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Promoting Internal Curing in Concrete by Replacing Sand with Sustainable Biochar

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Abstract: This study focuses on promoting internal curing in concrete by partially replacing sand with sustainable biochar. Biochar, a carbon-rich by-product produced from the pyrolysis of organic waste, has excellent water absorption and retention properties that can enhance the internal curing process. The replacement of sand with biochar not only contributes to better hydration of cement but also improves the microstructure and durability of concrete. By utilizing biochar, the study aims to reduce autogenous shrinkage, enhance compressive and tensile strength, and promote eco-friendly construction practices. This approach supports sustainable waste management while lowering the carbon footprint of concrete production, making it a viable alternative for green and durable infrastructure development.
Keywords: Biochar, Internal Curing, Partial Sand Replacement, Water Retention, Durability, Compressive Strength.

I. INTRODUCTION

Concrete is one of the most widely used construction materials due to its availability, affordability, and strength. However, the increasing demand for concrete has led to excessive consumption of natural resources such as river sand and gravel, raising concerns about resource depletion and environmental sustainability. Additionally, the rapid growth of cement production has significantly contributed to environmental issues, including greenhouse gas emissions, pollution, and ecological damage from raw material extraction. To address these challenges, researchers have explored the use of alternative and sustainable materials like fly ash, rice husk ash, recycled aggregates, and biochar. Biochar is a carbon-rich material produced through the pyrolysis of organic waste under limited oxygen conditions. It possesses unique properties such as high porosity, large surface area, stability, and water retention capacity, making it suitable for various applications. In the construction field, biochar has shown potential as a supplementary cementitious material (SCM). Its incorporation in concrete can influence workability, hydration, mechanical strength, and durability. This study reviews previous research on the mechanical strength properties of biochar-based concrete to better understand its effectiveness and potential in sustainable construction practices.

II. TO SPECIFIC OBJECTIVES

1) To evaluate the strength of concrete in which the sand is partially replaced with biochar by the following tests
- Compressive strength test
- Split tensile strength test
- Flexural strength test

2) To Improve Internal Curing and Hydration

III. MATERIALS AND METHODS

A. Materials

Material used for this study are cement, fine aggregate, coarse aggregate, portable water and biochar. Laboratory tests such as specific gravity, setting time, consistency, grain size distribution, compressive strength, split tensile strength and flexural strength were conducted to determine the properties of collected sample.

1) Cement

Ordinary Portland cement grade 53 is used for the preparation of concrete.

2) Fine Aggregate

Fine aggregate includes the particles that all pass through a 4.75 mm sieve and are retained in a 0.075 mm sieve. M-sand will be used as fine aggregate. The m-sand will first sieve through a 4.75 mm sieve to remove any particles greater than 4.75 mm and then washed to remove the dust.

3) Coarse Aggregate

Coarse aggregate includes the particle that passes through a 20mm sieve and retains in a 4.75 mm sieve. Gravel will be used as coarse aggregate. The aggregates were washed to remove dust and dirt.

4) Potable Water

Water used for mixing, and curing purposes should be clean, potable, fresh, and free from any bacteria. Water is a key ingredient in the manufacture of concrete.

5) Biochar

Biochar is a charcoal-like material produced by heating organic waste such as forestry residues, manure, and municipal waste in a process called pyrolysis. This conversion occurs in a high-temperature, low-oxygen environment, which prevents the biomass from fully combusting. We are collecting for the biochar is online shop.

B. Method

It involved the collection of materials such as Ordinary Portland Cement (OPC 53 grade), M-sand, coarse aggregate, potable water, and biochar. Preliminary laboratory tests were conducted on all materials to determine their physical properties and suitability for concrete production. Tests on cement included specific gravity, fineness, consistency, and setting time tests, while sieve analysis and specific gravity tests were performed on fine aggregate and biochar. Coarse aggregate was tested for specific gravity and water absorption. After evaluating the material properties, an M20 grade concrete mix with a proportion of 1:1.5:3 and a water-cement ratio of 0.5 was designed. Biochar was used as a partial replacement for fine aggregate at varying percentages of 1%, 3%, and 5%, along with a control mix without biochar. Fresh concrete was prepared and subjected to slump tests to determine workability.

Concrete specimens such as cubes, cylinders, and beams were then cast, compacted properly, and cured in water for 7 and 28 days. After curing, experimental investigations including compressive strength tests, split tensile strength tests, and flexural strength tests were carried out using standard testing procedures. Finally, the obtained results were analysed and compared with conventional concrete to evaluate the influence of biochar on internal curing, strength characteristics, and overall sustainability of concrete.

IV. RESULT AND DISCUSSIONS

A. Compressive Strength of Mortar Cube

The compressive strength of mortar cube for 3, 7, and 28 days are given in TABLE I.

TABLE II

COMPRESSIVE STRENGTH OF MORTAR CUBE

% Replacement	3days		7 days		28 days	
	Load applied, (KN)	Compressive strength, (N/mm2)	Load applied, (KN)	Compressive strength, (N/mm2)	Load applied, (KN)	Compressive strength, (N/mm2)
0	50	10.03	60	12.04	80	16.06
1	52	10.43	64	12.84	95	19.05
3	55	11.03	71	14.24	104	20.86
5	60	12.03	80	16.05	112	22.47

B. Compressive Strength of Cube

The compressive strength of cube after 28 days of curing is given in TABLE II

TABLE II

COMPRESSIVE STRENGTH OF CUBE

% Replacement	28 Days	
	Load applied, (KN)	Compressive strength, (N/mm2)
0	450	20.000
1	460	20.440
3	550	24.440
5	510	22.660

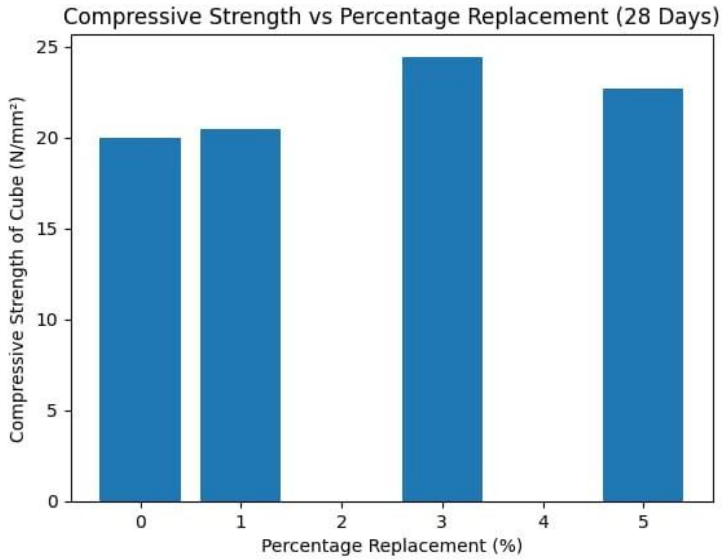

FIG. 1 Bar Chart of compressive strength of cylinder at 28 days

C. *Split Tensile Strength of Cylinder*

The split tensile strength of cylinder after 28 days of curing is given in TABLE III

TABLE III
SPLIT TENSILE STRENGTH OF CYLINDER

% Replacement	28 Days	
	Load applied, (KN)	Split tensile strength, (N/mm2)
0	243	3.437
1	241.5	3.416
3	244	3.451
5	248	3.508

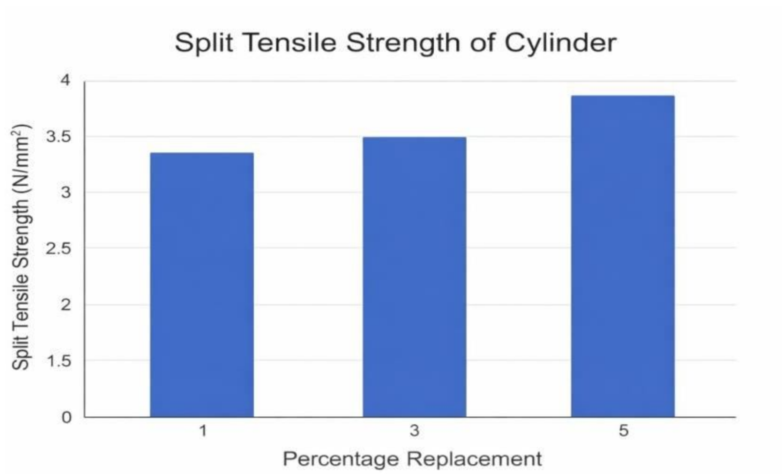

FIG. 2 Bar chart of split tensile strength of concrete cube at 28 days

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D. Flexural Strength of Cuboid

The flexural strength of cuboid after 28 days of curing is given in TABLE IV

TABLE IV
FLEXURAL STRENGTH OF CUBOID

% Replacement	28 Days	
	Load applied, (KN)	Flexural strength, (N/mm2)
0	10.6	7.950
1	10.6	7.950
3	11.7	8.775
5	10.7	8.025

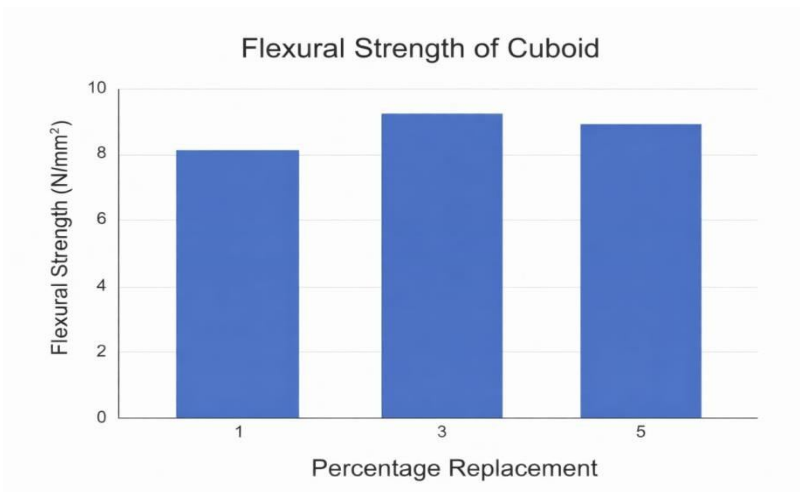

FIG. 3 Bar Chart of flexural strength of cuboid at 28 days

E. Internal Curing of Cube

The amount of water absorbed by the concrete cube after 28 days of curing is given in TABLE V

TABLE V
INTERNAL CURING OF CUBE

% Replacement	Initial amount of water (L)	Amount of water after curing of 28 days (L)	Amount of water absorbed (L)
0	8	7.300	0.700
5	8	7.425	0.575

V. CONCLUSIONS

This study investigated the use of biochar as a partial replacement for fine aggregate (sand) in concrete to promote internal curing and sustainable construction. Different percentages of biochar replacement (0%, 1%, 3%, and 5%) were tested and their mechanical properties were compared with conventional concrete.

From the experimental results, it was observed that the compressive strength of concrete increased with the addition of biochar up to 3% replacement, where the maximum compressive strength of 24.44 N/mm² was obtained at 28 days. When the replacement was increased to 5%, the strength slightly decreased but still remained higher than normal concrete. The split tensile strength and flexural strength of concrete also showed improvement with the addition of biochar, indicating that biochar contributes positively to the mechanical performance of concrete.

The internal curing test results showed that concrete containing 5% biochar absorbed less external water compared to normal concrete, which indicates that biochar can store water in its porous structure and gradually release it during cement hydration. This improves the internal curing effect and hydration process in concrete.

From the cost analysis, it was observed that biochar concrete is slightly more expensive than conventional concrete. However, the environmental benefits, improved curing, and better performance make it a sustainable alternative for construction materials. Therefore, it can be concluded that biochar can be effectively used as a partial replacement for sand in concrete, with 3–5% replacement giving optimum performance, while also supporting sustainable and eco-friendly construction practices.

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