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Replacement And Optimization of Biochar Brick & Plastering, For Carbon Sequestration

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Abstract: *The construction industry significantly contributes to global carbon emissions, creating an urgent need for sustainable and carbon-negative building materials. Biochar, a carbon-rich byproduct derived from the pyrolysis of agricultural biomass, has emerged as a potential additive that can both improve material performance and sequester atmospheric carbon. This research investigates the incorporation of biochar into conventional brick and plaster compositions to assess its environmental and structural viability. A novel carbon-channeling experimental setup was developed to simulate real-world exposure conditions using exhaust gases. Mechanical testing, including compressive strength, density evaluation, and water absorption analysis, was performed in parallel with CHNS elemental testing to determine carbon retention capabilities. Through detailed performance evaluation and statistical interpretation, this study aims to optimize the mix proportions of biochar-enhanced materials for eco-friendly construction, providing a sustainable alternative that aligns with climate change mitigation goals.*

Key Word: *Biochar, Carbon Sequestration, Sustainable Construction, CHNS Elemental Analysis, Compressive Strength, Eco-Friendly Materials, Low-Carbon Building, Green Engineering, Carbon-Absorbing Bricks.*

I.INTRODUCTION

The construction industry is one of the largest contributors to global greenhouse gas emissions, accounting for nearly 40% of energy-related CO_2 output. As the world transitions toward more sustainable and climate-resilient development strategies, there is a growing need for construction materials that not only reduce emissions during production but actively contribute to carbon sequestration. Biochar, a carbon-rich material derived from the pyrolysis of organic biomass under limited oxygen conditions, presents such an opportunity. Its highly porous structure, high surface area, and chemically stable form allow it to function both as a filler and a carbon sink in cementitious composites.

This study explores the feasibility of integrating biochar into brick and plaster formulations as a partial replacement for conventional materials. The objective is twofold: (1) to assess the structural performance of biochar-based composites in terms of compressive strength, density, and water absorption; and (2) to evaluate their carbon sequestration potential using a real-world carbon exposure simulation and CHNS elemental analysis. The work further aims to optimize the proportion of biochar to ensure that environmental benefits do not come at the cost of mechanical reliability. This investigation, rooted in experimental data and guided by IS code provisions, contributes to the broader movement toward low-carbon construction technologies and climate-conscious engineering practices.

II.MATERIAL AND METHODS

This study was conducted in the Material Testing Laboratory of the Civil Engineering Department at Vidya Academy of Science and Technology, Thrissur, to evaluate the potential of biochar in enhancing sustainability in construction materials. The research involved integrating biochar into brick and plaster formulations and examining its effects on carbon sequestration, mechanical properties, and durability.

Key materials used included biochar (produced via pyrolysis from bamboo biomass), Ordinary Portland Cement (OPC), coarse and fine aggregates, and coconut coir fibre. Bamboo biochar was selected for its superior carbon retention and low ash content. It was analyzed for specific gravity (1.5), sieve gradation (fineness modulus 4.405), and water absorption (30%), indicating moderate porosity and suitability for lightweight, thermally efficient construction.

Cement properties were evaluated through standard laboratory tests. Specific gravity was found to be 3.1. The standard consistency was achieved at 33.75% water, with an initial setting time of 30 minutes and fineness of 8% residue on a 90 µm sieve.

Coarse aggregates had a specific gravity of 2.89 and low water absorption (0.1%). An aggregate crushing value of 12.05% and a fineness modulus of 4.28 indicated suitability for structural applications. Coconut coir fibre (0.6% by weight) was added to improve tensile and crack resistance.

Though potassium hydroxide (KOH) was initially tested to boost CO_2 absorption in plaster, it negatively impacted surface integrity and was excluded from final mixes.

The experimental process began with mould preparation (20×10×10 cm). Material characterization tests were conducted prior to mixing. Bricks and plaster samples were cast with varying proportions of biochar and cement. Coconut fibre was manually mixed in for reinforcement. Specimens were cured in water for 28 days.

The biochar brick compositions included: (1) Standard: 10% cement, 20% biochar, 70% coarse aggregate; (2) Reduced Biochar: 15% cement, 15% biochar, 70% coarse aggregate; (3) Increased Biochar: 10% cement, 30% biochar, 60% coarse aggregate; and (4) No Coarse Aggregate: 50% cement, 50% biochar. For plastering, compositions included: (1) Standard: 25% cement, 75% biochar; (2) Reduced Biochar: 37.5% cement, 62.5% biochar; (3) Increased Biochar: 12.5% cement, 87.5% biochar

A carbon channeling setup was constructed to assess sequestration efficiency. Exhaust gas from motorcycles was passed through a sealed chamber with the samples at 37–40°C for 24 hours. Carbon content was later measured using CHNS Elemental Analysis.

Compressive strength, density, and water absorption tests were performed. Data was statistically analyzed to compare the mechanical and environmental performance of conventional and biochar-integrated samples. The results aimed to identify optimal compositions for sustainable and durable construction applications.

III. RESULT

The experimental evaluation demonstrated that biochar significantly influenced the performance of bricks and plaster. In terms of density, all biochar bricks except the no coarse aggregate (NCA) sample met the IS 2185 minimum requirement of 1800 kg/m³. The RBC (15% biochar) had the highest average density (2293 kg/m³), followed by SC (1997 kg/m³) and IBC (1936 kg/m³), while NCA (1545 kg/m³) fell below the threshold.

Compressive strength results showed that all biochar bricks surpassed the IS 2185 standard of 5 MPa. RBC performed best with 27.8 MPa, followed by NCA (24.47 MPa), SC (23.9 MPa), and IBC (15.5 MPa). Conventional bricks had a lower average strength of 20.67 MPa.

Water absorption analysis highlighted the moisture resistance of RBC, recording the lowest value at 6.35%, outperforming even conventional bricks (9.77%). SC and IBC showed slightly higher absorption (10.8% and 12.15% respectively), while NCA exceeded the limit at 13.44%.

CHNS elemental analysis revealed a positive correlation between biochar content and carbon sequestration. IBC bricks achieved the highest carbon retention (3.13%), while conventional bricks retained only 0.62%. In plastering, the increased biochar mix (IBP) captured 1.85%, significantly more than conventional plastering (1.38%).

Overall, RBC bricks were identified as the optimal choice for balanced performance, combining low water absorption, adequate strength, and high carbon capture. For plastering, while increased biochar content improved carbon sequestration, further optimization is needed to maintain structural performance.

IV.DISCUSSION

The experimental findings underscore the viability of biochar-based materials in sustainable construction. Among the tested samples, the RBC mix (15% biochar) emerged as the most optimal composition, achieving the highest compressive strength (27.8 MPa), superior density (2293 kg/m³), and the lowest water absorption (6.35%). These combined attributes make RBC bricks ideal for structural applications such as load-bearing walls

IBC bricks (30% biochar) demonstrated the highest carbon sequestration capacity (3.13%), confirming the positive role of biochar content in locking atmospheric carbon. While they maintained acceptable strength (15.5 MPa), their water absorption (12.15%) exceeds IS 2185 recommendations, potentially limiting their use in indoor dry zones or non-structural elements where environmental protection is not a primary concern.

NCA bricks, despite exhibiting strong compressive values (24.47 MPa), were disqualified for structural applications due to excessive water absorption (13.44%) and low density (1545 kg/m³). Their lightweight profile, however, makes them promising for insulation panels, cavity blocks, or temporary structures where thermal efficiency outweighs strength.

In plastering applications, the IBP mix (87.5% biochar) yielded the highest carbon retention (1.85%). While strength and adhesion tests were outside the study's current scope, the fine particle size of the biochar (Zone III grading) is expected to promote good surface bonding and workability. Its suitability for low-load applications such as chimney linings, decorative plasters, and false ceilings in energy-efficient buildings is evident. Moreover, its potential to reduce embodied carbon makes it attractive for projects pursuing green certifications.

These results validate the integration of biochar as a dual-function material—offering both mechanical utility and environmental gain. Through carbon sequestration and material substitution, biochar contributes to circular economy goals and sustainable infrastructure development.

V.CONCLUSION

This study conclusively demonstrates that biochar, when integrated into bricks and plaster, offers a dual advantage: enhancing material performance while significantly contributing to environmental sustainability through carbon sequestration. The integration of bamboo-derived biochar into brick formulations proved particularly effective, yielding favorable results in mechanical, physical, and environmental performance metrics.

Among the tested samples, the Reduced Biochar Composition (RBC) brick—comprising 15% biochar—emerged as the most balanced and optimal choice. It recorded the highest compressive strength (27.8 MPa), lowest water absorption (6.35%), and highest density (2293 kg/m³), outperforming even conventional bricks in critical parameters. These attributes not only validate its structural soundness but also highlight its suitability for moisture-prone areas such as kitchens and bathrooms. Additionally, its robustness and durability make it well-suited for high-impact, weather-exposed applications like kerb stones and outdoor pavements.

The Increased Biochar Composition (IBC) brick, containing 30% biochar, showed the highest carbon capture capacity (3.13%), proving biochar's effectiveness as a long-term carbon sink. However, it also exhibited increased porosity and higher water absorption (12.15%), suggesting a trade-off between sustainability and durability at higher replacement levels. Meanwhile, the No Coarse Aggregate (NCA) brick, although lightweight and strong (24.47 MPa), fell short in moisture resistance due to excessive water absorption (13.44%), limiting its use to non-load-bearing and insulation applications.

In plastering applications, the Increased Biochar Plaster (IBP) mix demonstrated enhanced carbon capture (1.85%) compared to conventional plaster (1.38%). While further mechanical testing is needed, the particle gradation of biochar (Zone III) supports its application in smooth-finish coatings, chimneys, and false ceilings—especially in green-certified or low-carbon building designs.

From a sustainability standpoint, this project reinforces biochar's role as a low-emission, resource-efficient construction material. Its use reduces the dependence on cement and coarse aggregates—both major contributors to construction-related CO_2 emissions—while sequestering atmospheric carbon within the built environment. This aligns closely with global goals of carbon neutrality, resource conservation, and circular construction.

In conclusion, biochar-based bricks and plasters offer a scalable, eco-friendly alternative to traditional materials. With continued optimization—especially in addressing moisture resistance and long-term performance—these materials hold immense promise for mainstream adoption in sustainable construction practices.

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