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Greening Hyderabad's Built Environment Through Low-Carbon Construction Materials: Problems, Solutions and an Implementation Framework for Public Projects, Corridors and High-Rise Housing

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Abstract

Hyderabad is expanding rapidly through large public programmes and high-rise development, yet most green-city initiatives address land, water and energy and give limited attention to the construction materials that determine a structure's embodied carbon, durability and waste footprint. This paper examines how conventional concrete-and-brick construction can be made substantially greener without abandoning it. Through a desk-based review of Indian standards, published literature, State policy announcements and project data, nine material-related problems affecting Greater Hyderabad Municipal Corporation (GHMC) works, the Outer Ring Road (ORR) corridor, HITEC City and tall residential buildings are identified, and a specific solution is proposed for each. The solutions cover cement and concrete mix strategies, recycled aggregates from construction and demolition (C&D) waste, lightweight walling, cool and permeable surfaces, durability measures, road-corridor materials, procurement and Schedule of Rates reform, incentives and verification, and supply-chain and skills support. An illustrative calculation shows that, under stated assumptions, replacing 30% of the cement in a concrete mix with fly ash lowers its cement-related emissions by about 29%, and replacing 50% with ground granulated blast-furnace slag (GGBS) lowers them by about 46%. The paper proposes a model specification, pilot projects with defined performance indicators, and a 36-month roadmap.

Keywords: *Embodied carbon, blended cement, fly ash, GGBS, C&D waste, AAC blocks, green procurement, high-rise buildings, Hyderabad, self-healing materials.*

1. Introduction

Hyderabad is building at a scale few Indian cities match. The State is pursuing the Musi rejuvenation

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programme, a proposed net-zero Bharat Future City across about 30,000 acres, and extensive road and transit works, while the skyline already includes more than 200 buildings taller than 100 metres [1], [2]. Public discussion has focused on rivers, lakes, trees and energy, yet cement, steel, bricks and aggregates drive a structure's lifetime carbon, durability and construction debris. Tall buildings and large infrastructure will keep using concrete, steel and masonry, so the question is how to build with better versions of them.

1.1.Research Questions and Contributions

This paper asks: (i) which material-related problems most limit the greenness of Hyderabad's public projects, corridors and high-rise buildings; (ii) what standards-compliant solutions exist for each; and (iii) how Government can implement and verify them at scale. It pairs nine problems with solutions (Section 5) and offers a model specification, an illustrative calculation, a pilot design and a roadmap (Sections 7 to 9).

2. Literature Review

2.1.Cement, Clinker and Embodied Carbon

Cement production is a major source of industrial carbon dioxide [3]. Most emissions arise in clinker manufacture, where limestone releases CO_2 in addition to the fuel burned [3], [4]. Because calcination is chemically unavoidable, the main route to lower emissions is using less clinker per unit of concrete: blending cement with supplementary cementitious materials (SCMs) such as fly ash and ground granulated blast-furnace slag, using calcined clay with limestone, and designing structures that need less material [4], [5]. Limestone calcined clay cement (LC3) can replace a large share of clinker at comparable strength [5], [6], has been recognised by the Bureau of Indian Standards (2024) and is produced commercially in India [16].

2.2.Construction and Demolition Waste

India's C&D Waste Management Rules, 2016 require local bodies to manage debris and encourage recycled products [7]. Hyderabad has two GHMC–Ramky Enviro recycling plants (Jeedimetla and Fathullaguda), each rated at up to 500 tonnes per day, but their products are mainly used for footpaths and road sub-base [8]. India recovers only about 1% of its C&D waste [9].

2.3.Walling,Envelope and Urban Heat

Lightweight walling such as autoclaved aerated concrete (AAC) and fly-ash products reduces dead load and improves thermal performance, while reflective roofs and shaded, vegetated or permeable surfaces reduce cooling energy and local heat [10]. National frameworks include ECBC, Eco-Niwas Samhita and the IGBC and GRIHA rating systems [11].

2.4.Self-Healing and Lime-Based Materials

Bacteria-based self-healing concrete uses dormant Bacillus spores and a calcium-based nutrient that seal fine cracks (below about 0.5 mm) with calcium carbonate when water enters [12]. It suits unfired mortars, renders and concrete, and remains at research and pilot stage, as do lime-rich materials that heal autogenously.

2.5.Telangana Policy Context

Telangana reportedly hosts over 1,245 IGBC-registered projects covering about 1.67 billion sq ft [13]. The IT & Industries Minister has urged a shift from conventional RCC to composite and steel systems, citing savings of about 40% in construction time and 30% in weight [1]. The State plans to implement ECBC in urban local bodies [14], while a 2018 report noted that Telangana had not yet incentivised IGBC-rated buildings and that CII had proposed a 20% cut in permit and impact fees [15].

3. Methodology

This is a conceptual, policy-oriented paper based on desk research. It reviewed Indian Standards, IRC guidelines and national rules on materials; literature on cement, SCMs, recycled aggregates and self-healing materials; and State announcements, project data and industry reports on Hyderabad up to October 2026. A solution was derived for each problem from existing standards and proven practice. The scope covers GHMC works, the ORR corridor, HITEC City, tall apartments, affordable housing, and the Musi and Future City projects. All values are indicative and to be validated by the pilots in Section 9. As shown in Table 1 Material-related problems affecting green development in Hyderabad.

4. Problems Identified

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Table 1 Material-related problems affecting green development in Hyderabad

ID	Problem	Why it matters
P1	High embodied carbon in cement-heavy concrete	Tall buildings and infrastructure use large volumes of OPC-based concrete; clinker drives most emissions.
P2	Low reuse of C&D waste	Recycling capacity exists, but products are confined to non-structural uses and very little debris is recovered.
P3	Heavy, resource-intensive walling	Burnt-clay masonry adds dead load to tall frames and consumes topsoil and fuel.
P4	Urban heat and high cooling demand	Glass-heavy towers, dark roofs and impervious paving raise cooling energy and block groundwater recharge.
P5	Durability and maintenance burden	Cracking, water ingress and aggressive soils shorten service life and raise repair costs.
P6	Resource-heavy road and corridor works	Roads and embankments rely on virgin soil, quarried stone and fresh bitumen.
P7	Procurement and specification barriers	Green materials are often missing from the Schedule of Rates, so engineers default to conventional items.
P8	Weak incentives and verification for private high-rises	Without incentives, audits and disclosure, green claims are voluntary and hard to trust.
P9	Supply-chain and skills gaps	Fly ash and GGBS logistics, block producers and trained site staff limit uptake.

5. Proposed Solutions

5.1.P1: Lowering the Embodied Carbon of Concrete

Problem: Structural concrete in towers, flyovers and public buildings is commonly specified with ordinary Portland cement (OPC) by default, locking in high embodied carbon.

Proposed solutions:

Blended Cement as the Default: Specify Portland Pozzolana Cement (PPC, IS 1489) or Portland Slag Cement (PSC, IS 455) for general work. These standards allow roughly 15–35% fly ash in PPC and about 25–70% slag in PSC. Minimum SCM Content Where Ready-Mix Uses OPC: Require 25–35% fly ash (IS 3812) or 40–50% GGBS (IS 16714) in slabs, beams and walls, subject to mix-design approval under IS 456.

Verification indicator:

Declared CO_2e per m^3 against a baseline OPC mix; 7, 28 and 56-day strengths; rapid chloride permeability result.

5.2.P2: Closing the Loop on C&D Waste

Problem: Hyderabad generates large volumes of construction debris and has recycling plants, yet

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recycled products are used mostly for footpaths and sub-base and most debris is still dumped or lost.

Proposed solutions:

Procurement Quota: Enforce the C&D Rules' call for municipal and public works to buy a share (reported as 10–20%) of materials from recycled C&D waste, starting with GHMC contracts. The exact obligation should be confirmed against the Rules. Broaden Approved Uses: Add recycled pavers, kerbs, drain covers, road sub-base and lean concrete, and allow recycled coarse aggregate in plain and lower-grade reinforced concrete within IS 383:2016 limits after testing (indicatively up to about 25% replacement).

Verification indicator:

Tonnes of debris diverted; share of GHMC aggregate demand met by recycled products; number of approved recycled product types.

5.3.P3: Lightweight, Lower-Impact Walling

Problem: Heavy burnt-clay infill increases dead load and seismic mass in tall frames, consumes fertile topsoil and fuel, and has poor insulation.

Proposed solutions:

AAC or Fly-Ash Blocks for Infill in Framed Buildings: AAC typically has a density of roughly 550–650 kg/m³ against about 1,800 kg/m³ for clay-brick masonry, so wall weight per unit volume is roughly a third. Use thin-bed mortar and 100–200 mm blocks. Fly-Ash Bricks and Blocks for Low-Rise and Affordable Housing: Use units conforming to IS 12894 and related standards, with stabilised earth or lime blocks where suitable.

Verification indicator:

Wall dead load in kg/m²; block compliance tests per lot; resulting steel and concrete quantities per m² floor area.

5.4.P4: Cooler Envelopes, Surfaces and Landscapes

Problem: Glass-heavy towers, dark roofs and sealed paving raise cooling demand, intensify urban heat and prevent rain from recharging groundwater.

Proposed solutions:

Envelope Limits: Cap the window-to-wall ratio at about 40% on the ECBC prescriptive path, use low-E double glazing with low solar heat gain, and add external shading (louvres, chajjas).

Cool Roofs: Require high solar-reflectance-index roof finishes (reflective coatings, tiles or white membranes) on public buildings and new towers.

Permeable and Cool Paving: Use permeable pavers (including those made from C&D waste) on footpaths, plazas and parking, with rainwater recharge pits.

Verification indicator:

Roof reflectance; window-to-wall ratio; energy use intensity (kWh/m²/year); measured indoor and surface temperatures; recharge volume.

5.5.P5: Durability and Self-Healing

Problem: Cracks and water ingress shorten service life, especially in drains, treatment plants and foundations in aggressive soils.

Proposed solutions:

Durability-Led Mixes: Use PSC, PPC or SCM-rich concrete with low water–cement ratio and adequate cover in sulphate- or chloride-exposed elements such as drains, nala structures, STPs and basements.

Lime and Self-Healing Mortars: Pilot lime-based and bacteria-based self-healing mortars and renders in water-retaining or hard-to-maintain elements. Do not rely on them for structural safety.

Verification indicator:

Chloride permeability; water absorption; measured crack closure in pilots; repair cost per m² over time.

5.6.P6: Greener Roads and Corridors (ORR and City Roads)

Problem: Corridors consume quarried stone, borrow soil and bitumen at very large scale.

Proposed solutions:

Embankments: Use fly ash in embankments and fills in line with IRC:SP:58, reducing borrow soil.

Pavement Layers: Use tested C&D aggregates and, where approved, steel slag in sub-base; use reclaimed asphalt pavement and waste-plastic-modified bitumen under IRC guidance (IRC:SP:98).

Verification indicator: Tonnes of virgin aggregate and borrow soil avoided; percentage of pavement layers using recycled or waste materials; life-cycle cost per km.

5.7.P7: Removing Procurement and Specification Barriers

Problem: If an item is not in the Schedule of Rates, site engineers and tenderers cannot easily specify or be paid for it, so conventional materials remain the default.

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Proposed solutions:
Schedule of Rates Reform: Add green items with tested rates: blended and SCM concrete, AAC and fly-ash blocks, recycled products, permeable pavers and cool roof finishes. Performance-Based Specifications: Specify strength, durability and a maximum embodied-carbon value rather than prescribing a cement type, so suppliers can innovate. Green Materials Cell and Digital Declaration: Create a small unit under MA&UD to own the standard, and add a material-declaration field to e-procurement and the Build Now approval portal.
Standard Drawings and Model Clauses: Issue them for GHMC, HMDA and Roads & Buildings works (see Sect. 8).
Verification indicator: Share of tenders using green items; number of SoR items added; time taken to approve green specifications.

5.8.P8: Incentives and Verification for Private High-Rises

Problem: Private tall buildings follow the cheapest compliant path unless there is a reward for going further and a check that claims are true.
Proposed solutions:
Tiered Incentives: Offer faster approvals and utility connections at a certified level; permit or impact-fee reductions at a higher level (the CII proposal of 20% is a reference point [15]); and limited additional FSI or TDR at the highest level. Verification: Require a material declaration at approval, third-party testing, random audits, and linkage of the occupancy certificate to compliance.
Verification indicator:
Number and floor area of projects entering each tier; audit pass rate; verified CO_2e savings.

5.9.P9: Supply Chain and Skills

Problem: Even good specifications fail if fly ash, GGBS, recycled products and blocks are not reliably available, or if site teams are not trained to use them.
Proposed solutions:
Supply Survey: Map fly ash sources (thermal power stations serving Telangana), GGBS sources (regional steel plants), cement producers, block makers and recycling plants.
Anchor Demand: Bundle the roughly 500,000-home Indiramma programme [16], GHMC works, corridor packages and Future City into predictable annual volumes.
Training:
Train engineers, contractors and masons on blended-cement concrete, curing, block masonry and recycled products with ITIs and construction skill councils.
Verification indicator:
Supply-gap assessment; number of qualified suppliers; trained personnel; delivery reliability.

6. Applying the Solutions to Project Types

Table 2 Priority solutions by project type

Project type	Key problems	Priority measures and targets
GHMC works	P2, P4, P5, P7	Recycled pavers and sub-base; blended cement in drains and STPs; cool roofs and rooftop solar on schools and markets; Schedule of Rates updated first.
ORR and expressway corridor	P1, P2, P6	Fly ash embankments; recycled and slag sub-base where approved; SCM-rich structural concrete; native planting, solar and EV charging.
HITEC City and IT corridor	P1, P3, P4, P8	Composite or efficient frames; SCM concrete; glazing and shading limits; mandatory green rating above a floor-area threshold; shaded public realm.
Musi rejuvenation and Future City	All	Write embodied-carbon targets and material specifications into master plans now, and publish results.

7. A Green Specification for Tall Apartment Buildings

As shown in Table 3 shows how key elements of a typical tall apartment block can be made greener within the same materials family.

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Table 3 Conventional versus proposed green specification for a high-rise apartment block

Element	Conventional practice	Proposed green specification	Basis
Raft and deep foundations	OPC concrete, high heat	PSC or 50–70% GGBS (or 35–50% fly ash) mix; 56-day acceptance with design approval; thermal control and curing.	IS 455, IS 16714, IS 456
Slabs and beams	OPC concrete	PPC, or OPC with 25–35% fly ash or 40–50% GGBS; at least 10-day curing.	IS 1489, IS 3812
Infill walls	Burnt-clay brick	AAC or fly-ash blocks with thin-bed mortar; plaster using washed recycled sand.	IS 2185 (Part 3), IS 12894
Envelope	Large glazed area, dark roof	WWR about 40% or less, low-E double glazing, external shading, cool roof.	ECBC, IGBC

8. Illustrative Embodied-Carbon Calculation and Model Clause

8.1.Illustrative Calculation

Table 4 compares three mixes with 400 kg/m³ of cementitious content and equal assumed performance. Illustrative emission factors are 0.90 t CO_2 per tonne for OPC, 0.02 for fly ash and 0.08 for GGBS; the figures cover cement-related emissions only, and actual values must come from supplier declarations. As shown in Table 4 Illustrative cement-related emissions per m³ of concrete.

Table 4 Illustrative cement-related emissions per m³ of concrete

Mix	Cement-related CO_2 (kg/m³)	Saving vs baseline	Hypothetical tower (20,000 m³)
Baseline: 400 kg OPC	360.0	–	–
30% fly ash (280 OPC + 120 FA)	254.4	105.6 kg (29.3%)	about 2,112 t CO_2 avoided
50% GGBS (200 OPC + 200 GGBS)	196.0	164.0 kg (45.6%)	about 3,280 t CO_2 avoided

8.2.Model Specification Clause (Illustrative)

C1. Cement: Portland Pozzolana Cement (IS 1489) or Portland Slag Cement (IS 455) shall be used unless OPC is specifically approved. Where OPC is used, SCM replacement shall be not less than 25% (fly ash) or 40% (GGBS) for slabs, beams and walls.
C2. Aggregates: recycled C&D products shall form not less than the minimum percentage stated in the Schedule for the named items; structural use of recycled aggregate requires testing under IS 383.

9. Implementation Framework

9.1.Pilot Design

Before statewide adoption, four monitored demonstration projects over about 24 months are proposed: a GHMC public building, an ORR or city road package, a HITEC City tower, and a residential apartment block. Each compares a green

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specification against a conventional design using the indicators in Table 5, with Osmania University, JNTU Hyderabad and IIT Hyderabad as possible research partners. As shown in Table 5 Proposed pilot indicators and hypotheses, Table 6 Phased 36-month roadmap

Table 5 Proposed pilot indicators and hypotheses

Indicator	Method	Proposed pilot target (hypothesis)
Cement-related CO_2e per m^3	Supplier declaration and mix design	At least 25% below baseline
Construction cost per m^2	Bills of quantities	Within ±5% of baseline, or lower
Strength and durability	7, 28 and 56-day tests; permeability and absorption	Meet or exceed design criteria
Debris diverted	Weighbridge records	Over 90% of site debris recycled or reused

9.2.Roadmap

Table 6 Phased 36-month roadmap

Phase	Actions
0–6 months	Constitute the Green Materials Cell; issue an interim order for State and GHMC works; update the Schedule of Rates; complete the supply survey; select pilot sites.
6–18 months	Build and monitor pilots; test materials at accredited laboratories; notify the private-sector incentive scheme; link material checks to the Build Now portal; start training.
18–36 months	Scale the standard to all State works above a value threshold; make embodied-carbon declaration mandatory for large projects; publish an annual Green Materials Report; feed pilot findings into updated specifications.

10. Risks, Limitations and Mitigation

Some green materials cost more upfront, although many blocks and blended cements are cost-neutral or cheaper, so decisions should use life-cycle cost, bulk purchasing and incentives. High-SCM concrete may gain early strength more slowly, which calls for admixtures and strict curing. Supply constraints require multi-source contracts; quality doubts are reduced by third-party testing; and greenwashing is countered by declaration, audit and penalties.

Conclusion

Hyderabad can make its tall buildings, corridors and public works substantially greener without leaving concrete and brick behind. The nine problems identified here have specific, standards-based answers, from blended cement and recycled C&D products to a reformed Schedule of Rates, tiered incentives and a supported supply chain. Because the Musi programme and Bharat Future City are still at the planning stage, the State can write material standards into them now; a monitored pilot programme would turn these proposals into evidence and then into policy.

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