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Performance-Driven Material Innovation: Evaluating Thermal Masonry Systems as Alternatives to Conventional Cavity Wall Construction

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ABSTRACT

The construction industry is increasingly shifting from conventional prescriptive detailing towards performance-based building solutions. In this context, thermal masonry systems represent a form of material innovation that integrates structural capacity and thermal performance within a single walling element. This paper assesses the viability of no-cavity thermal masonry as an alternative to traditional cavity wall construction in the South African built environment. A qualitative case-study approach was adopted, using Cem Brick's Thermal Brick as the case. The study examines the system's thermal, structural, construction, spatial and regulatory implications through technical documentation, comparative performance data, regulatory compliance information, field observation and supporting literature. The findings show that the Thermal Brick wall has a reported R-value of 0.62 m^2K/W, which is broadly comparable to the 0.63 m^2K/W reported for a clay cavity wall, while using a thinner wall profile. The system also has a lower reported thermal conductivity value and a higher reported thermal capacity value. Case-study data further indicates potential benefits in relation to construction time, cost efficiency, reduced wall complexity and ease of site execution. However, successful adoption is not determined by technical performance alone. Implementation also depends on rational design documentation, regulatory acceptance, contractor familiarity and professional confidence. The paper contributes to the discussion on innovative construction materials by positioning no-cavity thermal masonry as a performance-oriented socio-technical innovation rather than merely an alternative brick product. It concludes that thermal masonry systems may support more integrated, efficient and practical building-envelope solutions, although further independent testing and lifecycle evaluation are required.

Keywords: Construction innovation, Innovative materials, Performance-based design, Smart building envelopes, Thermal masonry

INTRODUCTION

The construction industry is facing increasing pressure to deliver buildings that are structurally sound, cost-effective, energy efficient, sustainable and responsive to changing regulatory and performance expectations (Skibniewski, 2025; Iluyomade & Okwandu, 2024). In this regard, innovative building materials are becoming important change agents, especially when

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they offer integrated solutions that simplify construction and enhance building performance (Patil & Minde, 2022). Walling systems are a critical field of innovation as the building envelope is an important component in the control of heat transfer, thermal comfort and overall energy efficiency of buildings (Patil & Minde, 2022). The use of cavity wall construction has been a traditional approach to improve the thermal and moisture performance of external walls. However, this requires layered construction, thicker walls, more detailing and increased labour which may be a practical barrier in cases where skills, quality of workmanship, cost sensitivity and regulatory approval influence material choice (Chen, Chun & Van den Bossche, 2025). One of the possible answers to the above-mentioned challenges are no-cavity thermal masonry systems. These systems achieve this by combining thermal insulation and structural capacity into a single masonry unit, thereby re-establishing masonry as a performance-driven building envelope solution that has implications for material specification, construction processes, regulatory compliance, and industry adoption (Xhexhi & Aliaj, 2023). In this paper, the use of no-cavity thermal masonry walls as a new building material for the South African construction industry is explored. Thus, this study is guided by the following research question: How can no-cavity thermal masonry systems be integrated as performance-driven alternatives to conventional cavity wall construction in the South African built environment?

LITERATURE REVIEW

Innovative Building Materials and Performance-Based Design

The construction sector is moving away from prescriptive construction practices to performance-based construction, where materials and systems are evaluated based on measurable performance such as energy efficiency, durability, constructability, cost, carbon impact, and conformance with regulations (Brahme & Vyas, 2021; Rajendra et al., 2023; Skibniewsk, 2024). This shift is especially relevant in developing construction contexts, where innovative materials must respond not only to technical performance requirements but also to site realities such as labour capability, affordability, ease of construction and regulatory approval (Skibniewski, 2024; Patil & Minde, 2022; Brahme & Vyas, 2021). Modern methods of construction are increasingly being marketed as a means of increasing efficiency in construction, reducing delays, improving quality and responding to housing delivery challenges, particularly where conventional methods are unable to meet demand (Bakhaty, Udeaja & Levatti, 2024). In this sense, no-cavity thermal masonry systems can be framed as performance-driven material innovations, which intend to combine structural and thermal functions in one walling solution. This discussion is focused on building envelope performance, where external walls contribute to heat transfer, thermal comfort, moisture protection, energy demand and building regulations compliance (Chen, Chun & Van den Bossche, 2025). The traditional method of improving the performance of external walls has long been the conventional cavity wall. This method in particular provides thermal resistance and moisture control, by separating inner and outer masonry leaves. However, cavity walls may also present practical difficulties such as thicker wall sections, more complicated detailing, higher labour requirements and greater dependence on the quality of workmanship (Xhexhi & Aliaj, 2023). These limitations become especially significant where construction skills, supervision capacity, cost sensitivity, and approval processes affect material selection and site execution (Oguntona et al., 2023; De Villiers et al., 2018; Jansen et al., 2017). Thermal masonry systems offer an alternative by embedding thermal performance within the masonry unit itself, rather than relying on a separate cavity or additional insulation layer (Hou et al., 2024). Their evaluation therefore requires a holistic performance lens that considers thermal conductivity, thermal resistance, thermal capacity, structural functionality, construction efficiency, labour requirements, and spatial optimisation. In this sense, the value of no-cavity thermal masonry lies in the performance of the complete walling system, rather than in the material as an isolated product (Xhexhi & Aliaj, 2023; Hou et al., 2024). For broader adoption, however, technical performance alone is insufficient. In South Africa, innovative walling systems must demonstrate alignment with regulatory requirements, particularly SANS 10400-XA, and may require rational design, technical documentation, performance testing, certification, and professional motivation where they do not fit neatly into conventional deemed-to-satisfy pathways (Bremer & Le Roux, 2026). Existing literature on innovative building materials often focuses on technical performance, with less attention given to how integrated walling systems affect construction processes, regulatory approval, and adoption in developing contexts (Lin, et al., 2025; Oguntona et al., 2023; Yang, 2023; Oke et al., 2018). This paper responds to that gap by evaluating no-cavity thermal masonry as a performance-driven socio-technical innovation within the South African built environment. Adoption of no-cavity thermal masonry in South Africa is however shaped by a combination of technical, institutional, economic and behavioural factors (Ejidike & Mewomo, 2023; Eze et al., 2023). Smart material adoption is affected by market readiness, technical constraints, regulatory pathways, inconsistent interpretation of standards and limited knowledge transfer between manufacturers, regulators and built environment professionals (Agrément SA, 2023; Mbambo et al., 2021; Jansen et al., 2017). This suggests that even where thermal masonry demonstrates performance benefits, uptake may be slow if professionals, contractors, municipalities and clients do not fully understand the system or trust its compliance pathway. This is supported by a wider literature that shows the common challenges to the adoption of innovative materials, which include costs, regulations, and market acceptance (Iluyomade & Okwandu, 2024). In developing contexts, these challenges are exacerbated by a lack of training, financial constraints and unequal access to innovation-enabling infrastructure (Skibniewski, 2025). Thus, for the Cem Brick case, adoption is not only a function of product availability. This requires credible local performance data, clear guidance on specifications, contractor education, municipal acceptance, professional confidence and alignment to South African regulatory processes. The overall conclusion is that no-cavity thermal masonry is a socio-technical innovation: its success is contingent on the interaction of material performance, construction practice, regulatory interpretation and stakeholder readiness.

METHODOLOGY

Research Design

The study uses a qualitative case-study approach, which is appropriate for investigating material innovations in the real world in their practical, regulatory and construction contexts. Case studies allow for the exploration of the how and why of the development and functioning of a particular innovation within a bounded context (Yin, 2018). The Thermal Brick from Cem Brick was chosen as the case study due to its alignment with South Africa's drive for higher performing building envelopes as per SANS 10400-XA and its ability to provide a no-cavity alternative to conventional cavity wall construction. The study is framed within an interpretivist paradigm recognising that material innovation in construction is influenced by technical performance, regulatory requirements, construction practices and stakeholder interpretation. The aim was not to do independent lab testing, but to look at technical information available, comparative performance data and construction evidence to understand the system as a performance driven material innovation.

Data Sources and Collection Methods

Four main sources of qualitative data were used in the study: archival documentation, field observation, informal expert consultation and peer-reviewed literature (n = 26). The archival documentation provided by Cem Brick consisted of product information, technical documentation, thermal performance comparisons, cost data and marketing materials. These documents provided an insight into the rationale behind the development, the claimed performance benefits and comparison with traditional cavity wall systems. Direct non-participant observation was undertaken, by means of a field visit to Cem Brick's demonstration wall installation in Bloemfontein. Observations included wall assembly, installation complexity, implications for workmanship and constructability. Informal expert consultation with Cem Brick technical and marketing staff offered additional contextual insight into design development, performance claims, regulatory navigation and stakeholder responses. The case was developed through peer-reviewed literature on wider debates on innovative materials, performance-based construction, regulatory compliance and adoption in developing construction contexts.

Data Analysis Approach

Data were analysed for within-case thematic analysis following Yin's (2018) case-study protocol. Documentation, observation, expert consultation and literature evidence was organized around six analytical themes corresponding to the study objectives. Triangulation of sources enhanced the credibility of the findings and reduced reliance on one form of evidence. The analysis was focused on the functioning of the no-cavity thermal masonry as a complete walling system and not as an isolated masonry product.

Table 1: Thematic framework used to analyse no-cavity thermal masonry as a performance-driven walling.

Theme	Main Focus	Evidence Source
Thermal and building envelope performance	Thermal resistance, conductivity, heat transfer and envelope performance	Technical documentation, performance comparisons, literature
Structural and material functionality	Structural capacity, durability, wall stability and material behaviour	Product documentation, field observation, literature
Construction efficiency and labour implications	Buildability, labour intensity, detailing, time and cost implications	Field observation, expert consultation, comparative data
Spatial optimisation	Wall thickness, usable floor area and space efficiency	Technical comparisons, case documentation
Regulatory compliance and rational design	SANS 10400-XA alignment, rational design and compliance documentation	Regulatory data, technical documentation, literature
Adoption considerations in South Africa	Market readiness, professional confidence and contractor familiarity	Expert consultation, literature, case evidence

FINDINGS

The findings are presented according to six themes used to evaluate the Cem Brick Thermal Brick as an integrated no-cavity walling system. These themes focus on the system's thermal, structural, construction, spatial, regulatory, and adoption-related performance within the South African construction context. The findings are interpreted through an integrated performance lens, which positions no-cavity thermal masonry as a walling system shaped by technical, construction, spatial, regulatory and adoption-related considerations.

Theme 1: Thermal and Building Envelope Performance

The case-study data indicates that the Cem Brick Thermal Brick wall achieves a reported R-value broadly comparable to a clay cavity wall, while using a thinner wall profile. Its lower reported K-value suggests reduced heat conductivity, supporting its function as a thermally improved walling unit. The higher reported thermal capacity value further suggests potential thermal mass benefits. However, as the data is manufacturer-provided, independent testing and rational design verification remain important. These findings support the interpretation of the Thermal Brick as a performance-driven envelope solution. The system incorporates thermal resistance within the masonry unit rather than a separate cavity and insulation layer to reduce heat transfer. However, as the data is manufacturer provided, the thermal performance reported should be verified with independent testing, U-value/R-value calculations, and rational design documentation prior to drawing further conclusions. These findings concur with Xhexhi and Aliaj (2023) who highlight that wall composition is a key factor that influences the building envelope performance. The results also support Hou et al., (2024) who observed that cavity masonry wall structures can improve thermal performance by integrating insulation and thermal mass. Chen, Chun and Van Den Bossche (2025) further confirm that the thermal behaviour of cavity walls is influenced by wall geometry, material conductivity and heat transfer behaviour, which supports the need to evaluate wall systems as complete assemblies, rather than individual materials.

Table 2: Thermal performance comparison of walling systems (Cem Brick, 2025).

Aspect	Cem Brick Thermal Brick Wall	Clay Cavity Wall
Wall thickness	210 mm	270 mm
R-Value: thermal resistance	0.62 m^2K/W	0.63 m^2K/W
K-Value: thermal conductivity	0.5244 W/mK	0.82 W/mK
CR-Value: thermal capacity	75 hours	65 hours

Theme 2: Structural and Material Functionality

The Thermal Brick is a solid, no-cavity walling system where the masonry unit serves both structural and thermal function. In the case-study documentation, the product is referred to as a concrete masonry unit that conforms to SANS 1215:2008, with 7.5 MPa and 10.5 MPa compressive strength options. This supports the interpretation that the no-cavity thermal masonry should be regarded as a multifunctional material system where the structural capacity, buildability, thermal resistance, durability and long-term service performance are intertwined. This outcome supports the contention of Iluyomade and Okwandu (2024) that innovative materials in sustainable construction are gaining increased recognition for their potential to boost energy efficiency, durability and lifecycle performance.

Theme 3: Construction Efficiency and Labour Implications and Cost Considerations

The case-study data suggests that the Cem Brick Thermal Brick system may reduce construction complexity, labour input, and cost. This aligns with Bakhaty, Udeaja and Levatti (2024), as well as Skibniewski (2025), who note that modern methods of construction are often adopted to improve construction efficiency, reduce delays, improve quality and respond to housing delivery pressures. Unlike conventional cavity walls, the no-cavity system reduces reliance on cavity formation, wall ties, insulation placement, and moisture-related detailing. The reported time and cost comparison indicates potential productivity and cost benefits, although these should be verified through further independent studies across different project conditions. However, because the time and cost data are manufacturer-provided, further independent verification would strengthen the reliability of these findings.

Table 3: Construction efficiency and cost comparison of walling systems (Cem Brick, 2025).

Indicator	Cem Brick Thermal Brick Wall	Clay Cavity Wall
Wall thickness	220 mm	270 mm
Construction time	30 minutes	1 hour 17 minutes
Relative cost per running meter	8.6% less expensive	9.4% more expensive
Construction complexity	Lower	Higher
Labour requirement	Reduced cavity-related detailing	More cavity-related detailing

Theme 4: Spatial Optimisation

Spatial optimisation emerged as a relevant performance consideration. The Thermal Brick wall achieves a reported R-value of 0.62 m^2K/W with a 210 mm wall, compared with a 270 mm clay cavity wall achieving a similar reported R-value of 0.63 m^2K/W. This suggests that the no-cavity system may provide comparable thermal resistance with an approximately 60 mm thinner wall profile, which may support usable floor area, material efficiency, and cost planning. This finding links to the broader performance-based view of building envelope systems, where material selection should be assessed not only according to thermal performance, but also according to its effect on overall building efficiency. Chen, Chun and Van Den Bossche (2025) show that cavity wall geometry and wall thickness influence thermal behaviour, while Hou et al., (2024) confirm that wall configuration affects energy performance.

Theme 5: Regulatory Compliance and Rational Design

Regulatory compliance remains central to the adoption of no-cavity thermal masonry in South Africa. The case-study documentation links the system to SANS 10400-XA thermal performance requirements and includes rational design guidance for local authority submissions. It also refers to engineering confirmation, CMACS certification, and SANS 1215 compliance. This indicates that the product must be supported by technical documentation and rational design evidence to be legible within municipal and professional approval processes. This finding is consistent with the literature on innovative building material adoption, which shows that technical performance alone is not sufficient for implementation. Iluyomade and Okwandu (2024) identify regulatory barriers and market acceptance as important challenges for innovative materials, while Skibniewski (2025) notes that adoption in developing contexts may be constrained by limited access to technology, training and implementation capacity.

Theme 6: Adoption Considerations Within the South African Construction Context

Adoption is not just a matter of product availability or technical performance. Results indicate that contractor experience, professional confidence, municipal acceptance, cost awareness and clear specification guidance are important for success. Hence, the Thermal Brick is an example of a socio-technical innovation. The adoption of the Thermal Brick is dependent on the dynamic relations between the material performance, regulatory acceptance, construction practice, and stakeholder readiness. Similarly, Bakhaty, Udeaja and Levatti (2024) state that the adoption of modern construction methods depends not only on technical performance but also on aspects such as cost, skills development, government support, technology readiness and stakeholder acceptance. It also supports the observation of Iluyomade and Okwandu (2024) that innovative materials are faced with challenges of adoption related to cost, regulation and market acceptance.

RESULTS AND DISCUSSION

The results suggest that the Cem Brick Thermal Brick should be interpreted as an integrated no-cavity walling system rather than simply as an alternative masonry unit. Its performance value lies in the combined effect of thermal resistance, structural functionality, construction efficiency, spatial optimisation and regulatory compliance. From a thermal-performance perspective, the most significant finding is that the Thermal Brick wall achieves a reported R-value of 0.62 m^2K/W compared with 0.63 m^2K/W for a conventional clay cavity wall. Although the cavity wall performs marginally better in absolute R-value terms, the difference is only 0.01 m^2K/W, while the Thermal Brick achieves this performance with a thinner wall profile. The case-study data further indicates a lower reported K-value of 0.5244 W/mK for the Thermal Brick compared with 0.82 W/mK for the clay cavity wall, suggesting reduced thermal conductivity. Its reported CR-value of 75 hours, compared with 65 hours for the clay cavity wall, also suggests potential thermal capacity benefits. These results indicate that the no-cavity system may offer comparable envelope performance while simplifying the wall build-up. However, because the comparative data are manufacturer-provided, the results should be treated as indicative and should be verified through independent thermal testing, U-value/R-value calculations and rational design assessment. The construction comparison also indicates practical advantages. The case-study data reports that a 1.8 m long wall section, two courses high, was constructed in 30 minutes using the Thermal Brick system, compared with 1 hour and 17 minutes for a comparable clay cavity wall. This represents a substantial reduction in construction time for the observed wall section. The reported cost comparison further indicates that the Thermal Brick wall is approximately 8.6% less expensive per running metre, while the clay cavity wall is reported to be 9.4% more expensive. These figures suggest potential productivity and cost benefits, particularly because the no-cavity system reduces the need for cavity formation, wall ties, insulation placement and moisture-related detailing. Nevertheless, these findings should be tested across larger project samples, different labour conditions and different building types before broader cost and productivity claims are made.

Spatially, the Thermal Brick wall provides comparable reported thermal resistance with an approximately 60 mm thinner wall profile than the clay cavity wall. This may have implications for usable floor area, space planning and cost planning, especially in projects where wall thickness affects net lettable or usable area. The spatial benefit is therefore not only a dimensional advantage, but part of the wider performance-based value proposition of the walling system. Regulatory compliance remains central to adoption. The case-study documentation links the system to SANS 10400-XA thermal performance requirements and refers to rational design guidance, engineering confirmation, CMACS certification and SANS 1215 compliance. This confirms that technical performance alone is insufficient for implementation. For professional and municipal acceptance, the system must be supported by credible documentation, rational design evidence and clear specification guidance. Overall, the Cem Brick Thermal Brick can be considered a performance-oriented socio-technical innovation whose adoption depends on the interaction between material performance, construction practicality, cost acceptability, regulatory confidence and stakeholder readiness.

CONCLUSION AND RECOMMENDATIONS

The Thermal Brick was identified as an integrated no-cavity walling system rather than merely another masonry unit. The results show that the system can be a potential support to performance-based building envelope design by integrating thermal resistance, structural functionality, simple construction, spatial efficiency and regulatory compliance into one walling solution. The data from the case-study suggests that the Thermal Brick has the potential to achieve a similar reported thermal resistance to traditional cavity wall construction, with potential benefits in terms of construction time, cost and wall thickness. However, the study also shows that successful adoption is about more than technical performance. In South Africa, no-cavity thermal masonry needs credible evidence of performance, rational design documentation, regulatory acceptance, contractor familiarity and professional confidence. Therefore, further independent testing of long-term thermal, structural, moisture, fire, and lifecycle performance is recommended. Future research should also expand the case-study evidence through comparative cost, carbon and post-occupancy studies to determine the broader applicability and long-term value of thermal masonry within South African building practice.

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