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A Critical Analysis of Interlocking Stabilized Soil Blocks (ISSB) in Residential Architecture: A Case Study of Obayemi House, Redemption Camp, Ogun State

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Abstract
This study investigates how interlocking stabilized soil blocks (ISSB) can serve as a viable and environmentally friendly alternative to traditional building materials in residential architecture. The study aims to evaluate the production, installation, and post-occupancy performance of ISSBs. This is accomplished by conducting a critical analysis of the experimental project that was carried out at Obayemi House, which is a semi-detached bungalow with two bedrooms located in Redemption Camp, Nigeria. In this investigation, a mixed-methods approach is utilized, which combines empirical data, and post-occupancy surveys with theoretical frameworks derived from sustainable design and performance-based architecture. This research focuses on key parameters such as the selection of raw materials, mix ratios, construction techniques, thermal insulation, durability, and economic feasibility. A comparison with traditional materials, such as fired bricks and concrete blocks, demonstrates that ISSBs have the potential to lessen their impact on the environment, reduce the costs of construction, and improve the comfort of occupants. According to the findings, ISSBs continue to face challenges in terms of aesthetics and moisture control in wet areas, despite the fact that they offer significant advantages in terms of sustainability, ease of construction, and rapid assembly. This study not only contributes empirical evidence towards sustainable material research but also provides recommendations for optimizing ISSB production and integration into broader architectural practices.

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Keywords: Interlocking Stabilized Soil Blocks (ISSB), Sustainable Construction, Sustainable Building Materials, Residential Architecture, Thermal Performance

1. Introduction

In the last few decades, sustainable construction has gone from being a niche issue to a central concern in modern architecture (Almssad, Almusaed & Homod, 2022; Mba *et al*., 2024) [1, 21]. This is primarily because environmental challenges are getting more severe, resources are being depleted, and there is a need for cost-effective building solutions (Kibert, 2016) [18]. The traditional construction materials, such as fired bricks and concrete blocks, have long been favored for their durability and widespread availability; however, their high energy consumption during production and carbon emissions have increasingly spurred interest in greener alternatives (Kibert, 2016; United Nations, 2015; Jonnala *et al*., 2024) [18, 16].

Greener alternatives such as Interlocking Stabilized Soil Blocks (ISSB) have gained prominence as an innovative technology that harnesses locally available soil combined with minimal stabilizers like cement and lime to create interlocking units (Jarju, 2019) [15]. This method reduces the energy-intensive processes typical of conventional brick manufacturing and also promotes local resource utilization and reduces environmental impact (Jarju, 2019; ASHRAE, 2019; Kathambi *et al*., 2024) [15, 2, 17]. However, despite these promising attributes, existing literature reveals contradictory findings regarding the long-term durability, thermal performance, and overall structural viability of ISSBs in residential applications. Some studies emphasize the potential of ISSBs to deliver substantial cost savings and environmental benefits through rapid assembly and reduced material usage

(Daramola & Ibitoye, 2018; Jarju, 2019; Kathambi *et al*., 2024) [15, 8, 17], while others raise concerns about aesthetic limitations and moisture absorption issues that may compromise performance in humid climates (Paulmakesh & Markos-Makebo, 2021; Atuhwera, 2015) [27, 3].

These unresolved debates and contradictory perspectives shed light on a gap in empirical research that necessitates a comprehensive evaluation of ISSB technology under real-world conditions. Addressing this gap, the study examines an experimental project at Obayemi House in Redemption Camp, Ogun State, Nigeria, where systematic data on the production, installation, and post-occupancy performance of ISSBs have been gathered and critically analyzed. The primary research objectives include:

- Investigating the raw materials, mix ratios, and mechanical production techniques involved in fabricating ISSBs.
- Analyzing the foundation techniques, wall erection processes, and overall structural assembly using ISSBs.
- Determining the thermal, acoustic, and aesthetic qualities of ISSB-constructed walls as experienced by occupants.
- Weighing the benefits and limitations of ISSBs against conventional construction materials within the broader context of sustainable design.

2. Theoretical Framework and Literature Review

Sustainable construction is a field rooted in the fundamental principles of sustainable development, as outlined by the Brundtland Commission (World Commission on Environment and Development, 1987), which calls for building practices that conserve resources, reduce waste, and lower ecological footprints. Over time, traditional construction methods that once relied heavily on materials like fired bricks and concrete have come under scrutiny due to their high energy consumption and significant environmental impacts (Jonnala *et al*., 2024; Almssad, Almusaed & Homod, 2022; Kibert, 2016) [1, 18, 16]. In contrast, the use of earthen materials, which draw on centuries-old vernacular traditions, has experienced a revival in modern construction because these materials offer a low environmental impact and superior thermal efficiency (Kibert, 2016; Jarju, 2019) [18, 15]. This evolution reflects a broader shift in the construction industry towards methods that not only meet structural needs but also adhere to principles of environmental stewardship and resource efficiency.

The shift is underpinned by an understanding that the long-term sustainability of built environments depends on the ability to integrate local materials and traditional techniques with modern performance criteria, thereby addressing both ecological and economic challenges in residential architecture (Spiegel & Meadows, 2010) [33]. In this context, the selection of materials plays a role in sustainable construction, and Interlocking Stabilized Soil Blocks (ISSB) represent an advancement in this regard.

ISSBs are produced by mixing locally available soil with stabilizers, such as cement and lime, in precise ratios to enhance both their mechanical strength and thermal performance (Nambatya, 2015; Jarju, 2019) [15, 25]. This process leverages simple, low-energy stabilization techniques instead of the energy-intensive firing process required for conventional bricks. The dual functionality of ISSBs, which provides both structural integrity and energy efficiency, aligns closely with contemporary sustainability paradigms that emphasize passive thermal regulation and reduced carbon footprints (ASHRAE, 2019) [2]. The theory behind this approach is simple yet powerful: in that by using materials that are locally sourced and minimally processed, builders achieve not only cost savings but also a reduction in environmental degradation, thus supporting the broader goals of sustainable development (Donovan, 2020) [9].

Performance-based design further refines this approach by shifting the focus from traditional prescriptive construction methods to the measurable functional outcomes of architectural elements (Augenbroe, 2019) [4]. In performance-based design, the quality of a construction material is evaluated based on its ability to meet specific performance metrics such as compressive strength, thermal insulation, and acoustic dampening (Hens, 2024) [13]. Research has shown that when earth-based materials like ISSBs are produced through controlled techniques, they exhibit consistency in block dimensions and interlocking capabilities, which are essential for rapid assembly and enhanced structural stability (Smith & Jones, 2018; Atuhwera, 2015; Qamar, Thomas & Ali, 2019) [32, 3, 28]. This method of design allows architects and engineers to set clear performance targets and rigorously test materials against these benchmarks, thereby ensuring that the final structure performs optimally under real-world conditions (Qamar, Thomas & Ali, 2019) [28]. Such an approach provides clarity in design decisions and also supports innovation by highlighting areas where traditional methods may fall short.

3. Methodology

The research adopts a mixed-methods approach, integrating both qualitative and quantitative data to provide a comprehensive evaluation of ISSB technology. The methodology is structured around three core components: experimental production, on-site construction analysis, and post-occupancy evaluation.

3.1 Experimental Production

The experimental production of Interlocking Stabilized Soil Blocks (ISSBs) was carried out using a systematic approach based on established principles in sustainable construction research. Experimental production refers to the systematic, controlled process of creating a product or material under conditions that mimic real-world applications while allowing adjustments to variables and measuring outcomes accurately (Ross & Morrison, 2013) [30]. In this study, experimental production involves the careful fabrication of Interlocking Stabilized Soil Blocks (ISSBs) using locally sourced lateritic soil, cement, and lime. This process is designed to simulate the actual production conditions but within a controlled laboratory and on-site environment so that critical parameters—such as mix ratios, compaction, curing time, and block dimensions—can be precisely monitored and evaluated.

3.2 On-Site Construction Process

Following production, the research shifted to a detailed on-site construction analysis at Obayemi House. Two foundation systems—ordinary strip foundations and pad foundations with ground beams—were employed to accommodate variations in soil quality. The research documented the step-by-step construction process, including:

- **Foundation Preparation:** Excavation, laying of ISSBs in interlocking patterns, and backfilling using a soil-gravel mixture (Sangori, 2012) [31].
- **Wall Erection:** Detailed observations were recorded during the placement of the first block course, ensuring proper water splashing to prevent mortar absorption, and the subsequent staggered interlocking of blocks (Elton & Whitbeck, 1997) [11].
- **Lintel Installation:** The use of angle irons and wooden lintels was meticulously observed to evaluate the structural integration and load distribution across openings (Chacon, 1999) [6].

3.3 Post-Occupancy Evaluation

Post-occupancy performance was evaluated through structured interviews with the occupants of Obayemi House. Key performance indicators included:

- **Thermal Insulation:** Assessment of temperature regulation within the building.
- **Acoustic Performance:** Evaluation of sound insulation properties.
- **Structural Durability:** Feedback on the perceived strength and stability of ISSB walls.
- **Aesthetic Appeal:** Opinions regarding the finish quality of external and internal wall surfaces.

The post-occupancy data were then correlated with on-site findings to validate the overall performance of ISSBs. This triangulated methodological approach ensures that the research captures technical and quantitative aspects of ISSB production and construction and also integrates qualitative insights from occupant experiences (Morse, 1991) [23]. This is done to provide a holistic understanding of ISSBs as a sustainable construction material.

4. Case Study: Obayemi House

Obayemi House, located in Redemption Camp, Ogun State, serves as the experimental ground for assessing the practical application of ISSBs in residential construction.

4.1 Production of ISSB Blocks

The production process began with the harvesting of locally sourced lateritic soil—a material readily available in the region. The soil was transported to a nearby production site, where it was mixed with stabilizers: cement and lime. Laboratory tests determined that the optimal mix ratio was 1:35 (cement to soil) with an additional 5% cement and 5% lime per weight of soil which was identified as optimal through a series of drop tests and box tests aimed at assessing block strength and durability. This specific formulation was critical in ensuring that the ISSBs possessed the required strength and durability for load-bearing applications.

A Bolyn press was employed in the production process to mold the soil-stabilizer mixture into uniform cuboids with precise dimensions (290 mm × 215 mm × 140 mm). The mechanical press not only ensured consistent compaction but also integrated interlocking features into each block. These features are essential for the rapid and stable assembly of the building's structure, as they allow the blocks to interlock seamlessly without the need for excessive mortar. The blocks were then cured for seven days before transportation to the construction site—a step that is crucial for achieving the desired compressive strength. Data on production costs, including the price of the machinery (130,000 Naira), were also collected to evaluate economic feasibility.

Fig 1: Site Production of ISSBS

Fig 1: Site of Production of ISSBS

Fig 3: ISSB after Being Transported From Where They Were Produced

4.2 Foundation Construction

Fig 4: Showing Laid First Course

In line with Lynch & Hack (1984) [20], the building's foundation utilized a dual approach to accommodate variations in soil stability across the site. In areas with relatively uniform soil, an ordinary strip foundation was constructed. This involved excavating trenches to the required depth and width, followed by the careful placement of ISSBs in an interlocking manner. In contrast, for sections of the site where soil conditions were less reliable, pad foundations with ground beams were employed (Curtin *et al*., 2006) [7]. These provided additional stability and ensured an even distribution of loads. The backfilling process involved compacting a mixture of soil and gravel in layers to secure the foundation further.

The choice to integrate ISSBs into the foundation phase was deliberate, as it demonstrated the blocks' adaptability not only as a walling system but also as a viable material for foundational applications. The seamless integration of ISSBs in the foundation highlighted their potential to serve multiple structural roles within a single project.

4.3 Wall Erection and Structural Assembly

With the foundation in place, the construction of the walls commenced. The process began with careful preparation—

splashing water on the foundation walls to prevent the ISSBs from absorbing moisture from the mortar. Starting at the corners, the first course of blocks was meticulously laid in a staggered pattern. This interlocking system is fundamental to ensuring structural stability, as it distributes loads evenly across the wall.

Fig 5: Showing Erection of Walling Units

As the wall rose, precise openings for doors and windows were incorporated into the design. The integration of angle irons and wooden lintels at these openings was a critical step. Angle irons were positioned along the edges of the openings to provide support for the lintels, which in turn were anchored securely to distribute the weight of the wall. The careful installation of these components prevented potential structural issues, such as sagging, and enhanced the overall durability of the construction.

The walling process was characterized by a composite finishing approach. While most internal walls were left unplastered, certain feature walls were treated with plaster to enhance aesthetic appeal. In functional areas such as the kitchen and toilets, ceramic tiles were employed to improve hygiene and ease of maintenance.

Fig 6: Lintel Installation

The roof structure, comprising a wooden rood, tie beams, wall plates, roof trusses, and aluminum roofing sheets, was assembled with equal precision. Additionally, a PVC ceiling was installed in the interior spaces, reflecting a judicious mix of traditional and modern materials.

4.4 Drainage and Water Management

A notable challenge during the construction of Obayemi House was its location on a small stream. To mitigate potential water-related issues, the design incorporated a drainage system that diverted running water away from the foundation. Large pipes were strategically placed below foundation levels to channel water into the central-external drainage systems. This proactive approach to water management not only safeguarded the structural integrity of the building but also highlighted the necessity for integrating sustainable water management practices in areas prone to moisture challenges.

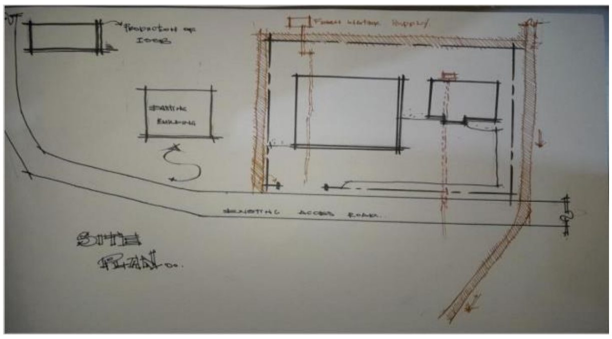

Fig 7: Drainage System

4.5 Post-Occupancy Experience

Fig 7: Post Occupancy Pictures of the Obayemi House

The final phase of the study involved assessing the building's performance from the perspective of its occupants. Feedback from residents indicated strong approval for the thermal insulation and soundproofing qualities of ISSB walls. All occupants noted that the solid, bullet-resistant nature of the walls contributed to a heightened sense of security. The natural thermal regulation provided by the soil-based blocks minimized the reliance on artificial heating and cooling systems, thereby reducing energy consumption and operational costs. However, the post-occupancy evaluation also revealed certain drawbacks. In wet areas such as kitchens and toilets, the external walls exhibited dirt accumulation, detracting from their visual appeal. This aesthetic shortfall, coupled with minor issues related to moisture absorption in specific walling units, pinpoints the need for improved finishing techniques and moisture control measures in future implementations of ISSB technology.

5. Analysis and Discussion

The Obayemi House project provides an invaluable case study for assessing the performance and potential of ISSB technology in residential construction. This section critically examines the empirical findings in light of established sustainable design principles and compares the ISSB system to conventional construction methods.

5.1 Production Efficiency and Economic Viability

One of the primary advantages of ISSBs mentioned earlier is the low-cost and locally sourced production process (Roberts, 2017; Jarju, 2019) [29, 15]. The use of lateritic soil—a material widely available in many parts of Nigeria—reduces the financial burden associated with procuring raw materials. The integration of a mechanical press, despite its initial cost of 130,000 Naira, allows for the mass production of uniform blocks with interlocking features. Such standardization minimizes waste and enhances construction speed, translating into substantial labor and time savings (George, 2010; Laovisutthichai, Lu & Bao, 2022) [12, 19].

5.2 Structural Integrity and Thermal Performance

Even from a structural standpoint, the ISSB system demonstrates remarkable strength and durability. The experimental mix ratio (1:35) combined with the stabilizing effects of cement and lime ensures that the blocks achieve the necessary compressive strength. The interlocking design enhances load distribution, resulting in walls that not only withstand external forces but also exhibit resistance to impacts (Paulmakesh & Markos-Makebo, 2021) [27]—a quality highlighted by the occupants' description of the walls as "bullet-resistant." Moreover, the inherent thermal mass of the soil-based blocks contributes to superior thermal insulation. This passive regulation of internal temperatures minimizes fluctuations and reduces the dependence on mechanical heating and cooling systems (Newton & Oxley, 2024; Jarju, 2019) [26, 15]. Studies in sustainable architecture have long championed the use of thermal mass to achieve energy efficiency (Ashrae, 2019; Braun *et al*., 2001; Morshed & Manjur, 2024).) [2, 5, 24]. The ISSB system thus aligns with contemporary energy conservation strategies and provides a tangible benefit in regions with significant temperature variations like Nigeria.

5.3 Environmental Impact and Sustainability

ISSBs also offer a compelling environmental advantage over conventional materials. The production process emits fewer greenhouse gases compared to the high-temperature firing required for bricks and the energy-intensive curing of concrete blocks (Qamar, Thomas & Ali, 2019) [28]. By utilizing locally available soil and minimizing the need for extensive transportation, the overall carbon footprint of construction projects could be significantly reduced. This environmental benefit is particularly relevant in the context of the United Nations Sustainable Development Goals, which emphasize responsible consumption and production (United Nations, 2015; Jarju, 2019) [15].

Additionally, the rapid assembly enabled by the interlocking mechanism reduces on-site construction time, further lowering the environmental impact associated with prolonged construction activities. The ease of installation also implies that less specialized labor is required, which is advantageous in regions with limited access to skilled construction workers (Elbashbishy & El-adaway, 2024) [10].

5.4 Comparative Assessment with Conventional Materials

When comparing the performance of Interlocking Stabilized Soil Blocks (ISSBs) with conventional construction materials, such as fired bricks and concrete blocks, it becomes clear that a deeper evaluation is necessary to understand not only the structural and mechanical differences but also the environmental, economic, and aesthetic implications of each system. Fired bricks and concrete blocks have been the mainstay of construction for decades because of their proven durability and uniformity; however, these materials come with a range of drawbacks. Their production processes require high energy inputs, leading to substantial greenhouse gas emissions and contributing to environmental degradation (Kibert, 2016; Hotza & Maia, 2015; Jonnala *et al*., 2024) [18, 14, 16]. Moreover, conventional methods typically depend on extensive mortar usage to bond the building units, a practice that increases both material consumption and labor costs, while also prolonging the overall construction timeline (Roberts, 2017; Jonnala *et al*., 2024) [29, 16]. In contrast, the ISSB system leverages an innovative interlocking design that minimizes the need for mortar, thus reducing material costs and shortening construction times (Jarju, 2019) [15]. This reduction in mortar dependency also contributes to lowering the overall expenses and also enhances the speed and efficiency of the construction process, making ISSBs an attractive option in regions where cost-effectiveness is paramount.

Despite these advantages, a comprehensive comparative assessment must also address some notable limitations of ISSBs. In the experimental study at Obayemi House, for instance, a key issue emerged in the aesthetic performance of ISSB walls, particularly in moisture-prone areas where dirt accumulation detracted from the visual appeal of the exterior surfaces. This aesthetic shortfall is notable because the external appearance of a building is essential for both occupant satisfaction and market acceptance. The problem indicates that while ISSBs excel in structural performance and economic efficiency, there is a pressing need for improved finishing techniques or supplementary treatments that enhance their aesthetic quality without compromising their functional benefits. Future research could focus on integrating advanced surface treatments or eco-friendly coatings designed to prevent moisture and dirt retention while preserving the natural properties of ISSBs (Daramola &

Ibitoye, 2018) [8]. Such innovations would help bridge the gap between the practical and visual aspects of construction, ensuring that sustainable materials like ISSBs fully compete with conventional materials on all fronts.

5.5 Integration of Theoretical Perspectives

The analysis of ISSB technology benefits from an integration of performance-based design and sustainable architecture frameworks. Performance-based design shifts the focus from prescriptive methods to measurable outcomes, such as thermal efficiency, acoustic performance, and structural stability (Hens, 2024) [13]. In this light, the ISSB system can be seen as an embodiment of performance-driven innovation—where empirical evidence from case studies directly informs the material's potential and practical applications (Smith & Jones, 2018; Qamar, Thomas & Ali, 2019; Nambatya, 2015; Jarju, 2019) [15, 32, 25, 28].

Furthermore, sustainability theories advocate for the use of local resources and the minimization of environmental impact (ASHRAE, 2019) [2]. The ISSB system, by using locally sourced soil and reducing energy consumption, aligns with these theories and exemplifies a pragmatic approach to green building practices (Donovan, 2020) [9]. Nonetheless, the challenges identified in aesthetic performance and moisture management call for a comprehensive application of these theories, suggesting that sustainability in construction must also consider occupant perceptions and long-term maintenance requirements (Meir *et al*., 2009) [22].

6. Implications for Future Residential Construction

The successful implementation of ISSBs in the Obayemi House project opens avenues for broader application in residential architecture, especially in developing regions where resource constraints and environmental concerns are evident. The economic benefits, coupled with superior thermal and acoustic performance, position ISSBs as a viable alternative for affordable housing. However, the research also highlights the importance of context-specific adaptations. Factors such as local soil composition, climatic conditions, and available construction expertise must be carefully considered when adopting ISSB technology on a larger scale.

7. Conclusion

The exploration of Interlocking Stabilized Soil Blocks (ISSB) through the lens of the Obayemi House project reveals a promising pathway towards sustainable, cost-effective residential construction. This study has demonstrated that ISSBs, when produced with precise mix ratios and integrated into a well-planned construction process, can yield structures that are both robust and energy-efficient. The case study uncovers several key findings:

- **Production and Economic Viability**
  The use of locally sourced lateritic soil, combined with an optimal mix ratio (1:35 with 5% cement and lime additions), facilitates the production of durable ISSBs. The deployment of a mechanical press (Bolyn press) ensures consistency and rapid production, significantly reducing both material and labor costs when compared to conventional methods.
- **Structural and Thermal Performance**
  The interlocking design of ISSBs streamlines construction and also enhances structural stability by distributing loads evenly. The inherent thermal mass of the blocks contributes to passive temperature regulation, thereby reducing the reliance on energy-intensive HVAC systems. These performance metrics are particularly important in regions experiencing extreme temperature variations.
- **Environmental Sustainability**
  By minimizing the need for energy-intensive firing processes and reducing transportation distances, ISSBs present a markedly lower carbon footprint compared to traditional fired bricks and concrete blocks. This environmental benefit resonates with global sustainability agendas and supports the transition towards greener construction practices.
- **Aesthetic and Practical Considerations**
  Despite the numerous benefits, challenges remain in terms of aesthetic appeal and moisture control. The post-occupancy evaluations highlighted issues such as dirt accumulation on external walls in wet areas, suggesting that additional finishing techniques or surface treatments may be required to optimize the material's visual and functional performance.
- **Broader Implications and Future Directions**
  The findings of this study advocate for the broaderadoption of ISSBs in residential construction, particularly in regions where local resources are abundant and economic constraints necessitate cost-effective building solutions.

In conclusion, ISSB technology embodies the intersection of innovation, sustainability, and practical construction methodologies, and while conventional materials have long dominated the construction landscape, the empirical evidence from Obayemi House suggests that alternative solutions like ISSBs can offer superior performance in terms of environmental impact, cost efficiency, and occupant comfort. The study reinforces the argument that sustainable design is not merely an aspirational ideal but a practical, achievable goal that transforms conception, construct, and inhabit our built environments. Future research should focus on refining production techniques, enhancing surface finishes, and exploring hybrid systems that integrate ISSBs with other sustainable materials to overcome identified limitations.

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