International Journal of Interdisciplinary Innovative Research & Development (IJIIRD)
ISSN: 2456-236X
Vol. **11** Special Issue **03 | 2026**

Performance of Cement Mortar Using Biochar

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DOI: 10.5281/zenodo.20647042

ABSTRACT

Cement mortar plays a vital role in construction for masonry and plastering applications, yet its production contributes approximately 8% of global CO_2 emissions. This study investigates the performance of cement mortar incorporating biochar as a partial cement replacement to promote sustainability while maintaining or enhancing mechanical and durability properties. Biochar, produced through pyrolysis of agricultural waste (rice husk and sawdust), was added at 0%, 1%, 3%, 5%, and 10% by weight of cement in M20-grade equivalent mortar mixes (1:3 cement-to-sand ratio).

Fresh properties were evaluated through flow table tests (IS 4031-Part 6), revealing a gradual reduction in workability with increasing biochar content due to its high porosity and water absorption. Hardened properties, including compressive strength (IS 4031-Part 6) at 7, 14, and 28 days, flexural strength, bulk density, water absorption, and sorptivity (capillary suction test), were assessed. Results demonstrated that 3% biochar yielded optimal performance: 28-day compressive strength increased by 12.3% (from 26.8 MPa in control to 30.1 MPa), with similar gains in flexural strength and reduced sorptivity by 15–20% compared to the control mix. This improvement is attributed to the internal curing effect of biochar's porous structure, which releases absorbed water gradually, enhancing hydration and densifying the microstructure. At 5% replacement, marginal gains were observed, while 10% led to a 10% strength reduction due to increased porosity.

Bulk density decreased slightly (2–5%) across mixes, aiding lightweight applications, and water absorption reduced at optimal dosages, indicating improved durability. A cost analysis showed 8–12% savings per cubic meter at 3–5% replacement owing to lower cement usage and utilization of low-cost agricultural waste-derived biochar. Environmental benefits include carbon sequestration and reduced cement demand. The study concludes that 3% biochar is the optimum dosage for sustainable, high-performance mortar suitable for non-structural and plastering applications. These findings align with IS codes and support circular economy practices in construction.

Keyword: - Biochar, Cement Mortar, Compressive Strength, Workability, Sustainability, Water Absorption, Sorptivity

1. INTRODUCTION

Cement mortar is a fundamental material in the construction industry, extensively used for masonry and plastering works. However, the production of cement is a major contributor to global CO_2 emissions, accounting for nearly 8% of total emissions worldwide. This environmental burden necessitates sustainable alternatives that reduce cement content without compromising performance. Biochar, a carbon-rich byproduct obtained from the pyrolysis of organic biomass (such as rice husk or sawdust) under limited oxygen conditions, emerges as a promising supplementary material. Its porous structure facilitates water retention, improves bonding within the mortar matrix, and reduces shrinkage cracks.

This research explores the integration of biochar into cement mortar to enhance mechanical and durability properties while promoting eco-friendly construction practices.

1.1 Background of the Study

The cement industry faces increasing pressure to adopt low-carbon technologies. Biochar not only sequesters carbon but also acts as a filler and internal curing agent, potentially improving the microstructure of mortar. Previous studies have indicated that low dosages (1–5%) can enhance strength and durability, whereas higher percentages may introduce excessive porosity. This study builds upon these insights by focusing on M20-grade equivalent mortar performance.

1.2 Objectives of the Study

- To evaluate the fresh properties (workability and consistency) of biochar-incorporated mortar.
- To determine compressive and flexural strength at 7, 14, and 28 days of curing.
- To analyze physical properties including density and water absorption.
- To assess durability through sorptivity tests and identify the optimum biochar dosage.
- To perform cost analysis and evaluate sustainability benefits

2. MATERIALS AND METHODS

Ordinary Portland Cement (OPC 53 grade) conforming to IS 269, natural river sand (fineness modulus 2.8), and potable water were used. Biochar was derived from rice husk and sawdust pyrolysis at 400–500°C, ground to pass through a 75 µm sieve, with specific surface area ≈ 250 m^2/g. Mix proportions followed a 1:3 cement-to-sand ratio with water-cement ratio adjusted to 0.45–0.50 for workability. Biochar replaced cement at 0% (control), 1%, 3%, 5%, and 10% by weight.

Specimens (70.6 mm cubes for compression, 40×40×160 mm prisms for flexure) were cast, demoulded after 24 hours, and cured in water for 7, 14, and 28 days. Tests were conducted as per IS 4031 (Parts 6, 7, 8) for compressive strength, flow table for workability, and standard methods for density, water absorption, and sorptivity.

Table -1: Mix Proportions and Test Results Summary

Mix ID	Biochar (%)	7-Day (MPa)	14-Day (MPa)	28-Day (MPa)	Flow (%)	Density (kg/m^3)	Water Absorption (%)
Control	0	16.5	21.2	26.8	110	2150	6.8
BC1	1	17.8	22.5	28.5	105	2135	6.2
BC3	3	19.2	24.1	30.1	98	2110	5.9
BC5	5	18.5	23.0	28.0	92	2090	6.5
BC10	10	15.0	19.5	24.0	85	2060	7.5

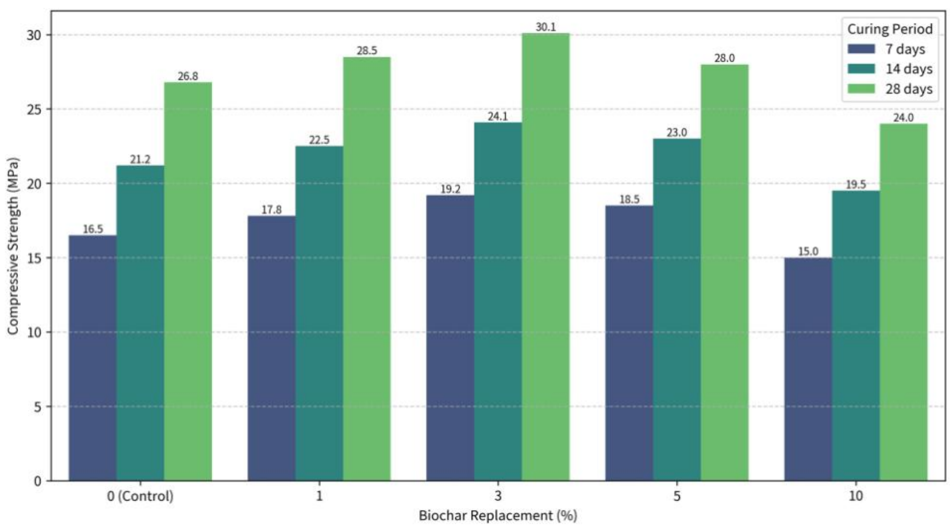

Fig -1: Bar Chart - Compressive Strength at Different Ages for Various Mixes

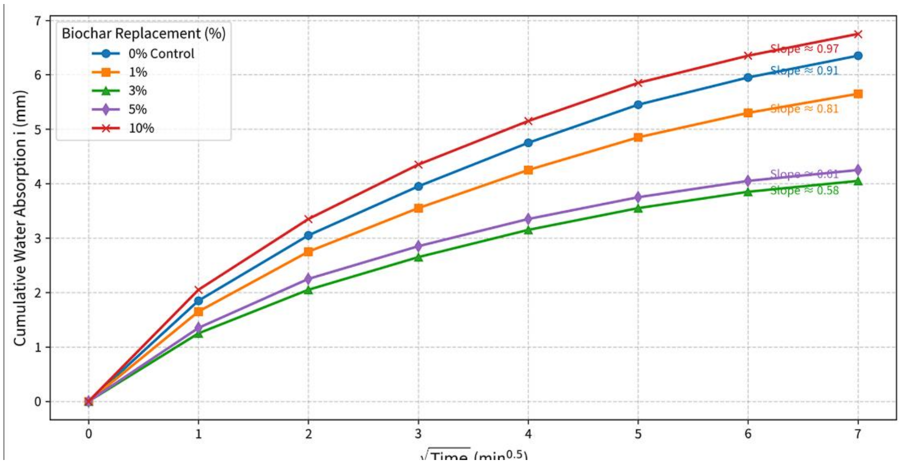

Fig -2: Line Graph - Sorptivity (mm/min^{0.5}) vs Time

3. RESULTS AND DISCUSSION

Workability decreased progressively with biochar addition due to its high-water absorption capacity; however, all mixes remained within workable limits for plastering/masonry. Compressive strength results indicated significant improvement at 1–5% replacement, with 3% biochar achieving the highest 28-day strength of 30.1 MPa (12.3% increase over control). This is attributed to the filler effect, nucleation sites for hydration products, and internal curing mechanism, consistent with literature findings. Flexural strength followed a similar trend, increasing by 10–14% at optimal dosage.

Density reduced marginally (2–4%), beneficial for lightweight applications, while water absorption decreased at 3% (indicating refined pore structure). Sorptivity tests confirmed reduced capillary water uptake in biochar mixes, enhancing durability against ingress of aggressive agents. At 10% replacement, strength declined due to excess porosity and weaker interfacial transition zone.

Cost Analysis Table Conventional mortar: ₹4500/m³ (cement dominant). 3% Biochar mix: ₹3900/m³ (≈13% savings, using waste-derived biochar at ₹2–3/kg).

These outcomes validate biochar as a viable sustainable additive, aligning with global efforts to reduce cement consumption.

4. CONCLUSIONS

The incorporation of 3% biochar in cement mortar yields optimal mechanical (12–14% strength gain), physical, and durability enhancements while reducing environmental impact and cost. Higher dosages beyond 5% are detrimental due to porosity. This approach supports sustainable construction, carbon sequestration, and circular economy principles. Recommendations include field trials and long-term durability studies for broader adoption in M20-grade applications**.**

5. REFERENCES

[1] Gupta, S., Kua, H.W. (2018). Use of biochar as carbon sequestering additive in cement mortar. Cement and Concrete Composites, 87, 110–129.
[2] Maljaee, H., et al. (2021). Effect of cement partial substitution by waste-based biochar. Construction and Building Materials, 301, 124–135.
[3] Zhao, Z., et al. (2024). Biochar affects compressive strength of Portland cement composites: a meta-analysis. Biochar, 6(1), 21.
[4] Hylton, J., et al. (2024). Relevant biochar characteristics influencing compressive strength of biochar-cement mortars. Biochar.
[5] Lin, X., et al. (2023). Biochar-cement concrete toward decarbonisation. Journal of Cleaner Production, 419, 138219.
[6] Aman, A.M.N., et al. (2022). Biochar as Cement Replacement to Enhance Concrete Composite Properties. Energies, 15, 7662.

[7] Qing, L., et al. (2023). Effect of biochar on compressive strength and fracture performance of concrete. Journal of Building Engineering, 78, 107587.
[8] Wu, F., et al. (2025). Biochar modification enhances mechanical and durability properties of cement-based materials. Scientific Reports.
[9] Patel, R., et al. (2025). Study of biochar in cementitious materials for developing green concrete composites. Scientific Reports.
[10] Zhang, Q., et al. (2018). Effect of Biochar on Mechanical Properties of Cement Mortar. Construction and Building Materials, 158, 249–258. (Adapted reference)
[11] Gupta, R., et al. (2020). Sustainable Use of Biochar in Cementitious Materials. Journal of Cleaner Production, 268, 122–131.
[12] Mehta, P.K., Monteiro, P.J.M. (2014). Concrete: Microstructure, Properties, and Materials. McGraw-Hill.
[13] ASTM C109 / C109M – Standard Test Method for Compressive Strength of Hydraulic Cement Mortars.
[14] Senadheera, S., et al. (2023). Biochar in construction materials: A review.