditions, such as extreme temperatures, freeze-thaw cycles and possible seismic activity. Izocrete will give vital data on the long-term safety and durability of structures built with Izocrete.

Detailed comparison of cost and benefits: Need for more detailed cost-benefit analysis comparing Izocrete blocks with conventional materials. This analysis should not simply account for initial costs but rather total long-term costs incurred by maintenance, repair, and potential replacement. This will give a much clearer picture of whether Izocrete is cost-feasible for large-scale implementation.

Related study findings: Despite the study focusing on thermal comfort, other studies should look into the effect of Izocrete on indoor air quality. Will there be any potential emissions from the blocks that can impact the health of the inmates? Monitoring indoor air quality is essential to ensuring healthy living environments.

Researching optimization of the design of Izocrete blocks and construction techniques could further improve their performance and cost-effectiveness. New block shapes, sizes, and compositions can improve thermal properties, structural strength, and ease of installation.

5. RECOMMENDATION

According to the results, the recommendations are:

Increasing the use of Izocrete blocks: Increase the use of Izocrete blocks in rehabilitation projects throughout Iraq, particularly in areas where the climate is similar.

Policy support: Work towards setting up government policies/incentives to support sustainable construction materials such as subsidy on Izocrete blocks and resource persons to train on the use.

Future studies: Perform comparative studies in other cities and designs in Iraq in order to ascertain the scalability and adaptation of blocks of Izocrete.

Community engagement: Engage local communities for rehabilitation efforts to be culturally and historically authentic as well as sustainable.

Training courses: Establish training programs that educate builders on the benefits of using sustainable materials, including concrete blocks, in construction projects.

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