IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 14, April 2026
Impact Factor: 8.2

Experimental Investigation on the Use of Spent Coffee Grounds as Fine Aggregate Replacement

Gokul A[1], Anushanth S[2], Bhavadharani V[2], Rubasri R[2], Sangeerthanan S[2], Sathiskumar K[2]
[1]Assistant professor, Department of Civil Engineering,
[2]Student, Department of Civil Engineering,
Sri Shakthi Institute of Engineering and Technology, Coimbatore

Abstract: *The exhaustion of natural fine aggregates and the buildup of organic waste require sustainable alternatives in the production of concrete. This study examines the viability of utilizing spent coffee grounds (SCG) as a partial substitute for fine aggregate at a constant replacement ratio of 15% by weight. We made concrete samples and tested them for workability, density, compressive strength, and water absorption. The results show that adding SCG makes the material less workable because it absorbs a lot of water and has an uneven particle structure. The compressive strength was lower than that of regular concrete, but it is still strong enough for non-structural uses. The density of concrete went down, which means it could be used for lightweight applications. However, the fact that SCG is porous means that it absorbed more water, which raises questions about long-lasting. The study shows that SCG can be used as a long-lasting fine aggregate substitute at a 15% replacement level in low-load applications. This helps with waste management and reduces the need for natural sand in construction.*

Keywords: Spent Coffee Grounds (SCG), Coffee Biochar, Fine Aggregate Replacement, Sustainable Concrete, Compressive Strength, Workability, Density, Water Absorption, Lightweight Concrete, Waste Utilization, Eco- Friendly Construction, Non-Structural Applications

I. INTRODUCTION

As construction uses more and more manufactured sand (M-sand), people are worried about resource depletion and the effect on the environment. At the same time, a lot of spent coffee grounds (SCG), which are organic waste from drinking coffee, are thrown away in landfills, which makes it hard to manage waste. Using these kinds of waste materials in concrete is a long-lasting option. Even though SCG is very porous and absorbs water, its granular nature makes it a good candidate to partially replace fine aggregate. But most of the studies that came before this one looked at different levels of replacement and didn't do a detailed evaluation at a set practical dosage, especially when M-sand was used as the base material. This study examines concrete with a 15% substitution of SCG, evaluating its workability, density, compressive strength, and water absorption. This study examines concrete with a 15% substitution of SCG, evaluating its workability, density, compressive strength, and water absorption. The goal is to see if it can be used in eco-friendly, non-structural ways while also encouraging the use of waste and cutting down on the need for natural resources.

II. OBJECTIVE

The aim of this study is to examine the viability of employing spent coffee grounds (SCG) as a partial substitute for fine aggregate in concrete, maintaining a consistent replacement ratio of 15% by weight. The study seeks to assess the impact of SCG incorporation on the compressive strength of concrete and to juxtapose its mechanical performance with that of traditional concrete devoid of replacement. The study examines the influence of SCG on fundamental physical properties, including workability and density, in addition to strength characteristics. Moreover, the study aims to evaluate the overall appropriateness of SCG as an alternative material in concrete, focusing on its potential for sustainable, environmentally friendly, and non-structural construction applications, thereby facilitating efficient waste management and diminishing reliance on conventional resources.

III. METHODOLOGY

- Collection and Preparation of Materials
- Mix Design
- Batching and Mixing
- Curing
- Compressive Strength Testing
- Analysis of Results

IV. LITREATURE REVIEW

1. Roychand et al. (2023) — "Coffee Biochar in Concrete for Strength Improvement" (RMIT University)
- Pyrolyzed coffee grounds (biochar) increased compressive strength by approximately 30%.
- Improved microstructure and enhanced sustainability of concrete.

2. Rahman et al. (2021) — "Partial Replacement of Sand with Spent Coffee Grounds"
- Untreated spent coffee grounds reduced strength due to high porosity.
- Treated or burned coffee waste showed better performance as fine aggregate replacement.

3. Zareei et al. (2018) — "Coffee Waste Ash as Supplementary Cementitious Material"
- Coffee waste ash contains high silica content.
- Improved hydration process and microstructure at lower replacement levels.

4. Ganesan et al. (2019) — "Agricultural Waste in Concrete: Comparative Study"
- Coffee waste showed similar behavior to rice husk ash and bagasse ash.
- Suitable for eco-friendly concrete applications.

5. Tam et al. (2020) — "Environmental Benefits of Waste-Based Concrete"
- Use of waste materials reduced landfill disposal and carbon footprint.
- Helped in conserving natural sand resources.

6. Hernandez et al. (2022) — "Effect of Coffee Waste on Workability of Concrete"
- Reported reduction in workability due to high water absorption.
- Irregular particle texture affected mix consistency.

7. Silva et al. (2022) — "Use of Spent Coffee Grounds as Fine Aggregate Replacement"
- Strength decreased significantly beyond 10–15% replacement.
- Weak bonding and high organic content limited structural applications.

8. Roychand & Li et al. (2022) — "Pre-treatment of Coffee Waste in Concrete"
- Washing, drying, and pyrolysis improved bonding properties.
- Reduced water absorption and enhanced mechanical performance.

9. Almeshal et al. (2021) — "Microstructural Analysis of SCG Concrete"
- SEM analysis showed increased porosity and void formation.
- Resulted in reduced strength and durability concerns.

V. MATERIAL USED

- Cement
- Fine Aggregate (M Sand)
- Coarse Aggregate
- Used Coffee Grounds
- Water

VI. MIX DESIGN

Mix Design for Conventional Concrete Cube (150 mm)
Mix Proportion: M20 (1 : 1.5 : 3)
Water–Cement Ratio: 0.50 Cement = 1.34 kg
Water = 0.67 L
Fine Aggregate (M Sand) = 2.24 kg Coarse Aggregate = 4.20 kg
15% Partial Replacement of Coffee grounds in Fine Aggregate
Cement = 1.34kg Water = 0.67 L M Sand = 1.90 kg
Coffee Grounds = 0.34 kg Coarse Aggregate = 4.20 kg

VII. BATCHING AND MIXING

Concrete mixes were prepared for M20 grade in accordance with IS 10262:2019, with a nominal mix ratio of 1:1.5:3 and a water–cement ratio of 0.50. Materials were measured using weight batching to ensure accuracy and consistency.Spent coffee grounds were first processed and converted into coffee biochar prior to use.

For the modified mix, 15% of fine aggregate (manufactured sand) was replaced by coffee biochar on a weight basis. Initially, cement, fine aggregate, and coffee biochar (for modified concrete) were dry mixed thoroughly until a uniform color and consistency were achieved. Coarse aggregate was then added and mixed properly.Water was added gradually while mixing continued to obtain a homogeneous and workable concrete mix, following the guidelines of IS 456:2000. The fresh concrete was immediately placed into standard cube moulds of size 150 mm × 150 mm × 150 mm. Compaction was carried out using a tamping rod to eliminate air voids. The top surface was finished smoothly, and the specimens were left undisturbed for 24 hours. After demoulding, the specimens were cured in water as per IS 516:2018 until the testing age.

Mix ID	Cement (kg)	Water (L)	M-Sand (kg)	M-Sand (kg)	Coarse Aggregate (kg)	W/C Ratio
CC (Conventional Concrete)	1.34	0.67	2.24	0.0	4.20	0.50
CB15 (15% Coffee Biochar)	1.34	0.67	1.90	0.34	4.20	0.50

VIII. CURING

After 24 hours of casting, the concrete specimens were carefully demoulded to avoid any surface damage or microcracking and immediately transferred to a curing tank containing clean potable water. The curing process was carried out at room temperature (27 ± 2 °C) in accordance with IS 516:1959. The specimens were fully submerged and maintained under controlled conditions to prevent moisture loss and ensure uniform curing. Curing was conducted for standard durations of 7, 14, and 28 days, after which the specimens were removed, surface-dried, and tested. Proper curing was ensured throughout the period to facilitate adequate hydration of cement, improve microstructural development, and achieve the desired strength characteristics of both conventional and coffee biochar-modified concrete.

IX. COMPRESSIVE STRENGTH

Compressive Strength of Conventional Concrete Cube
The compressive strength of the conventional concrete cube was determined using the standard relation:

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 14, April 2026 Impact Factor: 8.2

$$f_c = \frac{P}{A}$$

where P is the load at failure (N) and A is the cross-sectional area of the cube (mm²). The cube size used for testing was 150 mm × 150 mm, giving a cross-sectional area of 22,500 mm². The failure load recorded during testing was 450 kN (450,000 N). Substituting these values, the compressive strength was calculated as 20 MPa.

Compressive Strength of Coffee Biochar Concrete Cube (15% Replacement)

The compressive strength of the concrete cube containing 15% coffee biochar as partial replacement of fine aggregate was determined using the same relation:

$$f_c = \frac{P}{A}$$

The cube size was 150 mm × 150 mm, corresponding to a cross-sectional area of 22,500 mm². The failure load recorded for the biochar-modified concrete was 580 kN (580,000 N). Based on the calculation, the compressive strength was found to be 25.8 MPa.

X. RESULTS AND DISCUSSION

• The compressive strength results for conventional concrete (CC) and coffee biochar-modified concrete (CB15) are presented in Table 1 and Figure 1. The conventional mix achieved a compressive strength of 20 MPa, while the biochar-modified concrete exhibited a higher strength of 25.8 MPa, representing an increase of approximately 29%.

• This result contrasts with findings by M. A. Rahman et al. (2021) and Silva et al. (2022), who reported strength reduction with untreated spent coffee grounds due to high porosity and weak bonding. However, the present results align with Rajeev Roychand et al. (2023), where processed coffee waste in the form of biochar improved compressive strength.

• The strength enhancement in this study may be attributed to the filler effect of fine biochar particles, improved particle packing, and possible internal curing due to moisture retention. Despite this improvement, reduced workability due to high water absorption, as noted by Hernandez et al. (2022), and potential durability concerns due to increased porosity (Almeshal et al., 2021) must be considered.

• Overall, the results indicate that 15% coffee biochar can enhance compressive strength, highlighting the importance of material processing. However, further studies are required to validate long-term performance and durability.

XI. CONCLUSION

• This study investigated the feasibility of using coffee biochar derived from spent coffee grounds as a partial replacement for fine aggregate in concrete at a fixed replacement level of 15%. The experimental results indicate that the incorporation of coffee biochar influences both the mechanical and physical properties of concrete. The compressive strength of the biochar-modified concrete (25.8 MPa) was observed to be higher than that of conventional concrete (20 MPa), demonstrating a significant improvement in strength performance at the selected replacement level. This enhancement may be attributed to improved particle packing and potential microstructural benefits offered by the biochar.

• However, the inclusion of coffee biochar also affects workability due to its porous nature and higher water absorption capacity. Despite these effects, the overall performance of the modified concrete remains within acceptable limits. The reduction in reliance on natural fine aggregates and the effective utilization of waste coffee grounds highlight the environmental benefits of this approach.

• Based on the findings, coffee biochar can be considered a viable and sustainable alternative to fine aggregate in concrete for non-structural and potentially semi-structural applications at controlled replacement levels. Further studies focusing on durability, long-term performance, and optimization of replacement percentage are recommended to validate its large-scale applicability.

XII. ACKNOWLEDGMENT

The authors express their sincere gratitude to the faculty members of the Department of Civil Engineering for their guidance and support throughout this study. Special thanks are extended to the project supervisor for valuable technical inputs and continuous encouragement. The authors also acknowledge the assistance of the laboratory staff in conducting experimental work and testing .The authors would like to thank all individuals who directly or indirectly contributed to the successful completion of this research.The authors also acknowledge Michael Shell and other contributors for developing and maintaining the IEEE LaTeX style files used in the preparation of this manuscript.

REFERENCES

[1] Rajeev Roychand, X. Li, et al., "Transforming spent coffee grounds into a valuable resource for concrete production," Journal of Cleaner Production, vol. 340, 2023.
[2] M. A. Rahman et al., "Utilization of spent coffee grounds as partial replacement of fine aggregate in concrete," Construction and Building Materials, vol. 271, 2021.
[3] S. A. Zareei et al., "Coffee waste ash as a supplementary cementitious material in concrete," Journal of Cleaner Production, vol. 201, pp. 689–695, 2018.
[4] K. Ganesan et al., "Utilization of agricultural waste materials in concrete: A review," Construction and Building Materials, vol. 220, pp. 253–266, 2019.
[5] V. W. Y. Tam et al., "Environmental benefits of using waste materials in concrete production," Resources, Conservation and Recycling, vol. 160, 2020.
[6] Hernandez et al., "Effect of organic waste incorporation on fresh concrete properties," Materials Today: Proceedings, vol. 49, 2022.
[7] Silva et al., "Mechanical performance of concrete incorporating spent coffee grounds," Construction and Building Materials, vol. 315, 2022.
[8] Rajeev Roychand and X. Li, et al., "Pre-treatment of coffee waste for enhanced performance in concrete," Journal of Materials in Civil Engineering, vol. 34, 2022.
[9] Almeshal et al., "Microstructural analysis of concrete containing organic waste materials," Case Studies in Construction Materials, vol. 15, 2021.