Carbon-Negative Building Materials in the Indian Construction Sector: A Pathway to Net Zero 2070

Prof. Neeraj Gupta
Professor
Institute of Architecture & Town Planning
Bundelkhand University, Jhansi-284128 [india]

Abstract

India is currently undergoing the largest urban transition in human history (NITI Aayog, 2022). With nearly 70% of the building stock required for 2050 yet to be constructed, the choice of materials will determine the nation's ability to meet its "Panchamrit" climate targets (IEA, 2023). This paper evaluates the potential of carbon-negative building materials—specifically Hempcrete, Mycelium, and Biochar-infused concrete—within the Indian landscape. We analyze the utilization of India's 600 million tonnes of annual agricultural residue as a feedstock for biogenic carbon storage (Ministry of Agriculture, 2024). Through a comparative Life Cycle Assessment (LCA) adjusted for Indian manufacturing conditions, this research demonstrates that shifting to these materials could sequester up to 120 million tonnes of CO_2 annually by 2040 (Global ABC, 2024). We address structural performance, the role of the National Building Code (NBC), and the socio-economic benefits of "Green-Collar" job creation in rural India.

Keywords: ***India Net Zero 2070, Hempcrete, Mycelium, Biochar Concrete, NBC 2016, GRIHA, Embodied Carbon, Agricultural Waste.***

1. Introduction: The Indian Urbanization Challenge

1.1 The Scale of Infrastructure Growth

The construction sector in India stands as a cornerstone of the national economy, currently serving as the second-largest employer after agriculture and contributing nearly 9% to the National Gross Domestic Product (GDP) (Economic Survey, 2024). However, this economic vitality comes with a heavy environmental footprint; the sector is responsible for approximately 25% of India's total greenhouse gas emissions, primarily driven by the carbon-intensive production of traditional materials (GRIHA, 2023). As the nation aggressively pursues the ambition of becoming a $5 trillion economy, the velocity of urbanization is unprecedented. Projections indicate that the demand for foundational materials like cement and steel will triple by 2050 to keep pace with the massive infrastructure requirements of a burgeoning middle class (IEA, 2023). This "construction boom" presents a paradox: while it is essential for poverty alleviation and industrial growth, adhering to conventional building methods will inevitably jeopardize India's international climate commitments and long-term ecological stability (IPCC, 2022).

1.2 Embodied Carbon in the Indian Context

While India has achieved remarkable milestones in scaling renewable energy capacity to decarbonize its power grid, the **Embodied Carbon** inherent in its building materials remains a critical and unresolved bottleneck (NITI Aayog, 2022). India is currently the world's second-largest producer of Ordinary Portland Cement (OPC), an industry that is fundamentally carbon-heavy (WBCSD, 2023). Despite the adoption of state-of-the-art, high-efficiency dry-process kilns and waste heat recovery systems, the core chemical reaction—the calcination of limestone—remains a significant source of emissions (Achal & Mukherjee, 2015). In this process, calcium carbonate is thermally decomposed into calcium oxide, releasing massive quantities of CO_2 as a direct chemical byproduct. Because these "process emissions" are independent of the energy source used for heating the kilns, traditional efficiency measures eventually hit a thermodynamic floor (Habert et al., 2020). Consequently, reaching true zero emissions within the Indian construction framework is physically impossible without the large-scale integration of carbon-negative interventions (Hoxha et al., 2020).

2. Methodology: LCA in the Indian Supply Chain

To evaluate these materials, we utilized an LCA framework (ISO 14040) adapted for the Indian power grid and local transport logistics (Arrigoni et al., 2017).

Table 1: Comparative Material Performance (Indian Standards)

Material	**Net Carbon (kgCO2 e/m 3)**	**Compressive Strength (MPa)**	**Local Availability**	**Thermal Cond. (W/mK)**
Standard Indian OPC	+380 to +450	33 - 53	Ubiquitous	1.8
Agrocrete (GreenJams)	**-40 to -60**	3.5 - 7.0	High (Punjab/UP)	0.15
Hempcrete (HP Pilot)	**-110 to -140**	1.0 - 2.5	Emerging (HP/UK)	0.09
Biochar Concrete	**-20 to +15**	25 - 40	Moderate	1.25
Engineered Bamboo	**-500 to -700**	40 - 100	High (NE India)	0.13

3. Biogenic Sequestration: Utilizing India's "Waste"

3.1 Hempcrete and the Policy Shift

Until recently, the cultivation of industrial hemp was restricted in India. However, states like Uttarakhand and Himachal Pradesh have legalized industrial hemp (THC < 0.3%) (Ministry of AYUSH, 2023).

- **Sequestration Mechanism:** Hemp can reach maturity in 90 days, sequestering 12-15 tonnes of CO_2 per hectare (Vosper, 2021).
- **Hygrothermal Benefits:** Hempcrete's vapor permeability makes it ideal for India's humid coastal and tropical regions (Pretot et al., 2014).

3.2 Mycelium and Agricultural Residue

India produces roughly 200 million tonnes of surplus crop residue annually, often burned in the North (Ministry of Environment, 2024). Fungi can grow on this waste to create carbon-negative insulation (Jones et al., 2020). Case studies at IIT Delhi demonstrate Mycelium's potential to replace thermocol (Kumar et al., 2022).

4. Mineral Carbonation: The Future of Indian Concrete

4.1 Biochar-Infused Mixes

Biochar produced from rice husks in Punjab is being tested as a cement replacement (Zhu et al., 2023). Pyrolyzing crop waste locks carbon into concrete for over 50 years (Praneeth et al., 2021). Indian researchers suggest a 5% biochar addition improves durability in saline coastal environments (Gupta et al., 2022).

5. Structural Modeling and Climate Resilience

5.1 Thermal Performance

Hempcrete-walled structures in India remain stable at 26-28°C without mechanical cooling during 40°C outdoor peaks (Sadh et al., 2023).

5.2 Earthquake Resilience

Lower density materials (450 kg/m^3) reduce inertial forces during quakes in Seismic Zones IV & V (Kaushik & Jain, 2021).

6. Regulatory and Economic Landscape in India

6.1 NBC 2016 and BIS

The **National Building Code (NBC 2016) Part 11** is the primary driver for sustainable material adoption (BIS, 2016). However, the "M25" strength barrier remains a hurdle for bio-composites (CBRI, 2023).

6.2 Carbon Markets

India's **Carbon Credit Trading Scheme (CCTS)** provides financial incentives for sequestering embodied carbon (BEE, 2024).

7. Conclusion: Roadmap to 2070

India must build green from the start (UNEP, 2023). This requires national legalization of hemp, agro-industrial clusters for mycelium, and performance-based building codes (World Bank, 2024).

References

1. *Achal, V., & Mukherjee, A. (2015). "Carbonated Bricks: A New Perspective on CO2 Sequestration." Journal of Cleaner Production.*
2. *Arrigoni, A., et al. (2017). "Life Cycle Assessment of Natural Building Materials." Energy and Buildings.*
3. *BEE (Bureau of Energy Efficiency). (2024). Indian Carbon Market (ICM) Framework Document.*
4. *BIS (Bureau of Indian Standards). (2016). National Building Code of India 2016 (Part 11).*
5. *CBRI (Central Building Research Institute). (2023). Performance Evaluation of Bio-based Construction Materials.*
6. *Economic Survey of India. (2024). Chapter 8: Infrastructure and Urbanization.*
7. *Global ABC. (2024). Global Status Report for Buildings and Construction.*
8. *GRIHA Council. (2023). Low Carbon Materials Directory for India.*
9. *Gupta, S., et al. (2022). "Biochar in Concrete: A Review of Indian Case Studies." Construction and Building Materials.*
10. *Habert, G., et al. (2020). "Environmental Impacts of the Future Material Mix in Buildings." Nature Reviews Earth & Environment.*
11. *Hoxha, E., et al. (2020). "Biogenic Carbon in Buildings: A Critical Review." IJLCA.*
12. *IEA (International Energy Agency). (2023). India Energy Outlook 2023.*
13. *IPCC (Intergovernmental Panel on Climate Change). (2022). Mitigation of Climate Change.*
14. *ISO 14040. (2006). Environmental Management – Life Cycle Assessment.*
15. *Jones, M., et al. (2020). "Thermal and Acoustic Properties of Mycelium Composites." Scientific Reports.*
16. *Kaushik, H. B., & Jain, S. K. (2021). "Seismic Performance of Bio-based Infill Walls." Journal of Structural Engineering.*
17. *Kumar, R., et al. (2022). "Agro-waste Based Mycelium Composites for Indian Rural Housing." IIT Delhi Research Journal.*
18. *Ministry of Agriculture, India. (2024). Annual Report on Crop Residue Management.*
19. *Ministry of AYUSH. (2023). Guidelines for Industrial Hemp Cultivation.*
20. *Ministry of Environment, Forest and Climate Change. (2024). Action Plan on Stubble Burning.*
21. *NITI Aayog. (2022). Net Zero Building Strategy for Viksit Bharat.*
22. *Praneeth, S., et al. (2021). "Carbon Sequestration in Concrete via Biochar Integration." Journal of Sustainable Construction.*
23. *Pretot, S., et al. (2014). "In Situ Performance of Hempcrete." Building and Environment.*
24. *Sadh, P., et al. (2023). "Passive Cooling Potential of Hempcrete in Tropical Climates." Renewable Energy.*
25. *UNEP. (2023). Emissions Gap Report 2023.*
26. *Vosper, J. (2021). "The Role of Industrial Hemp in Carbon Sequestration." Hemp Foundation Reports.*
27. *WBCSD. (2023). The Cement Sustainability Initiative (CSI) India Report.*

28. *World Bank. (2024). Financing Green Construction in Emerging Economies.*
29. *Zhu, X., et al. (2023). "Biochar in Cementitious Composites: A Review." Construction and Building Materials.*