International Journal of Engineering and Techniques - Volume 12 Issue 4, July - August - 2026

Comparative Life Cycle Cost and Environmental Impact Assessment of Burnt Clay Bricks, AAC Blocks, and Compressed Stabilized Fly Ash Blocks: A Cradle-to-Gate Approach

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Abstract—Masonry materials account for a considerable share of resource consumption and greenhouse gas emissions in the construction industry. In India, burnt clay bricks have traditionally been the preferred walling unit, but their production relies on wood-fired kilns and large-scale clay excavation, both of which carry significant environmental consequences. Autoclaved Aerated Concrete (AAC) blocks and Compressed Stabilized Fly Ash Blocks (CSFB) have been proposed as more sustainable alternatives because they incorporate industrial by-products and do not require kiln firing. However, a direct, field-data-based comparison of these three materials under Indian manufacturing conditions has been limited in the literature. This study presents a comparative Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) of burnt clay bricks, AAC blocks, and CSFB blocks, adopting a cradle-to-gate system boundary and a functional unit of 1 m^3 of masonry material. Primary inventory data were collected through industrial site visits to three manufacturing units in Karnataka, India. Environmental impacts were quantified using openLCA 2.6.0 with the IPCC 2013 GWP 100a impact assessment method. Physical properties of the materials were tested in accordance with relevant Bureau of Indian Standards (BIS) specifications. The results show that burnt clay bricks carry the highest global warming potential at 355.04 kg CO_2 eq/m^3, driven almost entirely by wood combustion during kiln firing. CSFB blocks recorded the lowest at 100.08 kg CO_2 eq/m^3, while AAC blocks fell in between at 125.86 kg CO_2 eq/m^3. On the cost side, burnt clay bricks were the most affordable at ₹5,176.50/m^3, while CSFB blocks were the most expensive at ₹6,750.54/m^3. AAC blocks offered the most balanced performance across both environmental and economic dimensions. The findings provide quantitative, locally grounded evidence to support better material selection decisions in sustainable construction.

Keywords —*Life Cycle Assessment (LCA), Life Cycle Costing (LCC), Burnt Clay Brick, Autoclaved Aerated Concrete (AAC), Compressed Stabilized Fly Ash Blocks (CSFB), Global Warming Potential, Sustainable Construction, openLCA.*

I. INTRODUCTION

The construction industry is one of the largest consumers of natural resources globally, and masonry materials make up a substantial part of that demand. In India, burnt clay bricks have long been the dominant walling material, owing to their local availability, ease of use, and familiarity among builders. Yet the process of making them is both resource-intensive and polluting. Clay is excavated directly from agricultural land, and the bricks are fired in kilns at temperatures exceeding 900°C using wood, coal, or agricultural residues as fuel. The result is a material that contributes considerably to greenhouse gas emissions, air pollution, and the permanent loss of productive topsoil.

In response to these concerns, alternative masonry materials have been gaining ground. Autoclaved Aerated Concrete (AAC) blocks are manufactured using fly ash, cement, lime, and aluminium powder through a controlled aeration and steam-curing process. They are lightweight, thermally efficient, and make productive use of fly ash from thermal power plants. Compressed Stabilized Fly Ash Blocks (CSFB) take a different approach: fly ash and quarry dust are blended with a small proportion of cement and compacted under hydraulic pressure, with no firing or autoclaving required at any stage. Both materials divert industrial waste from disposal sites and reduce dependence on natural clay.

Despite the growing interest in these alternatives, material choices in the construction industry continue to be driven mainly by cost and habit. There is limited access to quantitative, locally relevant data that compares burnt clay bricks, AAC blocks, and CSFB blocks in terms of both their environmental impact and economic performance. Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) are well-established tools for exactly this kind of systematic comparison, but their combined application to these three materials using field-collected primary data from Indian plants has not been adequately addressed in the published literature.

This study aims to fill that gap. Site visits were conducted at three manufacturing units in Karnataka, production data were collected directly from plant operators, and the materials were tested in the laboratory under BIS specifications. The resulting LCA and LCC comparison is intended to provide engineers, contractors, and policymakers with clear, evidence-based information to support more sustainable masonry material selection.

A. Objectives of the Study

1) To compare the environmental impacts of burnt clay bricks, AAC blocks, and CSFB blocks through a cradle-to-gate Life Cycle Assessment using the IPCC 2013 GWP 100a methodology.

2) To evaluate and compare the life cycle costs of the selected masonry materials, covering procurement, on-site labour, and associated expenses.

3) To identify the masonry material that offers the most favourable balance between environmental performance and economic feasibility for sustainable construction applications in India.

II. LITERATURE REVIEW

Research on the life cycle assessment of construction materials has expanded notably over the past decade. Barbhuiya and Das [1] reviewed LCA methodologies applied to construction materials, covering inventory development, impact assessment, allocation procedures, and uncertainty handling. Their work highlights that the choice of system boundary and functional unit can significantly influence comparative outcomes — a consideration that shaped the design of the present study.

At the building level, Heeren et al. [3] combined LCA with thermal simulation and found that the electricity generation mix, operational energy demand, and construction material choices are the primary determinants of lifetime environmental impacts. Ramírez-Villegas et al. [2] reached a similar conclusion in a renovation-focused study, showing that embodied material impacts and operational energy must be considered together for a complete environmental picture.

For walling materials specifically, Dormohamadi et al. [7] compared 22 wall systems in Iran — including fired bricks, AAC blocks, and compressed earth blocks — and found that low-firing or no-firing alternatives consistently outperformed conventional fired bricks on environmental metrics. They also identified transportation as a non-trivial contributor, particularly when raw materials are sourced over long distances. Petrovic et al. [4] and Dsilva et al. [5] further established that embodied carbon in construction materials is a significant lifecycle driver that warrants design-stage attention.

On the economic side, Kaur et al. [6] showed that initial material cost is often a poor measure of long-term economic performance when maintenance and replacement are included over a 50-year horizon. Xue et al. [8] integrated LCA and LCC for campus buildings and found that both electricity consumption and material production are simultaneously the leading cost and environmental drivers, suggesting they should be focal points for improvement.

While the above studies provide valuable methodological and contextual grounding, the published literature lacks a combined LCA and LCC comparison of burnt clay bricks, AAC blocks, and CSFB blocks that is based on primary field data from Indian manufacturing units. Most existing studies rely on generic databases or address these materials individually rather than in direct comparison. The present study addresses this gap.

III. METHODOLOGY

A. Material Selection and Site Visits

Three masonry materials commonly used in construction across Karnataka were selected: burnt clay bricks, AAC blocks, and CSFB blocks. These materials were chosen because they span a wide range of manufacturing approaches and environmental profiles, from the most conventional and heat-intensive to the most process-efficient.

Site visits were carried out at a brick kiln in Nittur, Belagavi; the Shivshakti AAC Plant in Mandihal, Dharwad; and SG Interlocking Blocks in Savgaon, Belagavi. At each facility, the full production sequence was observed, and information on raw material quantities, electricity consumption, fuel usage, water demand, production capacity, and transportation distances were collected through direct observation and discussions with plant supervisors and operators. Electricity bills were reviewed where available.

B. Functional Unit and System Boundary

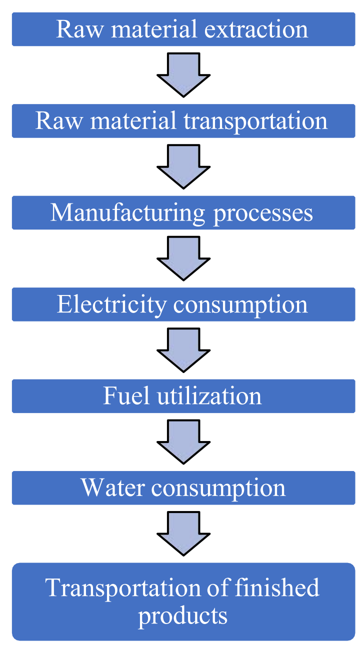

Fig. 1. Cradle-to-gate system boundary adopted for the life cycle assessment of the selected masonry materials.

Fig. 1. shows the Cradle-to-Gate system boundary adopted for the present study. The functional unit adopted for this study is 1 m^3 of masonry material. This unit was chosen to enable a consistent and fair comparison across materials that differ substantially in size, density, and individual unit

dimensions. All inventory data, labour requirements, and transportation demands were normalized to this basis.

A cradle-to-gate system boundary was applied, covering raw material extraction, transportation of raw materials to the plant, all manufacturing operations (mixing, moulding, firing, curing, or compression, as applicable), on-site fuel and electricity consumption, and delivery of the finished product. The use phase and end-of-life were not included, as the study focuses on the production stage where primary field data were available.

C. Manufacturing Processes

At the Nittur kiln, clay is excavated from an adjacent site using a JCB excavator, mixed with water, hand-moulded in wooden moulds, and sun-dried before stacking. Firing takes place in a zig-zag kiln over 20 to 25 days per batch of approximately 50,000 bricks, using wood as the primary fuel and rice husk and straw as kiln cover material.

At the Mandihal AAC plant, fly ash is slurried with water and mixed with cement, lime, gypsum, and aluminium powder in an automated batching system. The aluminium reacts with the alkaline mixture to release hydrogen gas, producing the characteristic porous structure. The blocks are then wire-cut and steam-cured in autoclaves, with steam generated by wood-fired boilers. Daily output is approximately 110 to 120 m³.

At the Savgaon CSFB unit, fly ash and quarry dust are mechanically blended with cement and water, conveyed into a hopper, and hydraulically compressed to form blocks. The blocks are shade-dried for 48 hours and water-cured for 11 to 15 days. No kiln, autoclave, or combustion process is involved at any stage. The plant produces approximately 1,200 blocks per day.

D. Experimental Testing

Compressive strength, water absorption, and density were tested on five specimens of each material at the Jain College of Engineering laboratory, Belagavi. Burnt clay bricks were tested per IS 3495 (Parts 1 and 2), AAC blocks per IS 2185 (Part 3), and CSFB blocks per IS 1725. A Universal Testing Machine (UTM) was used for compressive strength. Water absorption was measured after 24-hour immersion at room temperature. Density was calculated from the dry mass and measured volume of each specimen. All reported values are averages of five readings.

E. Life Cycle Inventory Data

All inventory parameters were expressed on a per-m³ basis before modelling. For clay bricks, the batch of 50,000 bricks was used as the reference, with values scaled to m³ using measured brick dimensions (220×110×70 mm). For AAC blocks, daily plant output of 115 m³ served as the reference denominator. For CSFB blocks, a daily production of 1,200 blocks (300×150×150 mm) was used. Where direct measurement was not possible — notably AAC electricity consumption — values from published literature were used. Key LCI data are summarized in Table I.

TABLE I
LIFE CYCLE INVENTORY DATA SUMMARY (PER m³)

Parameter	Clay Brick	AAC Block	CSFB Block
Wood / Biomass Fuel (kg)	188.0	17.4	0
Electricity (kWh)	1.062	25.0	10.0
Water (L)	295	300	150
Clay (kg)	1357	0	0
Fly Ash (kg)	0	422.5	846
Cement (kg)	0	97.5	108
Lime (kg)	0	117.0	0
Quarry Dust (kg)	0	0	846
Aluminium Powder (kg)	0	0.325	0
Diesel – JCB (L)	0.00236	0	0
Raw Material Procurement Distance (t-km)	0.944	294.3	18.0
Product Delivery Distance (t-km)	44.25	97.5	144.0
Total Transport (t-km)	45.19	391.8	162.0

F. Environmental Assessment using openLCA

Environmental impacts were modelled in openLCA 2.6.0 using the IPCC 2013 GWP 100a impact assessment method. Inventory data for each material were entered manually as foreground processes. Background datasets for electricity (UCTE production mix) and road transport (16-tonne lorry, RER scenario) were sourced from the ecoinvent database. Combustion emissions from wood fuel were estimated using standard emission factors, as no exact ecoinvent match was available for the kiln conditions observed on site. The assessment covered global warming potential (GWP), air emissions, water emissions, and resource consumption.

G. Life Cycle Cost Analysis

Three cost components were considered in the LCC: material procurement cost, collected as delivered-to-site market rates from suppliers (these rates already include manufacturing, factory labour, and delivery, so no separate transport cost was added to avoid double counting); on-site labour cost, calculated using the Karnataka Schedule of Rates for a team of one skilled mason and one unskilled helper at a combined daily wage of ₹1,400; and a miscellaneous cost of 5 % of total direct cost to account for handling, supervision, and minor site contingencies. All costs were computed per m³ of masonry material.

IV. RESULTS AND DISCUSSION

A. Physical Properties

The experimental results are summarized in Table II. Burnt clay bricks from the Nittur kiln achieved an average compressive strength of 8.77 N/mm², placing them in the second-class brick category under IS 1077. This is adequate for standard wall construction and reflects the quality of bricks produced at the site.

AAC blocks recorded an average compressive strength of 3.77 N/mm², consistent with the medium-density grade under IS 2185 Part 3. Although this is lower than the other two materials, it is sufficient for non-load-bearing partition walls and infill panels in framed structures, which represent the most common use of AAC in building construction. CSFB blocks recorded an average strength of 7.00 N/mm², meeting the standard CSFB classification — a result worth noting given that no heat input is involved in their production.

CSFB blocks also showed the lowest water absorption at 13.57 %, compared to 17.28 % for clay bricks and 19.85 % for AAC blocks. Lower water absorption generally indicates a denser microstructure and better resistance to moisture-related degradation. In terms of density, AAC blocks at 650.67 kg/m³ weigh considerably less than clay bricks and CSFB blocks, both of which are approximately 1,800 kg/m³. This difference directly affects dead loads on structural systems and, as discussed later, also influences on-site labour productivity.

TABLE II
PHYSICAL PROPERTIES OF MASONRY MATERIALS (AVERAGE OF FIVE SPECIMENS)

Property	Clay Brick	AAC Block	CSFB Block
Compressive Strength (N/mm²)	8.77	3.77	7.00
Water Absorption (%)	17.28	19.85	13.57
Density (kg/m³)	1797.52	650.67	1801.78
BIS Classification	Second Class	Medium Density	Standard CSFB

B. Global Warming Potential

The GWP results are presented in Table III. Burnt clay bricks recorded the highest value at 355.04 kg CO_2 eq/m³, which is approximately 2.8 times that of AAC blocks and 3.5 times that of CSFB blocks. Fig. 2. represents the graphical comparison of the GWP of different materials. Contribution analysis in openLCA identified wood combustion during kiln firing as the source of 98 % of this impact, with electricity consumption and transportation accounting for the small remainder. The scale of this contribution from a single process underscore how significantly kiln firing dominates the environmental profile of burnt clay bricks. Fig. 4. shows a Sankey diagram for Burnt clay brick production.

AAC blocks generated 125.86 kg CO_2 eq/m³, with cement and lime production jointly responsible for 93 % of that figure. The lime component (117 kg/m³, representing 18 % of block mass) is particularly significant, since limestone calcination releases CO_2 as a direct chemical by-product rather than a combustion emission, making it harder to address through fuel substitution alone.

CSFB blocks had the lowest GWP at 100.08 kg CO_2 eq/m³. The cement stabilizer at 6 % by mass accounted for 97 % of this impact, meaning that reducing cement content or replacing part of it with supplementary cementitious materials would be the most direct way to further improve CSFB's environmental performance.

Fig. 3. shows the major contributors to GWP for each masonry materials.

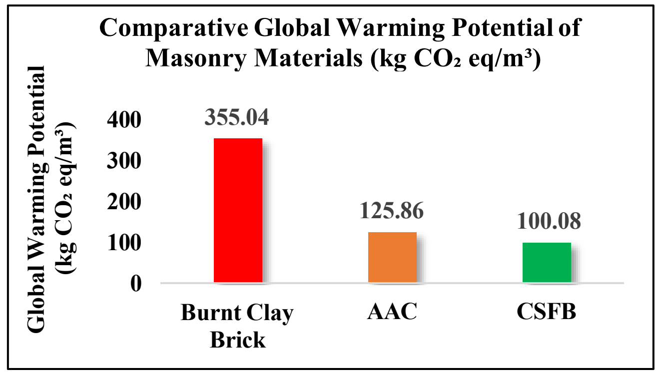

Fig. 2. Comparative global warming potential of burnt clay bricks, AAC blocks, and CSFB blocks (kg CO_2 eq/m³).

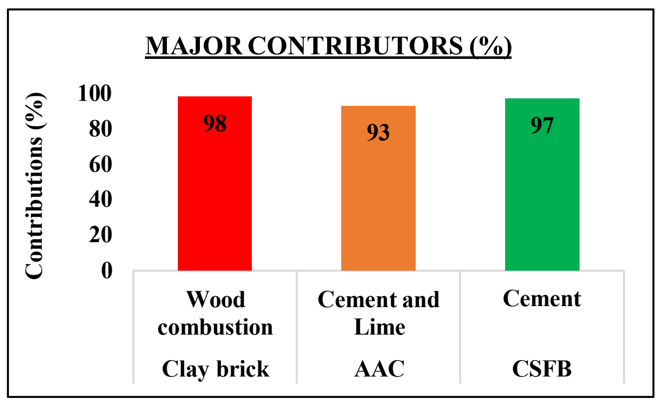

Fig. 3. Major contributors to global warming potential for each masonry material (percentage contribution).

TABLE III
GLOBAL WARMING POTENTIAL AND CONTRIBUTION ANALYSIS

Material	GWP (kg CO_2 eq/m³)	Primary Contributor	Contribution (%)
Burnt Clay Brick	355.04	Wood combustion during kiln firing	98
AAC Block	125.86	Cement and Lime production	93

Material	GWP (kg CO_2 eq/m³)	Primary Contributor	Contribution (%)
CSFB Block	100.08	Cement stabilization process	97

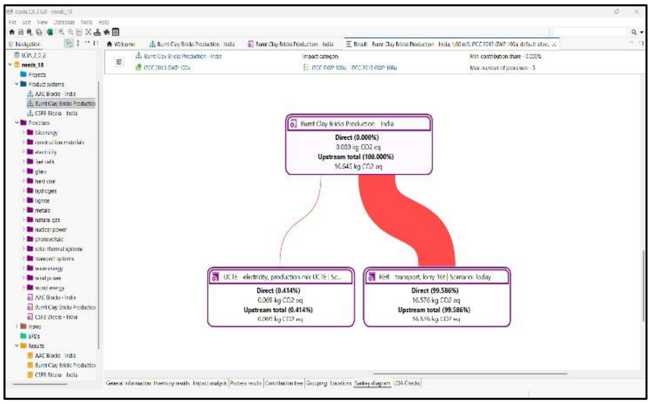

Fig. 4. Sankey diagram showing process contributions to global warming potential for burnt clay brick production.

C. Air and Water Emissions

Burnt clay bricks produced significantly higher particulate matter ($PM_{2.5}$–10) emissions at 0.00283 kg/m³, which is roughly 13 times the levels recorded for AAC (0.00021 kg/m³) and CSFB blocks (0.00022 kg/m³). In the Indian context, where kilns are typically located near residential and agricultural areas, these particulate emissions have direct public health implications.

Water emission intensity was also highest for clay bricks, with Total Organic Carbon (TOC) at 0.0785 kg/m³ compared to 0.000368 kg/m³ for AAC and 0.000345 kg/m³ for CSFB blocks. BOD and COD values followed the same pattern. These emissions arise primarily from biomass combustion and associated soil disturbance at the kiln site. AAC and CSFB blocks, with more controlled manufacturing environments, produced much lower water emission loads.

D. Resource Consumption

Clay brick production requires 1,357 kg of natural clay per m³, all of it extracted directly from agricultural land. CSFB blocks, by contrast, incorporate 846 kg of fly ash and 846 kg of quarry dust per m³, making up 94 % of the total block mass from industrial by-products. AAC blocks incorporate 422.5 kg of fly ash per m³ (65 % by mass). This level of waste material utilization offers an environmental benefit that extends beyond GWP reduction, contributing to reduced landfill use and lower pressure on natural raw material sources.

E. Electricity and Water Consumption

AAC block manufacturing required the most electricity at 25 kWh/m³, driven by automated batching, slurry mixing, conveyor systems, wire cutting, and autoclave-related operations. CSFB blocks consumed 10 kWh/m³ for hydraulic compression and mixing. Burnt clay bricks needed only 1.062 kWh/m³, used almost entirely for pumping water, since the kiln runs on biomass rather than electricity.

Water consumption was similar for clay bricks (295 L/m³) and AAC blocks (300 L/m³). CSFB blocks required considerably less at 150 L/m³, used mainly for the curing stage.

F. Transportation Demand

Transportation demand varies considerably across the three materials, as shown in Table IV. AAC blocks require 391.8 t-km/m³, which is more than eight times that of clay bricks. The main reason is lime, sourced from Rajasthan at a distance of approximately 1,650 km, contributing around 193 t-km/m³ on its own. This single supply chain decision accounts for nearly half of AAC's total transport footprint. If lime could be procured from a regional source, AAC's environmental profile would improve considerably without any change to the product itself.

CSFB blocks show a moderate transport demand of 162 t-km/m³, with the majority arising from finished product delivery over an average distance of 80 km. Raw materials are all sourced within 30 km. Burnt clay bricks have the lowest demand at 45.19 t-km/m³, benefiting from a deeply local supply chain — one of the few areas where conventional bricks outperform their alternatives.

TABLE IV
COMPARATIVE ENVIRONMENTAL PERFORMANCE INDICATORS (PER M³)

Indicator	Clay Brick	AAC Block	CSFB Block
GWP (kg CO_2 eq/m³)	355.04	125.86	100.08
Electricity (kWh/m³)	1.062	25.0	10.0
Water Consumption (L/m³)	295	300	150
Total Transport (t-km/m³)	45.19	391.8	162.0
$PM_{2.5}$–10 Emissions (kg/m³)	0.00283	0.00021	0.00022
TOC to Water (kg/m³)	0.07851	0.000368	0.000345
SO_2 Emissions (kg/m³)	0.00297	0.03492	0.03865
NOx Emissions (kg/m³)	0.11213	0.11568	0.12778

G. Life Cycle Cost Analysis

The LCC results are presented in Table V and represented in a graph in Fig. 5. Burnt clay bricks have the lowest total cost at ₹5,176.50/m³, supported by a low unit price of ₹7 per brick. Their on-site labour cost, however, is the highest at ₹800/m³ because the small brick size requires more individual handling per cubic metre laid (approximately 590 bricks per m³, at a productivity rate of 1.75 m³/day).

AAC blocks are priced at ₹63 per block, giving a procurement cost of ₹4,662/m³ at 74 blocks per m³. Their significantly larger size and lower weight allow a mason to lay 3.5 m³/day, which cuts the on-site labour cost to ₹400/m³ — exactly half that of clay bricks. The total LCC of ₹5,315.10/m³ is only marginally above clay bricks, despite the higher unit price, which shows how on-site productivity can offset the cost of a more expensive material.

CSFB blocks carry the highest total cost at ₹6,750.54/m³, driven by a unit price of ₹40 per block and a requirement of 148 blocks per m³. The approximately 30 % cost premium over clay bricks is a real constraint in cost-sensitive construction environments. That said, for projects where sustainability targets, environmental certification, or regulatory requirements around industrial waste utilization apply, this premium may be justifiable.

TABLE V
LIFE CYCLE COST ANALYSIS RESULTS (₹/M³)

Material	Procurement	Labour	Misc. (5%)	Total LCC
Clay Brick	₹4,130	₹800	₹246.50	₹5,176.50
AAC Block	₹4,662	₹400	₹253.10	₹5,315.10
CSFB Block	₹5,920	₹509	₹321.45	₹6,750.54

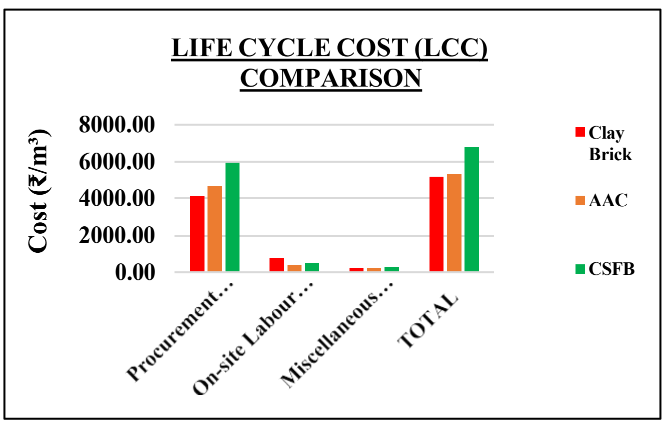

Fig. 5. Comparative life cycle cost analysis of the selected masonry materials (₹/m³).

H. Sustainability Ranking

Table VI brings together the environmental and economic rankings for all three materials. CSFB blocks rank first environmentally but last on cost. Clay bricks rank first economically but last on environmental performance. AAC blocks rank second on both dimensions, making them the only material to perform consistently in the middle ground. For projects where both sustainability and budget matter, AAC blocks offer the most practically balanced option.

It is important to note that these rankings reflect manufacturing and market conditions as observed in Karnataka during 2025–26. Changes such as regional lime sourcing for AAC production, a carbon pricing policy, or optimized cement content in CSFB blocks could shift these rankings in a meaningful way.

TABLE VI
SUSTAINABILITY RANKING OF MASONRY MATERIALS

Material	Environmental Rank	Economic Rank	Overall Assessment
Clay Brick	3rd (Lowest)	1st (Best)	Economically most competitive; highest environmental burden
AAC Block	2nd	2nd	Most balanced — recommended for sustainable construction
CSFB Block	1st (Best)	3rd (Highest)	Best environmental profile; highest life cycle cost

V. CONCLUSIONS

This study carried out a field-data-based comparative LCA and LCC of burnt clay bricks, AAC blocks, and CSFB blocks under real manufacturing conditions in Karnataka, India. The findings lead to several clear conclusions.

Burnt clay bricks carry by far the highest environmental burden of the three materials, with a GWP of 355.04 kg CO_2 eq/m³ that is almost entirely explained by wood combustion in the kiln. This single process accounts for 98 % of the total impact, which means that transitioning to cleaner fuels or adopting energy-efficient kiln technologies would produce the largest environmental benefit for this material.

CSFB blocks demonstrated that commercially viable masonry production without any heat input is feasible, and the results confirm their environmental advantage. Their higher cost relative to clay bricks remains a practical barrier, but it is not permanent. Reducing cement content through supplementary binders, better local market development, or policy support for industrial waste utilization could all help close this gap over time.

AAC blocks sit in a position that is often underappreciated: not the cheapest material, and not the cleanest, but reasonably competitive on both fronts. Their high transportation demand — largely a consequence of sourcing lime from Rajasthan — is the most actionable improvement opportunity. Securing regional lime supply alone would meaningfully reduce AAC's transport-related footprint without requiring any change in the product.

Across all three materials, cement emerged as the dominant environmental contributor in the two alternatives. Reducing or partially replacing clinker-based cement — through fly ash cement, slag cement, or other supplementary materials — is the most broadly applicable strategy for improving the sustainability of both AAC and CSFB blocks.

The study also confirms a recurring challenge in sustainable construction: the material with the best environmental performance is not always the most affordable under current market conditions. Narrowing that gap will require a combination of technical innovation, supply chain improvement, and policy measures that more accurately reflect the environmental cost of conventional masonry production.

. ACKNOWLEDGMENT

The authors thank the management and staff at Sunil Narvekar Brick Kiln (Nittur, Belagavi), Shivshakti AAC Plant (Mandihal, Dharwad), and SG Interlocking Blocks (Savgaon, Belagavi) for permitting site access and sharing production records. The support of the Department of Civil Engineering, Jain College of Engineering, Belagavi, for laboratory facilities and academic guidance throughout this work is also gratefully acknowledged.

. REFERENCES

[1] S. Barbhuiya and B. B. Das, “Life cycle assessment of construction materials: Methodologies, applications and future directions for sustainable decision-making,” Case Studies in Construction Materials, vol. 19, 2024. doi: 10.1016/j.cscm.2024.e03150.

[2] R. Ramírez-Villegas, O. Eriksson, and T. Olofsson, “Life cycle assessment of building renovation measures—Trade-off between building materials and energy,” Energies, vol. 12, no. 2, p. 344, 2019. doi: 10.3390/en12020344.

[3] N. Heeren, C. L. Mutel, B. Steubing, Y. Ostermeyer, H. Wallbaum, and S. Hellweg, “Environmental impact of buildings—What matters?” Environmental Science & Technology, vol. 49, no. 16, pp. 9832–9841, 2015. doi: 10.1021/acs.est.5b01735.

[4] B. Petrovic, J. A. Myhren, X. Zhang, M. Wallhagen, and O. Eriksson, “Life cycle assessment of building materials for a single-family house in Sweden,” Energy Procedia, vol. 158, pp. 3547–3552, 2019. doi: 10.1016/j.egypro.2019.01.913.

[5] J. Dsilva, S. Zarmukhambetova, and J. Locke, “Assessment of building materials in the construction sector: A case study using life cycle assessment approach to achieve the circular economy,” Heliyon, vol. 9, no. 12, p. e20404, 2023. doi: 10.1016/j.heliyon.2023.e20404.

[6] S. Kaur, T. S. Sidana, and V. K. Paul, “Life cycle costing of building envelope,” International Journal of Creative Research Thoughts, vol. 8, no. 6, pp. 1793–1802, 2020.

[7] M. Dormohamadi, R. Rahimnia, and V. Bunster, “Life cycle assessment and life cycle cost analysis of different walling materials with an environmental approach,” International Journal of Life Cycle Assessment, vol. 29, no. 3, pp. 355–379, 2024. doi: 10.1007/s11367-023-02259-6.

[8] Z. Xue, H. Liu, Q. Zhang, J. Wang, J. Fan, and X. Zhou, “The impact assessment of campus buildings based on a life cycle assessment– life cycle cost integrated model,” Sustainability, vol. 12, no. 3, p. 1136, 2020. doi: 10.3390/su12031136.

[9] Bureau of Indian Standards, IS 3495 (Parts 1 & 2): Methods of Tests of Burnt Clay Building Bricks. New Delhi: BIS, 1992.

[10] Bureau of Indian Standards, IS 2185 (Part 3): Concrete Masonry Units — Autoclaved Cellular (Aerated) Concrete Blocks. New Delhi: BIS, 2005.

[11] Bureau of Indian Standards, IS 1725: Solid Masonry Units — Specification, 3rd rev. New Delhi: BIS, 2023.

[12] Karnataka Public Works Department, Schedule of Rates for Building Works. Bengaluru: Government of Karnataka, 2024.

[13] openLCA, openLCA 2.6.0 Software Platform. Berlin: GreenDelta, 2024. [Online]. Available: https://www.openlca.org