

# SUSTAINABLE CONCRETE BLOCKS INCORPORATING BIOCHAR AND BASALT ROCK FIBRE: EXPERIMENTAL ASSESSMENT OF MECHANICAL AND DURABILITY PERFORMANCE

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**Abstract-** This study evaluates sustainable concrete blocks produced by partially replacing fine aggregate with biochar and incorporating basalt rock fibre as a discrete reinforcement, with all experimental details derived from the attached project report and excluding any SEM analysis or SEM-related discussion. Five mixes were investigated: a control mix and four biochar-modified mixes containing 1%, 1.25%, 1.5%, and 1.75% biochar, while basalt rock fibre was maintained at 0.3% in the modified mixes. The experimental program covered slump, compressive strength, split tensile strength, water absorption, and porosity. Results showed that increasing biochar content reduced slump from 75 mm to 50 mm, while compressive strength remained within a narrow range of 27.05-28.11 MPa. Water absorption decreased from 7.16% in the control mix to 4.95% at 1.75% biochar, and porosity dropped from 14.37% to 5.45%, indicating significant durability improvement. The 1.5% biochar mix provided the most balanced overall performance by retaining strength while substantially lowering absorption and porosity. These findings support the use of biochar and basalt rock fibre in non-load-bearing concrete block applications aimed at greener construction.

**Keywords-** Biochar, basalt rock fibre, sustainable concrete blocks, compressive strength, split tensile strength, water absorption, porosity, green construction.

## I. INTRODUCTION

The construction industry consumes large quantities of raw materials and contributes substantially to environmental degradation through carbon emissions, aggregate extraction, and energy-intensive production systems. Conventional concrete remains indispensable for infrastructure, but its ecological cost has driven interest in low-impact alternatives that can conserve natural resources without unacceptable losses in performance. Sustainable concrete blocks are particularly attractive because they allow partial replacement of conventional ingredients in products widely used for partitions, infill walls, and non-load-bearing masonry.

Biochar is a carbon-rich material obtained from the pyrolysis of agricultural and organic biomass under limited oxygen conditions, and its lightweight, porous structure makes it relevant for cementitious applications. The project report describes biochar as

having high porosity, low density, and carbon sequestration potential, which together make it attractive as a sustainable replacement material in concrete blocks. Because biochar can alter density, moisture movement, and pore structure, its dosage must be optimized so that environmental benefit does not come at the expense of engineering performance.

Basalt rock fibre was selected as a complementary reinforcement because it improves crack resistance, tensile behavior, and toughness in concrete systems. The report states that basalt fibres are durable, chemically stable, and suitable for sustainable construction, with the fibre used in this study having an aspect ratio of 600 and a dosage of 0.3% in modified mixes. This combination of biochar and basalt fibre creates a hybrid material system intended to balance sustainability, mechanical reliability, and durability.

The project report identifies the underutilization of biochar in construction despite its potential to reduce dependence on natural aggregates, valorize biomass waste, and support carbon reduction goals. At the same time, the report notes that higher biochar contents can adversely influence mechanical performance because its porous structure may increase internal voids and reduce cohesion. The main research need, therefore, is to determine whether biochar can be incorporated into concrete blocks in a dosage range that preserves practical strength while improving durability-related properties.

The present manuscript addresses that need by examining concrete blocks made with 0%, 1%, 1.25%, 1.5%, and 1.75% biochar, alongside basalt rock fibre reinforcement in the modified mixes. The aim is to identify an optimum composition suitable for sustainable non-load-bearing block applications using the results of fresh, mechanical, and durability tests from the report. SEM analysis and SEM-based interpretation are intentionally omitted

from this manuscript, in line with the stated requirement.

The reported study was designed to evaluate compressive strength, water absorption, structural performance, and comparative behavior of biochar-incorporated blocks relative to conventional concrete blocks. The objectives also included studying split tensile strength, workability, and the broader applicability of biochar blocks in sustainable construction practice. Together, these objectives position the work as an applied experimental investigation rather than a purely materials-characterization study.

## II. LITERATURE CONTEXT

The literature summarized in the report indicates that biochar can improve compressive strength by about 5% to 30% when used in optimum proportions, while also reducing thermal conductivity and improving sustainability performance. The report also cites work showing that moderate biochar dosages in cement mortars improved strength and reduced water absorption, whereas higher dosages increased porosity and reduced compressive strength. A cited meta-analysis further suggested that biochar produced above 450 °C can enhance 28-day compressive strength more effectively, indicating that biochar characteristics strongly influence cement composite behavior.

The report's basalt fibre review shows that basalt fibre improves tensile strength, toughness, ductility, and crack resistance when used in small dosages. One study summarized in the report identified 0.25% fibre as an optimum level for improved concrete performance, while other cited work emphasized basalt fibre's high elastic modulus, thermal stability, and chemical resistance. These findings support the decision to combine biochar with basalt fibre in the present investigation.

## III. MATERIALS AND METHODS

### A. MATERIALS

Ordinary Portland Cement of 53 grade conforming to IS 12269 was used as the primary binder, and the report gives its specific gravity as 3.10 with

acceptable setting characteristics. Coarse aggregate conforming to IS 383:2016 was used with a maximum size of 12.5 mm, angular shape, and fineness modulus around 6.37. Manufactured sand was used as fine aggregate, with the report listing a specific gravity of 2.15, water absorption of 3.61%, fineness modulus of 3.0, and Zone II grading.

Biochar was introduced as a partial replacement for fine aggregate at 1%, 1.25%, 1.5%, and 1.75%, and the report describes its specific gravity as approximately 0.6. Basalt rock fibre with an aspect ratio of 600 was used at 0.3% in modified mixes to improve toughness and crack resistance. Potable water conforming to IS 456:2000 was used for mixing and curing.

The report provides physical properties for the cement, coarse aggregate, and M-sand used in the investigation. Cement showed fineness of 2.4% retained on 90-micron sieve, initial setting time of 31 minutes, and final setting time of 475 minutes, which the report considered acceptable relative to code limits. Coarse aggregate properties included specific gravity of 2.37, bulk density of 1590 kg/m<sup>3</sup>, aggregate impact value of 12.52%, aggregate crushing value of 26.67%, water absorption of 0.3%, and flakiness index of 24.2%. The M-sand was reported to have specific gravity 2.15, water absorption 3.61%, fineness modulus 3.0, and Zone II grading.

### B. EXPERIMENTAL PROGRAM

Five mixes formed the experimental matrix: a control mix without biochar and four biochar-modified mixes containing 1%, 1.25%, 1.5%, and 1.75% biochar. The modified mixes also included 0.3% basalt rock fibre, and the performance evaluation covered slump, compressive strength, split tensile strength, water absorption, and porosity. The testing program was intended to assess how incremental biochar addition affects workability, strength retention, and durability-related properties in concrete blocks.

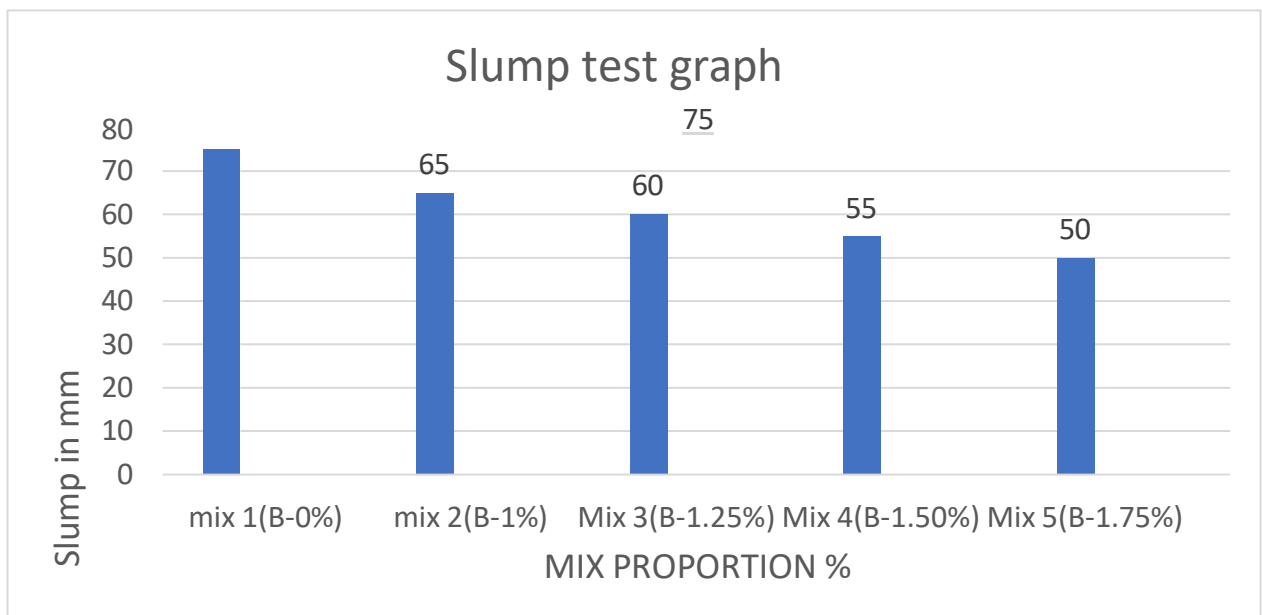
## IV. RESULTS AND DISCUSSION

### A. WORKABILITY

The slump values reported for the mixes were 75 mm for the control, 71 mm at 1% biochar, 65 mm at

1.25%, 62 mm at 1.5%, and 50 mm at 1.75%. This because it highlights the trade-off between consistent reduction in slump indicates that the sustainability-oriented material substitution and combined effect of porous biochar and basalt fibre fresh-state handling performance. At low to increased internal friction and reduced the free moderate dosages, the reduction in slump appears water available for flow. Even so, the recorded manageable, but the sharpest drop occurs at the slump values suggest that all mixes remained highest replacement level. This implies that larger-workable enough for casting and compaction in scale manufacturing may require careful water block production. control or admixture use if higher biochar contents are adopted.

The workability trend is practically important are adopted.

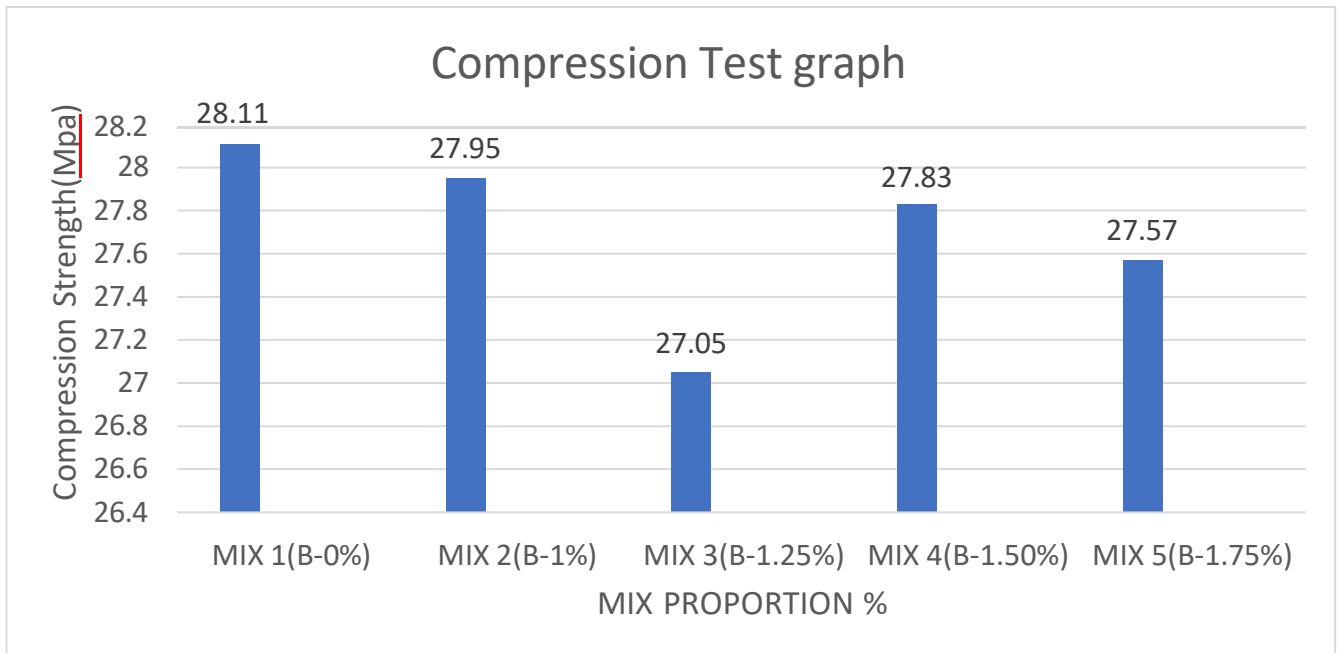


**Fig. 1: Slump values in mm for the mixes**

## B. COMPRESSIVE STRENGTH

The compressive strengths reported were 28.11 MPa for the control mix, 27.95 MPa for 1% biochar, 27.05 MPa for 1.25%, 27.83 MPa for 1.5%, and 27.57 MPa for 1.75%. The overall reduction relative to the control is modest, which indicates that the tested biochar replacement range did not cause severe strength loss. The 1.5% mix performed better than the 1.25% and 1.75% mixes, suggesting that the response is dosage-sensitive rather than monotonically decreasing.

This pattern can be interpreted as evidence that moderate biochar content may support better moisture regulation and internal curing, whereas excessive porous material may weaken the matrix. The relatively small spread in compressive strength also suggests that basalt fibre contributed indirectly by limiting microcrack propagation and preserving matrix integrity. For non-load-bearing or lightly loaded concrete blocks, the reported strength values remain technically useful.

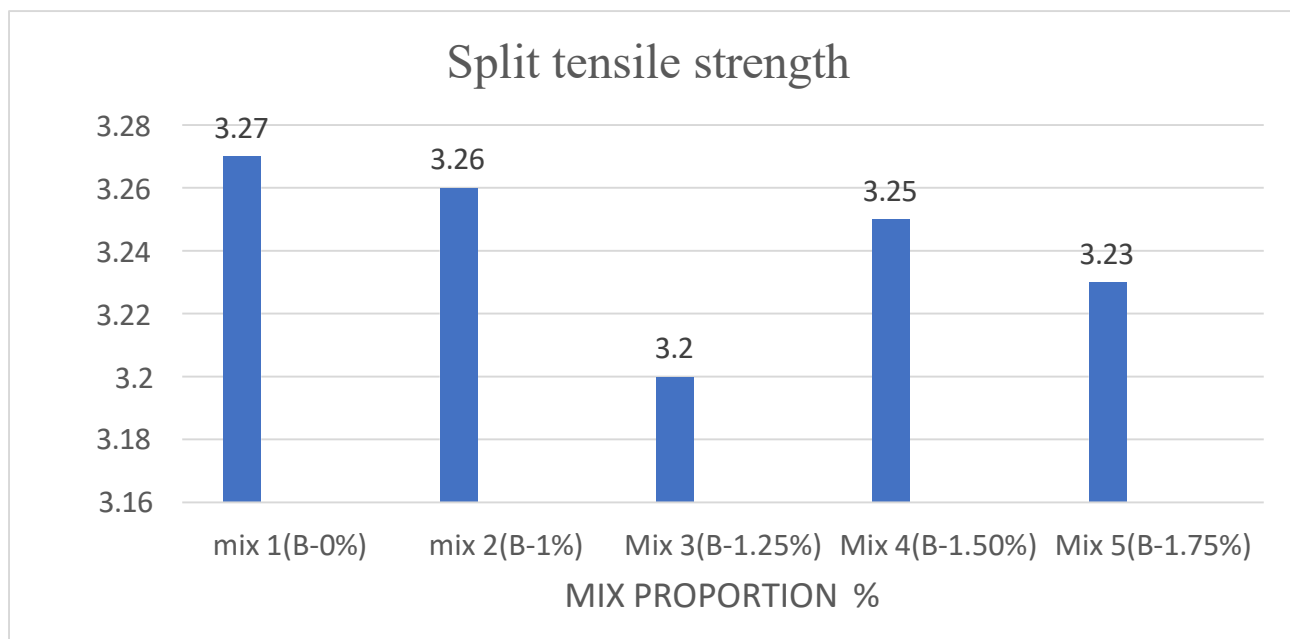


**Fig. 2: Compressive Strength**

**C. SPLIT TENSILE STRENGTH**

The split tensile strength values were 3.27 MPa for the control mix, 3.25 MPa at 1% biochar, 3.20 MPa at 1.25%, 3.25 MPa at 1.5%, and 3.23 MPa at 1.75%. These values show only small variation across the mixes, indicating that tensile integrity was largely maintained despite the inclusion of lightweight porous biochar. The recovery at 1.5% biochar further supports the interpretation that this

dosage provides a favorable performance balance. The stability of tensile strength is significant because porous replacement materials often increase brittleness when used without reinforcement. In this case, basalt fibre likely helped bridge developing cracks and sustain load transfer after cracking initiated. That mechanism aligns with the literature summarized in the report and strengthens the case for using fibre and biochar together rather than biochar alone.



**Fig. 3 Split Tensile Strength**

#### D. WATER ABSORPTION

Water absorption decreased from 7.16% in the control mix to 6.41% at 1% biochar, 5.89% at 1.25%, 5.21% at 1.5%, and 4.95% at 1.75%. This is one of the clearest positive trends in the study because it indicates improved resistance to water ingress as biochar content increased. Reduced water absorption is highly desirable in concrete blocks because it can limit dampness-related problems and improve long-term serviceability. The drop in absorption suggests that biochar may

have improved moisture regulation and contributed to a more refined internal structure after curing. Although biochar is itself porous, the hardened composite behavior indicates that the overall transport pathways became less favorable for bulk water ingress. This result is especially important for masonry applications exposed to varying humidity or intermittent wetting.

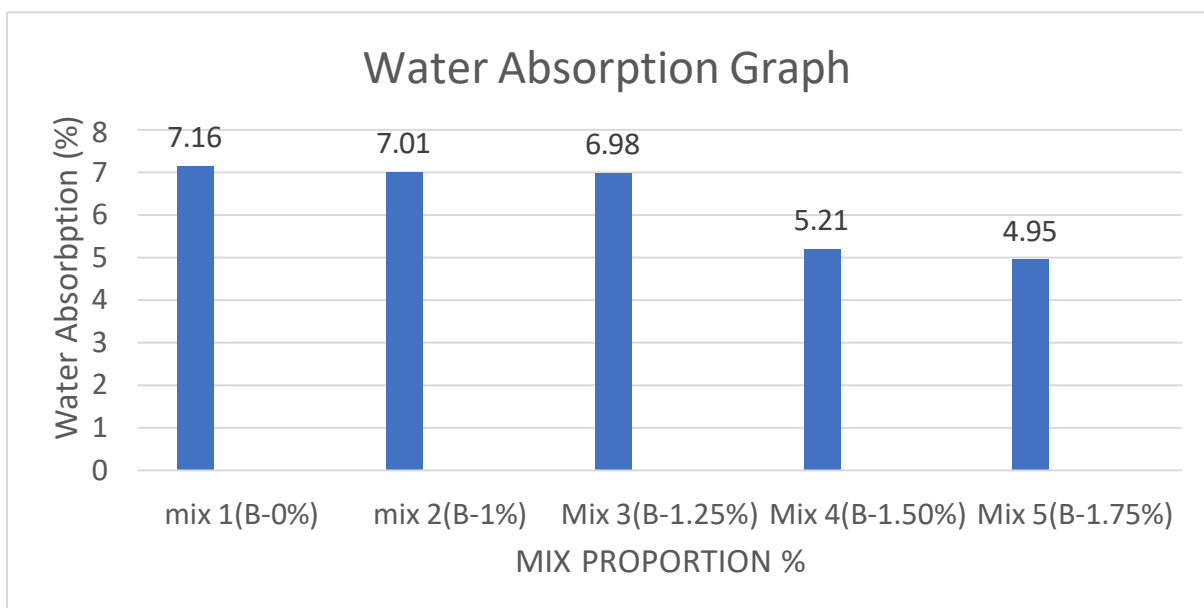


Fig. 4: Water absorption

#### E. POROSITY

The reported porosity values were 14.37% for the control mix, 12.15% at 1% biochar, 8.01% at 1.25%, 5.62% at 1.5%, and 5.45% at 1.75%. This substantial reduction mirrors the water absorption trend and indicates that the hardened matrix became less permeable as biochar content increased within the tested range. The largest improvements occurred between the control and the 1.5%-1.75% mixes. Lower porosity is a critical durability indicator because it reduces the pathways available for water and aggressive agents to enter the block. In the present data, the strong porosity reduction was achieved without a proportionate loss in compressive strength, which makes the result especially encouraging. The combined porosity and absorption trends are central to the practical value of the material system.

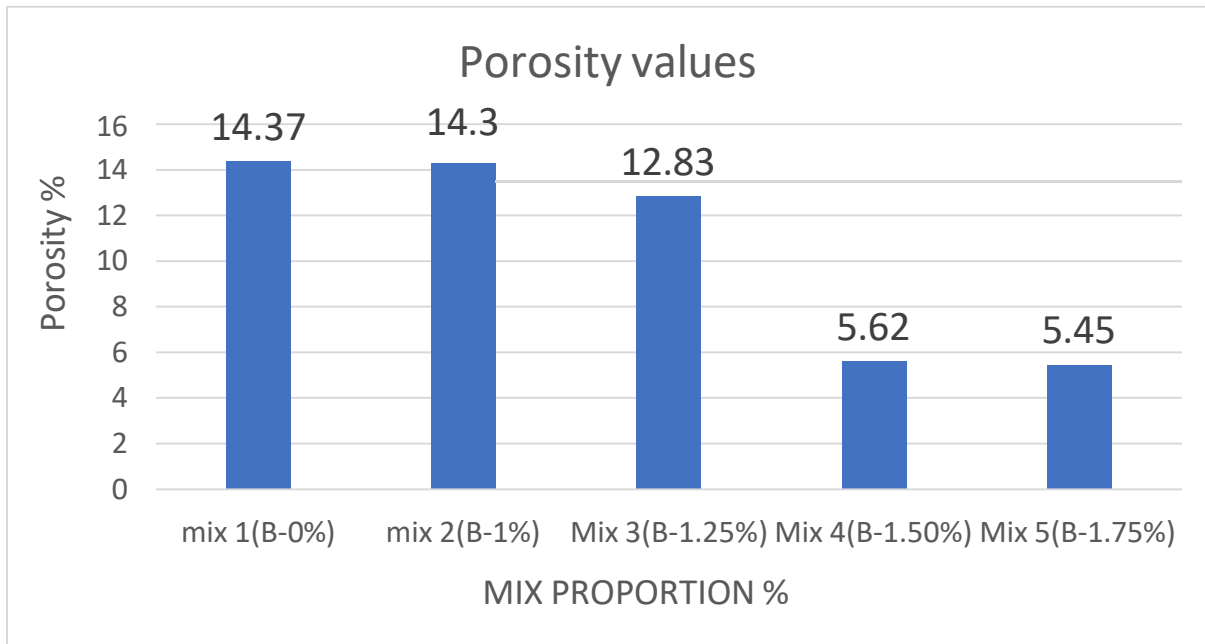


Fig. 5: Porosity

#### F. OPTIMUM MIX INTERPRETATION

Among the tested mixes, the 1.5% biochar mix appears to provide the most balanced overall performance. It retained compressive strength close to the control at 27.83 MPa, maintained split tensile strength at 3.25 MPa, and reduced water absorption and porosity to 5.21% and 5.62%, respectively. Although the 1.75% mix produced slightly lower water absorption and porosity, its compressive strength was somewhat lower than that of the 1.5% mix.

This balance is important for block applications because a practical optimum should consider fresh behavior, strength, and durability together rather than maximizing a single parameter. On that basis, 1.5% biochar with 0.3% basalt fibre can be interpreted as the most suitable formulation among the reported mixes. The 1.75% mix remains promising where moisture resistance is prioritized over marginal strength retention.

#### V. ENGINEERING IMPLICATIONS

The results suggest that low-level biochar replacement can be used to produce more sustainable concrete blocks without major compromise in mechanical performance. The reduction in water absorption and porosity is

particularly relevant for blocks used in partitions, infill walls, and other non-load-bearing applications where serviceability and durability strongly influence field performance. Basalt fibre addition appears to enhance the robustness of the system by helping maintain tensile behavior despite the introduction of a porous sustainable additive.

From a sustainability perspective, the material system supports biomass waste utilization, lower dependence on conventional fine aggregate, and potential carbon sequestration within a durable construction product. These advantages make the proposed blocks suitable for green building and resource-efficient construction strategies. The study therefore contributes not only to material science but also to practical block technology for environmentally conscious construction.

#### VI. LIMITATIONS

The manuscript is based on a single project dataset with a limited range of biochar dosages and a fixed fibre content of 0.3%. Because the report does not provide broader statistical replication or long-term environmental exposure data, the findings should be interpreted as a strong experimental baseline rather than a final universal prescription. The manuscript also

intentionally excludes SEM analysis and SEM discussion, consistent with the stated requirement.

Additional limitations include the dependence of biochar performance on feedstock, pyrolysis conditions, particle size, and pre-treatment, all of which can affect composite behavior. As a result, the optimum identified here should be validated against other biochar sources before industrial scaling.

#### VII. FUTURE RESEARCH

Future studies should examine long-term durability, shrinkage, thermal conductivity, abrasion resistance, and life-cycle environmental performance of biochar-based blocks. Full-scale block production trials and field exposure studies would also help establish manufacturability and service performance under realistic conditions. Economic analysis is another necessary step if the material is to be promoted for commercial block production. Further work may also explore other sustainable hybrid systems by varying fibre dosage, biochar fineness, and replacement strategy. Even without SEM, alternative non-microscopy characterization tools can be used to deepen understanding of transport and hydration behavior in these composites.

#### VIII. CONCLUSION

The attached project data demonstrate that biochar and basalt rock fibre can be combined successfully to produce sustainable concrete blocks with acceptable mechanical performance and substantially improved durability indicators. Increasing biochar content reduced slump, but all mixes remained workable enough for practical casting. Compressive strength remained within a relatively narrow range of 27.05-28.11 MPa, while split tensile strength stayed close to 3.2-3.27 MPa across all mixes.

The most important gains were seen in water absorption and porosity, which declined markedly as biochar content increased. On the basis of balanced overall performance, the 1.5%

biochar mix with 0.3% basalt rock fibre appears to be the most suitable option among the mixes investigated. The study supports the development of greener non-load-bearing concrete blocks using waste-derived biochar and durable mineral fibre reinforcement.

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