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Comparative Study of Autoclaved Aerated Concrete (AAC) Blocks and Conventional Concrete Blocks for Sustainable Construction

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ABSTRACT

Rapid urbanisation demands walling materials that are simultaneously energy-efficient, low-carbon and affordable. This paper presents a multi-criteria comparison of Autoclaved Aerated Concrete (AAC) blocks with conventional solid and hollow concrete blocks across physical, mechanical, thermal, acoustic, structural, economic and environmental indicators, benchmarked against IS 2185 (Parts 1 and 3), IS 6041 and IS 6441. Compressive strength, thermal conductivity and capillary sorptivity were determined on fifteen AAC and fifteen concrete block specimens at the DCE Darbhanga laboratory, while the remaining parameters were compiled from Indian Standard limits, manufacturer data and published literature. Although concrete blocks develop higher compressive strength (5.0–15.0 N/mm² against 3.0–4.5 N/mm² for AAC), AAC masonry reduces wall self-weight by about 70 per cent, jointing mortar consumption by 75 per cent and thermal transmittance by 76 per cent (0.78 against 3.25 W/m²K). For a ten-storey commercial building modelled in Seismic Zone III, AAC infill lowered structural steel by 8.5 per cent and concrete volume by 6.8 per cent, giving a 10.2 per cent reduction in total structural cost, while EnergyPlus simulation indicated an 18.3 per cent annual cooling energy saving. Embodied carbon is 54 per cent lower per square metre of wall. An engineering decision matrix is proposed to guide material selection.

KEYWORDS *: Autoclaved aerated concrete; Concrete masonry units; Thermal transmittance; Embodied carbon; Life-cycle cost.*

INTRODUCTION

Growing Need for Sustainable Construction Materials

The global construction industry accounts for approximately 36 per cent of the world's final energy consumption, 39 per cent of energy-related carbon dioxide (CO_2) emissions and nearly 40 per cent of virgin raw material extraction. In developing countries such as India, rapid population growth and urban migration drive the construction of millions of square metres of residential, commercial and industrial floor space every year. Masonry walling constitutes 30 to 45 per cent of the total dead load in multi-storey RCC framed structures, the proportion varying with building height, column spacing and wall-to-floor area ratio [1]. It also governs both the thermal performance of the building envelope and the quality of the indoor environment.

Traditionally, fired clay bricks and conventional concrete masonry units (CMUs), both solid and hollow, have dominated masonry envelope systems. However, the production of fired bricks consumes fertile topsoil and burns high-sulfur coal in uncontrolled kilns, causing significant atmospheric pollution and soil

degradation [2]. Although conventional concrete blocks reduce the loss of agricultural land, their production depends heavily on ordinary Portland cement (OPC), the calcination of which emits approximately 0.85 to 0.90 tonnes of CO_2 per tonne of clinker. In addition, the high density of these units increases earthquake-induced base shear and therefore demands heavier RCC foundations, columns and beams [3]. Consequently, cellular and lightweight masonry technologies that decouple environmental degradation from structural performance are attracting increasing attention from civil and structural engineers.

Existing research, however, concentrates largely on isolated parameters — thermal, mechanical or economic — and lacks a thorough, India-specific synthesis across physical, structural, economic and environmental dimensions under Indian Standard specifications [4], [5]. By offering a unified, multi-criteria comparative framework to guide material selection for framed and load-bearing masonry applications, the present study addresses that gap.

Background on Conventional Concrete Blocks

According to IS 2185 (Part 1): 2005 [6], conventional concrete masonry blocks are produced from a consolidated mixture of cement, coarse aggregate (6 to 10 mm graded gravel), fine aggregate (river sand or manufactured M-sand) and water, compacted using mechanical vibratory presses and water-cured for 14 to 28 days [7]. Three principal typologies are recognised:

1. Solid concrete blocks: dry densities of 1800 to 2200 kg/m³, compressive strengths of 4.0 to 15.0 N/mm², and a solid volume exceeding 75 per cent of the gross block volume. They are traditionally used in load-bearing external walls, retaining walls and heavy foundation masonry.
2. Hollow concrete blocks (Grades A and B, load-bearing): internal voids of 25 to 50 per cent with a minimum web thickness of 25 mm, densities of 1500 to 1800 kg/m³ and compressive strengths of 3.5 to 7.0 N/mm², offering marginally improved thermal insulation relative to solid blocks owing to enclosed air pockets.
3. Grade C non-load-bearing hollow blocks: intended strictly for internal partitions, with densities of 1000 to 1500 kg/m³ and compressive strengths exceeding 1.5 N/mm².

Despite their proven structural capacity, conventional concrete blocks exhibit significant thermal bridging ($k \approx 1.10–1.75$ W/m·K), require thick mortar bedding joints (10 to 15 mm), impose substantial structural dead load (2.8 to 4.2 kN/m² for 200 mm masonry) and entail considerable on-site labour and water curing [8].

AAC Blocks: Composition and Autoclaving Process

Autoclaved Aerated Concrete, originally patented in 1924 by the Swedish architect Axel Eriksson, is an ultra-lightweight, cellular, precast building material governed in India by IS 2185 (Part 3): 1984 (Reaffirmed 2020) [9]. It is synthesised from a finely pulverised slurry of the following constituents:

- Siliceous material: Class F pulverised fuel ash conforming to IS 3812 [10], comprising 65 to 70 per cent of the total dry solid mass, or quartz sand.
- Calcareous binders: ordinary Portland cement (OPC 53 grade, 15–20 per cent) and quicklime (CaO, 10–15 per cent).
- Sulfate setting regulator: gypsum ($CaSO_4 \cdot 2H_2O$) or anhydrite ($CaSO_4$), 2–4 per cent.
- Blowing agent: finely divided aluminium powder (0.05–0.08 per cent by weight of solids).
- Water: potable water at a controlled water-to-solid ratio of 0.55 to 0.65.

During slurry mixing and mould casting, an exothermic reaction occurs between the finely ground metallic aluminium powder and the calcium hydroxide liberated by cement and lime hydration:

$$2Al + 3Ca(OH)_2 + 6H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O + 3H_2 \text{ (gas)} \quad (1)$$

The evolution of microscopic hydrogen bubbles expands the cake volume by approximately 200 to 300 per cent, creating an evenly dispersed, closed-cell, spherical micro-porosity with pore sizes ranging from 50 µm to 1.5 mm. Following pre-curing and wire cutting to high dimensional tolerances (±1.5 mm), the green blocks are transferred to an autoclave chamber, where they undergo high-pressure hydrothermal curing at 1.2 to 1.4 MPa and 180 to 200 °C for 10 to 12 hours. This hydrothermal

mineralogy imparts exceptional dimensional stability, low drying shrinkage (below 0.04 per cent), superior fire resistance and a remarkable strength-to-density ratio [11]. The complete manufacturing sequence is shown in Fig. 1.

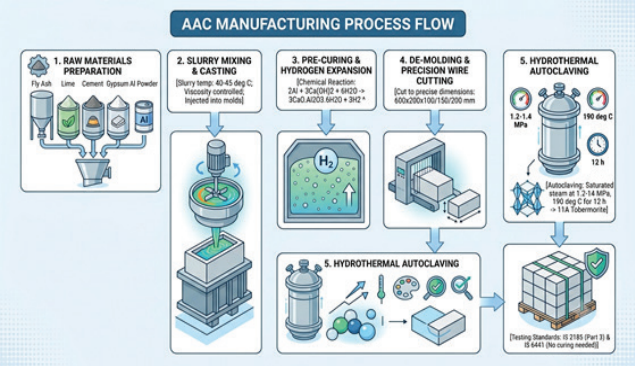


Fig. 1. AAC manufacturing process flow

Objectives and Scope of the Study

The principal objectives of this study are:

1. To determine whether AAC blocks provide advantages in strength-to-weight ratio, thermal insulation and life-cycle cost that offset their lower compressive strength for non-load-bearing infill applications in framed structures, and to identify the conditions under which each material system is optimal.
2. To compile and verify baseline performance parameters from laboratory testing, published experimental studies, manufacturer data and Indian Standard specifications.
3. To establish whether the higher unit cost of AAC blocks is offset by reductions in mortar, plastering, structural steel and HVAC operational costs over the building life cycle, and to quantify the net economic advantage for a representative 100 m^2 wall assembly.
4. To evaluate life-cycle environmental indicators, including embodied carbon (kg CO_2e/m^2), industrial waste diversion and green building certification credits under GRIHA v2019 and LEED v4.1.
5. To synthesise an engineering application decision matrix delineating structural and non-structural deployment domains.

LITERATURE REVIEW

Research comparing autoclaved cellular concrete with conventional cementitious masonry units spans four decades and may be grouped under four themes: mix development and the valorisation of secondary materials, thermal and durability performance, comparative sustainability assessment, and the structural behaviour of masonry assemblages.

Mix Development and Valorisation of Secondary Materials

A substantial body of work has examined the replacement of virgin constituents in cellular and conventional concrete units with industrial residues. Wang et al. [12] prepared non-autoclaved aerated concrete from the pyrolysis residues of oil-based drilling cuttings, confirming that silica-rich industrial wastes can substitute for primary siliceous feedstock without compromising the cellular structure. Poon et al. [13] demonstrated that recycled aggregates can be incorporated into moulded concrete bricks and blocks at moderate replacement levels with acceptable strength loss, while Tam et al. [7], reviewing recycled aggregate concrete over the period 2000 to 2017, found replacement ratios of up to 30 per cent generally tolerable for non-structural applications. These studies establish the technical basis for the high fly ash content that distinguishes AAC from conventional concrete blocks, but they address the constituent material rather than the performance of the completed wall.

Thermal and Durability Performance

Mathey and Rossiter [14], in an early and still widely cited review, concluded that AAC combines low thermal conductivity with adequate load-bearing capacity, rendering it suitable for both structural and non-structural use, although supplementary insulation may be required in severe climates. Chaipanich and Chindaprasirt [15] examined the properties and durability of AAC masonry blocks in detail, reporting that the closed-cell pore structure governs moisture transport and that prolonged saturation measurably reduces compressive strength. Namsone et al. [11] observed comparable durability behaviour in high-performance foamed concrete, confirming that the cellular pore system rather than the binder chemistry

controls freeze-thaw and moisture response. Kubilay et al. [16] provided high-resolution field measurements of wind-driven rain on low-rise buildings, quantifying the driving-rain exposure against which the capillary behaviour of porous walling units must be assessed.

Comparative Sustainability Assessment

Gautam and Saxena [17] compared AAC blocks with fired red bricks and reported significant reductions in embodied energy and dead load, although the analysis was confined to material-level indicators. Kamal [8] extended the assessment to the sustainability potential of AAC in building envelopes, and Dey et al. [4], in a recent state-of-the-art review, consolidated four decades of AAC research and identified life-cycle assessment and region-specific cost modelling as the principal outstanding gaps. Azhar et al. [5] addressed part of that gap through a climate-specific meta-analysis of global AAC performance, showing that decarbonisation outcomes vary substantially with climate zone and grid carbon intensity. Oladiran and Simeon [18] and Rogers Simeon and Oladiran [19] surveyed awareness, barriers and improvement strategies for AAC adoption in Nigeria and South Africa, concluding that limited comparative performance data, rather than technical inadequacy, constrains uptake in developing economies.

Structural Behaviour of Masonry Assemblages

Cheng et al. [2] compared the in-plane shear performance of masonry walls strengthened with different fibre-reinforced materials, establishing reference shear capacities for unreinforced and strengthened panels. Sreekeshava et al. [20] investigated the strengthening of masonry wallettes using a polyester geo-fabric reinforced cementitious matrix, and Chitra and Mohan [3] examined the ductility behaviour of reinforced concrete beam-column joints, which governs the seismic demand transmitted to and by infill masonry. Collectively, these studies indicate that infill mass and stiffness, rather than unit compressive strength alone, dominate the seismic response of framed structures.

Research Gap

The literature consistently confirms the thermal, environmental and dead-load advantages of AAC, yet the evidence remains fragmented. Material-level studies do not extend to wall assemblies; thermal studies rarely quantify the structural or foundation consequences of reduced mass; and sustainability assessments seldom adopt Indian Standard specifications or Indian cost structures. No published study simultaneously quantifies mechanical, thermal, structural, economic and cradle-to-gate environmental outcomes for AAC and conventional concrete blocks under IS 2185, IS 6041 and IS 6441. The present work addresses that gap through an integrated, multi-criteria comparison supported by laboratory testing, structural modelling and life-cycle costing.

MATERIALS AND METHODS

Raw Material Composition and Manufacturing Parameters

Compressive strength, thermal conductivity and capillary sorptivity were determined by original laboratory testing on fifteen AAC block samples and fifteen solid concrete block samples at DCE Darbhanga laboratory operating in accordance with ISO/IEC 17025 [21]. Data for water absorption, drying shrinkage, fire resistance and acoustic transmission were compiled from IS 2185 specification limits, manufacturer technical datasheets and peer-reviewed studies, because these parameters are standardised and exhibit little inter-manufacturer variability.

The AAC samples were manufactured in June 2026 and randomly selected from a production batch of 5,000 blocks to ensure representativeness. The sample size was fixed at fifteen against the minimum of ten specimens required by IS 6441 (Part 5) [22], so that variability could also be analysed statistically. Specimens were cured for 28 days and conditioned to a moisture content of 10 ± 2 per cent as required by IS 2185 (Part 3) before testing. Solid concrete block samples were manufactured in June 2026 and water-cured for 28 days in accordance with IS 2185 (Part 1), and ten hollow concrete block samples were obtained from a comparable source. All samples conformed to to the nominal dimensions given in Table 1, with dimensional tolerances verified as per IS 2185 [6]. The comparative composition and manufacturing parameters of the three unit types are summarised in Table 1.

Table 1. Raw material composition and manufacturing parameters of the masonry units

Parameter / Constituent	AAC Block	Solid Concrete Block (SCB)	Hollow Concrete Block (HCB, Gr A)
Primary binder	OPC 53 grade (15–20%) + lime (10–15%)	OPC 43/53 grade (10–14%)	OPC 43/53 grade (10–14%)
Pozzolan / aggregate	Class F fly ash (65–70%) as per IS 3812	Graded river/M-sand + 6–10 mm crushed stone	Graded sand + 6–10 mm crushed gravel
Aerating agent	Aluminium powder (0.05–0.08%)	None (compacted dense concrete)	None (moulded with internal cores)
Sulfate source	Gypsum / anhydrite (2–4%)	None / gypsum in cement	None / gypsum in cement
Manufacturing method	Chemical expansion + wire cutting + autoclaving	Heavy vibro-compaction, hydraulic press	Heavy vibro-compaction with core mould
Curing regime	Hydrothermal steam (1.2–1.4 MPa, 190 °C, 12 h)	Atmospheric water ponding/ spray (14–28 days)	Water spray / steam curing (14–28 days)
Standard dimensions	600 × 200 × (100/150/200) mm	400 × 200 × (150/200) mm	400 × 200 × (150/200) mm
Dimensional tolerance	±1.5 mm length/height, ±1.0 mm width	±3.0 to ±5.0 mm	±3.0 to ±5.0 mm

Testing Protocols and Governing Standards

The selected protocols address the multi-criteria research question: compressive strength verifies IS 2185 compliance and enables calculation of the strength-to-density ratio; thermal conductivity quantifies envelope energy performance; water absorption and capillary sorptivity assess durability under driving rain; and drying shrinkage evaluates crack risk in thin-bed jointed masonry [15]. Taken together, these parameters determine suitability for framed infill applications in tropical and composite climates. Testing followed IS 6441 (Parts 1 to 9): 1972 and IS 2185 (Part 1): 2005, with the international AAC specification ASTM C1693 [23] consulted for cross-reference.

- Oven-dry density (IS 6441, Part 1): specimens (150 × 150 × 150 mm prisms for AAC; full-size units for concrete blocks) were conditioned in a ventilated oven at 105 ± 5 °C until constant mass was achieved.
- Compressive strength (IS 6441, Part 5 and IS 2185, Part 1): measured on a compression testing machine calibrated to 2000 kN. Specimens were loaded perpendicular to the direction of rise at a constant stress rate of 0.05 to 0.10 N/mm²/s until ultimate crushing. Moisture content of AAC specimens was controlled at 10 ± 2 per cent by weight at the time of testing, as required by IS 2185 (Part 3).
- Water absorption and moisture movement: a 24-hour cold water immersion test was carried out to measure total volumetric absorption, and capillary sorptivity was assessed concurrently in accordance with ASTM C1585 [24].
- Thermal conductivity (k-value): determined using a guarded hot plate apparatus conforming to ASTM C177 [25] and IS 3792 [26] under steady-state heat flux at a mean specimen temperature of 25 °C.
- Drying shrinkage (IS 6441, Part 2): measured by recording the initial reference length of fully saturated specimens with an extensometer dial gauge and tracking longitudinal contraction to a constant dry state.

COMPARATIVE ANALYSIS

Table 2 presents the verified experimental data alongside the standardised Indian Standard specification limits for the three masonry types.

Table 2. Comparative performance of AAC, solid concrete and hollow concrete blocks

Property / Parameter	AAC Blocks	Solid Concrete Blocks (SCB)	Hollow Concrete Blocks (HCB, Gr A)
Governing Indian code	IS 2185 (Part 3): 1984	IS 2185 (Part 1): 2005	IS 2185 (Part 1): 2005
Oven-dry density	550–650 kg/m³	1800–2200 kg/m³	1500–1800 kg/m³
Compressive strength	3.0–4.5 N/mm²	5.0–15.0 N/ mm²	3.5–7.0 N/mm²
Thermal conductivity, k	0.16–0.20 W/m·K	1.10–1.75 W/m·K	0.85–1.15 W/m·K

U-value (200 mm wall)	0.78 W/m²·K	3.25 W/m²·K	2.62 W/m²·K
Sound insulation (STC)	40–44 dB	48–50 dB	44–46 dB
Water absorption (24 h)	25–35% by dry mass	6–10% by dry mass	8–12% by dry mass
Capillary sorptivity	0.82 kg/ m²·min$^{0.5}$	1.45 kg/ m²·min$^{0.5}$	1.60 kg/ m²·min$^{0.5}$
Unit weight per block	≈13.8 kg (600 × 200 × 200 mm)	≈32.8 kg (400 × 200 × 200 mm)	≈22.7 kg (400 × 200 × 200 mm)
Wall self-weight (200 mm)	1.15–1.25 kN/ m²	3.80–4.20 kN/ m²	2.80–3.20 kN/ m²
Fire resistance rating	4.0 h (150–200 mm)	2.0–3.0 h	1.5–2.0 h
Dimensional tolerance	±1.5 mm	±3.0 to ±5.0 mm	±3.0 to ±5.0 mm
Mortar type / bed thickness	Thin-bed polymer adhesive (2–3 mm)	Cement–sand 1:6 (10–15 mm)	Cement–sand 1:6 (10–15 mm)
Laying speed (mason team)	18–22 m²/day	8–10 m²/day	10–12 m²/day
Plastering requirement	3–4 mm skim coat / gypsum plaster	12–15 mm internal + 18 mm external	12–15 mm internal + 18 mm external
On-site water curing	Nil	7–14 days	7–14 days
Fly ash utilisation	65–70% by dry mass	0–15%	0–15%
Embodied carbon (200 mm wall)	29–35 kg CO_2e/m²	64–76 kg CO_2e/m²	48–58 kg CO_2e/m²

Detailed Analysis of Key Parameters

Density and Self-Weight Reduction

The dry density of AAC blocks (550 to 650 kg/m³) is approximately one-third to one-fourth that of solid concrete blocks (1800 to 2200 kg/m³) and less than half that of hollow concrete blocks (1500 to 1800 kg/m³). For a 200 mm wall, AAC reduces masonry self-weight from about 4.0 kN/m² to about 1.2 kN/m², a reduction of roughly 70 per cent. In the ten-storey building analysed under Structural Superstructure Savings, this dead load reduction produced a 22.4 per cent reduction in seismic base shear when modelled in ETABS as per IS 1893: 2016 [27], which in turn permitted reductions in column and foundation dimensions. The magnitude of these effects is site- and design-specific and will vary with building height, column spacing and soil conditions.

Compressive Strength and Infill Performance

While solid concrete blocks provide the higher raw compressive strengths (5.0 to 15.0 N/mm²) required for unreinforced load-bearing walls up to G+3, framed high-rise towers require only non-load-bearing infill. As per IS 6041 [28], IS 1905 [29] and NBC 2016, a compressive strength of 3.0 N/mm² is adequate for infill masonry. AAC blocks, at 3.0 to 4.5 N/mm², comfortably meet this threshold while satisfying wind and impact criteria.

Thermal Insulation and HVAC Savings

The thermal conductivity of AAC (k ≈ 0.18 W/m·K) is roughly one-eighth that of solid concrete (k ≈ 1.45 W/m·K). The resulting wall thermal transmittance is 0.78 W/m²·K for AAC against 3.25 W/m²·K for solid concrete. To quantify the operational benefit, a ten-storey office building (12,000 m² built-up area, 40 per cent window-to-wall ratio, composite climate as per ECBC [30], HVAC COP of 3.2, occupancy 08:00 to 18:00) was modelled in EnergyPlus 9.5. Replacing 200 mm solid concrete walls with AAC walls reduced annual cooling energy by 18.3 per cent, from 142 kWh/ m² to 116 kWh/m². Varying the window-to-wall ratio and roof insulation level across the range encountered in Indian commercial practice gives savings of 12 per cent (30 per cent WWR with high roof insulation) to 24 per cent (50 per cent WWR with low roof insulation). In many applications, AAC walls satisfy ECBC envelope requirements without additional external insulation.

Water Absorption and Capillary Sorptivity

Total immersion absorption is high (25 to 35 per cent) because of open-surface macropores, but it is capillary sorptivity that governs performance under ambient driving rain. The closed spherical internal pores of AAC give a very low capillary sorptivity (0.82 kg/m²·min$^{0.5}$ against 1.45 to 1.60 kg/m²·min$^{0.5}$ for concrete blocks), which, when detailed with breathable external coatings, effectively protects against dampness and efflorescence under the driving-rain exposures measured for low-rise buildings by Kubilay et al. [16].

Fire Resistance

AAC carries a certified four-hour fire endurance rating at 150 to 200 mm thickness and is non-combustible (Euroclass A1) under IS 2185 (Part 3). Dense concrete blocks achieve two to three hours but are prone to explosive surface spalling under abrupt thermal shock.

Dimensional Precision and Mortar Usage

Wire-cut AAC blocks with a tolerance of ±1.5 mm permit thin-bed polymer adhesive joints. This eliminates the requirement for ten days of on-site water curing, reduces mortar consumption by 75 to 80 per cent, and allows direct application of a 3 to 4 mm skim coat or gypsum plaster in place of thick sand–cement plaster.

COST ANALYSIS

An itemised cost analysis was carried out for 100 m² of completed masonry walling of 200 mm nominal thickness at prevailing commercial construction rates in the Indian market, converted at ₹83 per US dollar. The results are presented in Table 3.

Table 3. Itemised direct cost comparison for 100 m² of finished 200 mm masonry wall

Cost Component	AAC Blocks (thin-bed adhesive)	Solid Concrete Blocks (1:6 mortar)
1. Block units (base material)	₹68,000 (US$819) [860 blocks @ ₹3,300/m³]	₹55,000 (US$663) [1,312 blocks @ ₹42/block]
2. Jointing mortar / adhesive	₹9,600 (US$116) [36 bags polymer adhesive @ ₹265]	₹18,500 (US$223) [28 bags cement + 5.2 t sand]
3. Masonry labour and laying	₹18,000 (US$217) [5 days @ 20 m²/day]	₹32,000 (US$386) [11 days @ 9 m²/day]
4. Wall plastering (int. + ext.)	₹28,000 (US$337) [thin skim coat + rendering]	₹58,000 (US$699) [15 mm internal + 18 mm external]
5. Water curing and cleaning	₹1,500 (US$18) [no curing required]	₹8,000 (US$96) [14 days continuous curing]
Total direct walling cost	₹1,25,100 (US$1,507)	₹1,71,500 (US$2,066)
Direct saving with AAC	₹46,400 per 100 m² (27.06%)	—

Structural Superstructure Savings

A typical ten-storey commercial office building was modelled in ETABS v19 with the following parameters: plan dimensions 40 m × 30 m (1,200 m² per floor), floor-to-floor height 3.5 m, regular column grid of 6 m × 6 m (7 × 6 bays), Fe500 reinforcement, slab thickness 150 mm, live load 3 kN/m² for office occupancy as per IS 875 (Part 2) [31], floor finish 1.5 kN/m², Seismic Zone III, medium soil (Type II, Z = 0.16) as per IS 1893: 2016, importance factor 1.0, response reduction factor R = 5, and response spectrum analysis as per IS 1893 Clause 6.4.

The baseline configuration was selected to represent typical urban commercial construction in composite-climate cities such as Delhi, Jaipur and Pune, in line with NBC 2016 guidance, a 6 m grid being standard for office buildings with a 3.5 m floor-to-floor height. Zone III denotes moderate seismicity and covers a large share of India's urban population. Two infill scenarios were modelled: (i) 200 mm solid concrete block masonry (unit weight 20 kN/m³, wall load 4.0 kN/m per floor height) and (ii) 200 mm AAC block masonry (unit weight 6.5 kN/m³, wall load 1.3 kN/m per floor height). Load combinations were taken from Table 18 of IS 456: 2000 [32]. Preliminary column sizes ranged from 450 × 450 mm at ground floor to 300 × 300 mm at the top floor, with beams of 300 × 450 mm. The principal outcomes were as follows.

- Dead load: the AAC scheme reduces total building dead weight by 3,200 tonnes.
- Reinforcement steel: column and beam bending moments and axial forces fall by 12 to 16 per cent, giving an 8.5 per cent reduction in total structural steel across the frame (approximately 38 tonnes saved at ₹65,000 per tonne, a saving of ₹24,70,000).
- Concrete volume: reduced column and footing cross-sections give a 6.8 per cent reduction in M30/M40 concrete volume (approximately 210 m³ saved at ₹5,200 per m³, a saving of ₹10,92,000).
- Foundations: for weak soils, pile group quantities and depths reduce by 14 to 18 per cent, worth approximately ₹18,00,000 for this building.

Weighting the material savings by their cost shares —

structural steel at 55 per cent of superstructure cost with 8.5 per cent savings, RCC concrete at 35 per cent with 6.8 per cent savings, and formwork and labour at 10 per cent unchanged — gives a weighted superstructure saving of 7.1 per cent. Including the foundation savings, the total structural cost reduction is 10.2 per cent. Repeating the analysis across Seismic Zones II to V and across soft, medium and hard soil conditions gives structural savings in the range of 8 to 16 per cent, confirming that outcomes are site-specific and depend on seismic demand and foundation conditions. This spread is consistent with the climate- and context-dependence of AAC performance reported by Azhar et al. [5].

Operational Life-Cycle Costing and HVAC Energy Amortisation

Owing to an envelope U-value of 0.78 W/m²·K for AAC against 3.25 W/m²·K for solid concrete blocks, the peak chiller cooling load for typical conditioned office space falls by approximately 18 to 22 tonnes of refrigeration per 1,000 m² of external wall, saving about ₹9,00,000 per 1,000 m² of façade in initial HVAC sizing. Expressed per unit of wall area, the annual cooling energy reduction averages 16.5 kWh per m² of external wall, equivalent to the 26 kWh per m² of floor area reported under Thermal Insulation and HVAC Savings for the same building.

A 50-year operational horizon was evaluated assuming a real discount rate of 6 per cent per annum, consistent with Indian public infrastructure appraisal practice; energy price escalation of 3 per cent per annum, based on 2010–2020 average commercial electricity tariff trends in composite-climate cities; maintenance at 0.5 per cent of initial wall capital per annum; and HVAC equipment replacement in years 15 and 30 at 60 per cent of initial HVAC capital cost. Under these assumptions, the present-value energy saving of ₹1,845 per m² of AAC wall over 50 years exceeds the initial material cost premium of ₹540 per m² by a factor of 3.4. Actual savings will vary with energy tariffs, climate and building operation practices.

SUSTAINABILITY AND ENVIRONMENTAL IMPACT

Industrial Byproduct Utilisation

Thermal coal-fired power stations generate millions of tonnes of pulverised fuel ash annually, which occupies valuable agricultural land in containment slurry ponds and poses severe groundwater leaching hazards [17]. AAC blocks contain 65 to 70 per cent fly ash by dry solid weight. A single production facility generating 300,000 m³ of AAC blocks per year consumes approximately 135,000 tonnes of fly ash, directly repurposing industrial waste into durable civil infrastructure. Conventional concrete blocks, by contrast, typically contain 0 to 15 per cent fly ash and rely primarily on virgin-mined aggregates.

Embodied Energy and Carbon Footprint

Table 4. Cradle-to-gate life-cycle inventory of the three masonry unit types

Life-Cycle Metric	AAC	Solid Concrete Block (SCB)	Hollow Concrete Block (HCB)
Embodied energy (MJ/m³)	1,050–1,250	1,800–2,200	1,400–1,650
Embodied energy (MJ/m² of 200 mm wall)	210–250	360–440	280–330
Embodied carbon (kg CO_2e/m^3)	145–175	320–380	240–290
Embodied carbon (kg CO_2e/m^2 of wall)	29–35	64–76	48–58
Virgin aggregate consumption (kg/m²)	0	340	220
Potable water for curing (L/m²)	0 (closed factory loop)	65–80	50–65

A cradle-to-gate life cycle assessment was carried out as per ISO 14044 [33], with the system boundary extending from raw material extraction to the factory gate, a functional unit of 1 m² of finished 200 mm wall including jointing mortar or adhesive and 12 mm plaster, and GWP_{100} characterisation factors taken from Ecoinvent 3.8 [34]. On this basis, AAC masonry (32 kg CO_2e/m^2) exhibits 54 per cent lower embodied carbon than solid concrete masonry (70 kg CO_2e/m^2)

under baseline assumptions of the Indian electricity grid mix, a 100 km transport distance and OPC 53 cement. Sensitivity analysis shows the reduction to be robust, ranging from 48 to 62 per cent depending on grid carbon intensity (0.82 to 0.95 kg CO_2e/kWh) and transport distance (50 to 200 km).

The reduction is attributable to three factors: the substitution of uncalcined fly ash (65 to 70 per cent by weight) for virgin cement and aggregate; a 65 per cent decrease in mass per m² of wall; and a 75 per cent decrease in jointing mortar consumption under thin-bed adhesive. The comparison assumes equivalent wall area and does not account for variations in transport distance, on-site construction energy or end-of-life recycling potential, all of which may differ with project location.

Green Building Certification Credits

- GRIHA v2019: contributes directly to Criterion 6 (soil preservation), Criterion 9 (sustainable building materials, above 60 per cent fly ash), Criterion 13 (ECBC envelope optimisation) and Criterion 21 (zero on-site curing water).
- LEED v4.1: eligible for the EQ credit (indoor thermal and acoustic comfort), the EA credit (optimise energy performance under ASHRAE 90.1) and the MR credit (recycled content from pre-consumer industrial waste).

RESULTS AND DISCUSSION

Synthesising the comparative parameters of Tables 2 to 4 yields three principal findings.

1. Structural efficiency. Taking mid-range values, AAC exhibits a compressive strength-to-density ratio of approximately 6.3 × 10^{-3} N·m³/(mm²·kg) (3.75 N/mm² at 600 kg/m³) against 5.0 × 10^{-3} for solid concrete blocks (10.0 N/mm² at 2000 kg/m³). AAC is therefore substantially more efficient for non-load-bearing framed infill masonry, where structural economy is governed by dead load minimisation rather than by unit strength.
2. Thermal and acoustic synergy. Whereas solid concrete blocks rely purely on inertial thermal mass and the acoustic mass law, AAC blocks provide an integrated thermal insulating envelope without additional synthetic polymer insulation layers, while retaining an STC rating adequate for internal partitions.
3. Moisture mechanics. Although AAC exhibits a high saturation capacity under hydraulic immersion testing, its low capillary sorptivity under ambient driving rain demonstrates that moisture penetration concerns are largely alleviated when correct construction practice is observed, namely damp-proof course installation, starter courses and breathable coatings.

These findings are consolidated in the engineering application decision matrix of Fig. 2, which maps each material system to the building typologies and exposure conditions for which it is best suited.

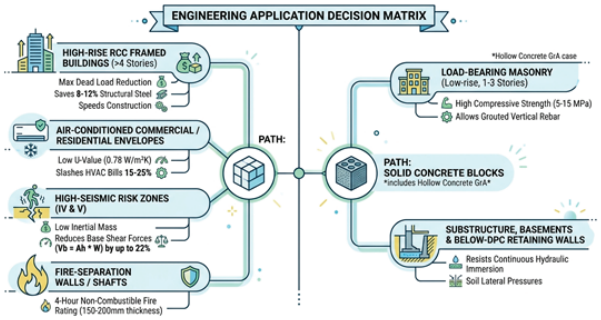


Fig. 2. Engineering application decision matrix for AAC and conventional concrete block masonry

CONCLUSIONS AND RECOMMENDATIONS

1. Physical and mechanical performance. AAC blocks have an oven-dry density of 550 to 650 kg/m³, approximately 70 per cent lighter than solid concrete blocks, reducing 200 mm wall self-weight from about 4.0 kN/m² to about 1.2 kN/m². Although conventional concrete blocks provide higher raw compressive strength (5.0 to 15.0 N/mm² against 3.0 to 4.5 N/mm² for AAC), AAC meets and exceeds the minimum requirements of IS 2185 (Part 3) for framed infill.
2. Thermal and energy performance. A thermal conductivity of 0.18 W/m·K lowers wall thermal transmittance to 0.78 W/m²·K, a 76 per cent reduction relative to uninsulated concrete blockwork, cutting annual cooling energy demand by 18.3 per cent in the modelled building and by

12 to 24 per cent across the range of envelope configurations examined.

3. Economic life-cycle viability. Despite a 15 to 25 per cent higher unit purchase price, AAC masonry achieves an approximately 27 per cent direct cost saving per 100 m² of finished wall (Table 3) under the assumed cost structure, driven by a 75 per cent reduction in jointing mortar consumption, elimination of thick sand–cement plastering and faster installation. In multi-storey framed buildings, the accompanying dead load reduction yields an 8.5 per cent saving in structural reinforcement steel and a 6.8 per cent saving in concrete volume, giving a 10.2 per cent reduction in total structural cost once foundation savings are included. These savings are sensitive to regional variation in labour and material costs, and site-specific analysis remains necessary.

4. Environmental decarbonisation. AAC blocks reduce embodied carbon by 54 per cent per square metre of wall assembly (32 kg CO_2e/m^2 against 70 kg CO_2e/m^2), utilise 65 to 70 per cent industrial fly ash by weight, and divert thermal power waste from landfill.

Engineering recommendations

- For high-rise commercial and residential framed towers above G+3, AAC blocks with 2 to 3 mm thin-bed polymer adhesive should be adopted as the standard infill material in order to optimise structural dead load reduction, seismic shear mitigation and operational energy efficiency.
- For low-rise load-bearing structures below G+2 without RCC frames, high-strength solid or grouted hollow concrete blocks conforming to IS 2185 (Part 1) remain preferable, as they carry direct axial gravity and shear loads.
- For substructure, retaining and wet utility masonry, the high porosity and capillary structure of AAC may cause freeze–thaw damage in cold climates where moisture is trapped, efflorescence and surface degradation where rising damp is uncontrolled, and a measurable loss of compressive strength under prolonged saturation [15]. AAC may nevertheless be used in above-ground wet areas such as bathrooms and kitchens provided that a continuous damp-proof course is installed at plinth level, wet surfaces are treated with cementitious waterproofing or waterproof tile adhesive, and breathable silicate-based or acrylic external coatings are applied to allow moisture vapour to escape. Without these precautions, mould growth, plaster delamination and reduced service life may follow. Detailed construction guidance is given in Clause 6 of IS 6041: 1985.

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REFERENCES

1. Bureau of Indian Standards (2016), National Building Code of India 2016, Volumes 1 and 2, BIS, New Delhi.
2. S. Cheng, S. Yin and L. Jing (2020), Comparative Experimental Analysis on the In-Plane Shear Performance of Brick Masonry Walls Strengthened with Different Fibre Reinforced Materials, Construction and Building Materials, Vol. 259, 120387.
3. R. Chitra and S. J. Mohan (2021), Reinforced Concrete Beam-Column Joint's Ductility Behaviour, Materials Today: Proceedings, Vol. 51, pp. 1069-1073.
4. P. Dey, A. Paul, M. Dhar, D. Das and R. Saha (2025), State-of-the-Art Review and Future Prospects of Autoclaved Aerated Concrete for Building a Sustainable Tomorrow, Environment, Development and Sustainability, pp. 1-42.
5. J. Azhar, S. Aydin and M. S. Zami (2025), Decarbonizing Buildings with Autoclaved Aerated Concrete (AAC): Climate-Specific Meta-Analysis of Global Performance, Journal of Asian Architecture and Building Engineering.
6. Bureau of Indian Standards (2005, Reaffirmed 2021), IS 2185 (Part 1): Concrete Masonry Units - Specification - Part 1: Hollow and Solid Concrete Blocks, BIS, New Delhi.
7. V. W. Y. Tam, M. Soomro and A. C. J. Evangelista (2018), A Review of Recycled Aggregate in Concrete Applications (2000-2017), Construction and Building Materials, Vol. 172, pp. 272-292.
8. M. A. Kamal (2020), Analysis of Autoclaved Aerated Concrete (AAC) Blocks with Reference to Its Potential and Sustainability, Journal of Building Materials and Structures, Vol. 7, No. 1, pp. 76-86.

9. Bureau of Indian Standards (1984, Reaffirmed 2020), IS 2185 (Part 3): Specification for Concrete Masonry Units - Part 3: Autoclaved Cellular (Aerated) Concrete Blocks, BIS, New Delhi.

10. Bureau of Indian Standards (2013), IS 3812 (Part 1): Pulverized Fuel Ash - Specification - Part 1: For Use as Pozzolana in Cement, Cement Mortar and Concrete, BIS, New Delhi.

11. E. Namsone, G. Sahmenko and A. Korjakins (2017), Durability Properties of High Performance Foamed Concrete, Procedia Engineering, Vol. 172, pp. 760-767.

12. C. Wang, X. Lin, D. Wang, M. He and S. Zhang (2018), Utilization of Oil-Based Drilling Cuttings Pyrolysis Residues of Shale Gas for the Preparation of Non-Autoclaved Aerated Concrete, Construction and Building Materials, Vol. 162, pp. 359-368.

13. C. S. Poon, S. C. Kou and L. Lam (2002), Use of Recycled Aggregates in Moulded Concrete Bricks and Blocks, Construction and Building Materials, Vol. 16, No. 5, pp. 281-289.

14. R. G. Mathey and W. J. Rossiter (1990), A Review of Autoclaved Aerated Concrete Products, NISTIR 4331, National Institute of Standards and Technology, Gaithersburg, MD.

15. A. Chaipanich and P. Chindaprasirt (2015), The Properties and Durability of Autoclaved Aerated Concrete Masonry Blocks, in Eco-Efficient Masonry Bricks and Blocks: Design, Properties and Durability, Woodhead Publishing, Cambridge, pp. 215-230.

16. A. Kubilay, D. Derome, B. Blocken and J. Carmeliet (2014), High-Resolution Field Measurements of Wind-Driven Rain on an Array of Low-Rise Cubic Buildings, Building and Environment, Vol. 78, pp. 1-13.

17. P. Gautam and N. Saxena (2013), Comparison of Autoclaved Aerated Concrete Blocks with Red Bricks, International Journal of Engineering Research and Technology, Vol. 2, No. 10.

18. O. Oladiran and D. R. Simeon (2023), Consciousness and Prospects of Autoclaved Aerated Concrete (AAC) Blocks for Wall Construction: Comparative Study of Nigeria and South Africa, Journal of Construction Business and Management, Vol. 6, No. 2, pp. 1-10.

19. D. Rogers Simeon and O. Joseph Oladiran (2023), Barriers and Improvement Strategies for the Use of Autoclaved Aerated Concrete Blocks, Journal of Contemporary Research in the Built Environment, Vol. 7, No. 1.

20. K. S. Sreekeshava, A. S. Arunkumar and B. V. Ravishankar (2021), Strengthening of Brick Masonry Wallette by Polyester Geo-Fabric Reinforced Cementitious Matrix, Materials Today: Proceedings, Vol. 46, pp. 2392-2399.

21. International Organization for Standardization (2017), ISO/IEC 17025: General Requirements for the Competence of Testing and Calibration Laboratories, ISO, Geneva.

22. Bureau of Indian Standards (1972, Reaffirmed 2017), IS 6441 (Parts 1 to 9): Methods of Test for Autoclaved Cellular Concrete Products, BIS, New Delhi.

23. ASTM International (2020), ASTM C1693-11(2020): Standard Specification for Autoclaved Aerated Concrete (AAC), ASTM International, West Conshohocken, PA.

24. ASTM International (2020), ASTM C1585: Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes, ASTM International, West Conshohocken, PA.

25. ASTM International (2019), ASTM C177: Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus, ASTM International, West Conshohocken, PA.

26. Bureau of Indian Standards (1978, Reaffirmed 2021), IS 3792: Guide for Heat Insulation of Non-Industrial Buildings, BIS, New Delhi.

27. Bureau of Indian Standards (2016), IS 1893 (Part 1): Criteria for Earthquake Resistant Design of Structures - Part 1: General Provisions and Buildings, BIS, New Delhi.

28. Bureau of Indian Standards (1985, Reaffirmed 2020), IS 6041: Code of Practice for Construction of Autoclaved Cellular Concrete Block Masonry, BIS, New Delhi.

29. Bureau of Indian Standards (1987, Reaffirmed 2017), IS 1905: Code of Practice for Structural Use of Unreinforced Masonry, BIS, New Delhi.

30. Bureau of Energy Efficiency (2017), Energy Conservation Building Code 2017, Ministry of Power, Government of India, New Delhi.

31. Bureau of Indian Standards (1987, Reaffirmed 2018), IS 875 (Part 2): Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures - Part 2: Imposed Loads, BIS, New Delhi.

32. Bureau of Indian Standards (2000, Reaffirmed 2021), IS 456: Plain and Reinforced Concrete - Code of Practice, BIS, New Delhi.

33. International Organization for Standardization (2006), ISO 14044: Environmental Management - Life Cycle Assessment - Requirements and Guidelines, ISO, Geneva.

34. Ecoinvent Association (2021), Ecoinvent Database Version 3.8, Zurich, Switzerland.