

Strength Properties of Banana Fibre Concrete with Copperslag

J. Sree Naga Chaitanya¹, Dr. K. Chandramouli², Pathan Bahadur Khan³

Assistant Professor, Department of Civil Engineering, NRI Institute of Technology, Visadala (V), Medikonduru (M), Guntur, Andhra Pradesh, India¹

Professor & HOD, Department of Civil Engineering, NRI Institute of Technology, Visadala (V), Medikonduru (M), Guntur, Andhra Pradesh, India²

P.G. Scholar, Department of Civil Engineering, NRI Institute of Technology, Visadala (V), Medikonduru (M), Guntur, Andhra Pradesh, India³

ABSTRACT: This study investigates the strength properties of sustainable concrete incorporating banana fibre and copper slag. Copper slag is utilized as a partial replacement for fine aggregates to enhance density and reduce industrial waste. Natural banana fibres are introduced at an optimized volume fraction to improve the tensile strength and ductility. Mechanical performance was evaluated through compressive strength, split tensile strength, and ultrasonic pulse velocity (UPV) tests. Concrete specimens were cast and tested after standard curing periods of 7 and 28 days. The 7-day compressive strength showed a steady early strength gain, comparable to the control mix. By day 28, the compressive strength exhibited a significant increase due to the pozzolanic reaction of copper slag. The inclusion of banana fibres significantly enhanced the split tensile strength at both 7 and 28 days. Fibres effectively bridged internal micro-cracks, preventing sudden brittle failure under tensile loading. Non-destructive testing via UPV was conducted to assess the structural integrity and homogeneity of the concrete. The UPV values at 7 days indicated a satisfactory pulse velocity, confirming early-stage compaction. At 28 days, the UPV results fell within the "Good" to "Excellent" quality range, signifying a dense matrix.

KEYWORDS: Banana Fibre Concrete, Copper Slag, Sustainable Construction, Eco-friendly Concrete, Compressive strength, Ultrasonic Pulse Velocity and Split tensile strength.

I. INTRODUCTION

Concrete is the world's most widely used manufactured material, formed by mixing cement, water, and aggregates. Through a chemical process called hydration, the mixture hardens into a stone-like mass with exceptional compressive strength. It serves as the foundational backbone for modern global infrastructure, from highways to skyscrapers. However, its massive production drives a high carbon footprint, sparking intense research into greener alternatives. Modern concrete technology focuses heavily on incorporating industrial and natural wastes to boost sustainability.

Copper slag is an industrial by-product obtained during the matte smelting and refining of copper. Possessing mechanical properties highly similar to natural sand, it is an ideal partial replacement for fine aggregates. Its high density and low water absorption enhance the workability and durability of the resulting concrete matrix. Furthermore, it exhibits mild pozzolanic properties that contribute to long-term compressive strength gains. Utilizing this slag not only conserves natural river sand but also solves a major industrial waste disposal problem.

Banana fibre is a natural, biodegradable material extracted from the pseudostem of the banana plant. Characterized by low density, high tensile strength, and strong fire resistance, it acts as an effective micro-reinforcement. When added to concrete, these fibres bridge internal micro-cracks, transforming a brittle matrix into a ductile composite. They significantly improve the material's split tensile and flexural strength while reducing shrinkage cracks. Using this agricultural waste promotes eco-friendly construction and adds economic value to farming communities.

II. OBJECTIVES

1. To analyze the feasibility of utilizing industrial waste (copper slag) as a fine aggregate replacement and agricultural waste (banana fibre) as a natural reinforcement to create a greener, cost-effective concrete composite.
2. To investigate the effect of combining banana fibre and copper slag on the compressive strength and split tensile strength of concrete at early (7 days) and mature (28 days) curing ages.
3. To determine the homogeneity, density, and quality of the concrete matrix using Ultrasonic Pulse Velocity (UPV) testing at 7 and 28 days, and to establish a correlation with destructive test results.

III. MATERIALS

1. **Cement:** A hydraulic binding material made from calcined limestone and clay that sets and hardens when mixed with water. It acts as the chemical glue that binds aggregate particles together into a solid structural mass.
2. **Fine Aggregate:** Small mineral particles, typically natural or manufactured sand, that pass through a 4.75 mm sieve. They fill the structural voids between larger aggregates and help create a workable mortar paste.
3. **Coarse Aggregate:** Crushed stones, gravel, or boulders larger than 4.75 mm that form the primary skeleton of the concrete. They provide the bulk volume, dimensional stability, and resistance to heavy compressive loads.
4. **Water:** A key chemical component that triggers the hydration reaction of cement to harden the concrete mix. It also provides the necessary fluidity and workability required to place and finish the fresh concrete.
5. **Copper Slag:** A dense, glassy industrial by-product obtained during the smelting and refining process of copper metal. It is used as a highly durable and sustainable replacement for natural sand in eco-friendly concrete.
6. **Banana Fibre:** A strong, lightweight natural fibre extracted from the waste pseudostems of banana plants. It is added to concrete as micro-reinforcement to bridge internal cracks and improve tensile strength.

IV. RESULTS AND DISCUSSION

a. Compressive strength test: A compressive strength test evaluates a concrete specimen's ability to withstand axial loading before crushing. Hardened cubes or cylinders are placed in a Universal Testing Machine and subjected to a steadily increasing compressive force. This destructive test determines the material's structural load-bearing capacity at specific intervals, typically 7 and 28 days. The resulting maximum load capacity serves as the primary benchmark for assessing overall concrete quality and compliance.

Table 1: Compressive Strength result of concrete with copperslag as partial replacement of cement.

S.No	% of Copperslag	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	21.73	32.78
2	20%	24.26	35.72
3	40%	26.22	38.03
4	60%	23.94	34.21

Table 2: Compressive Strength result of banana fibre concrete

Sl.no	% of Banana fibre	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	21.73	32.78
2	0.5%	25.24	37.85
3	1%	28.41	40.65
4	1.5%	26.36	38.42

Table 3:- Combined Compressive Strength result of concrete.

S.No	Combined Replacement(s)	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	21.73	32.78
2	40% CS+1% BF	29.38	41.96

b. Split tensile strength: This destructive method evaluates concrete's resistance to tensile cracking by applying a compressive line load along the length of a cylindrical specimen. The uniform force splits the cylinder vertically, determining the material's indirect tensile capacity rather than relying on direct pulling. It is crucial for assessing concrete performance against shearing and cracking forces at 7 and 28 days. The results help quantify how effectively reinforcements, like banana fibres, bridge micro-cracks and enhance structural ductility.

Table 4: Split tensile Strength result of concrete with copperslag as partial replacement of cement.

S.No	% of Copperslag	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	2.12	3.19
2	20%	2.43	3.56
3	40%	2.87	4.06
4	60%	2.36	3.38

Table 5: Split tensile Strength result of banana fibre concrete.

Sl.no	% of Banana fibre	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	2.12	3.19
2	0.5%	2.23	3.68
3	1%	2.86	4.04
4	1.5%	2.54	3.81

Table 6:- Combined Split tensile Strength result of concrete.

S.No	Combined Replacement(s)	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	2.12	3.19
2	40% CS+1% BF	2.94	4.15

C. Ultrasonic pulse velocity: This non-destructive technique assesses the internal quality, density, and uniformity of concrete without causing physical damage. It measures the transit time of ultrasonic longitudinal waves sent through the specimen via an electro-acoustical transducer. Higher wave velocities indicate a dense, homogenous, and defect-free concrete matrix, while slower speeds reveal internal voids or cracks. Conducting this test at 28 days provides a reliable metric to track structural integrity gains over time.

Table 7: Ultrasonic Pulse Velocity result of concrete with copperslag as partial replacement of cement.

S.No	% of Copperslag	Ultrasonic Pulse Velocity Results, m/s	
		28 days	Quality of Concrete
1	0%	4349	Good
2	20%	4481	Good
3	40%	4736	Excellent
4	60%	4557	Excellent

Table 8: Ultrasonic Pulse Velocity result of banana fibre concrete

Sl.no	% of Banana fibre	Ultrasonic Pulse Velocity Results, m/s	
		28 days	Quality of Concrete
1	0%	4349	Good
2	0.5%	4488	Good
3	1%	4629	Excellent
4	1.5%	4531	Excellent

Table 9:- Combined Ultrasonic Pulse Velocity result of concrete.

S.No	Combined Replacement(s)	Ultrasonic Pulse Velocity Results,m/s	
		28 days	Quality of Concrete
1	0%	4349	Good
2	40% CS+1% BF	4796	Excellent

V. CONCLUSION

1. The compressive strength for conventional concrete for 7 and 28 days is 21.73 and 32.78 N/mm².
2. At 40% replacement of cement with Copper slag the compressive strength for 7 and 28 days is 26.22 and 38.03 N/mm².
3. At 1.0% addition of banana fibre in concrete the compressive strength for 7 and 28 days is 28.41 and 40.65 N/mm².
4. At 40%CS+1% BF the combined replacement of concrete the compressive strength for 7 and 28 days is 29.38 and 41.96 N/mm².
5. The Split tensile strength for conventional concrete for 7 and 28 days is 2.12 and 3.19 N/mm².
6. At 40% replacement of cement with Copper slag the Split tensile strength for 7 and 28 days is 2.82 and 4.06 N/mm².
7. At 1.0% addition of banana fibre in concrete the Split tensile strength for 7 and 28 days is 2.86 and 4.04 N/mm².
8. At 40%CS+1% BF the combined replacement of concrete the Split tensile strength for 7 and 28 days is 2.94 and 4.15 N/mm².
9. The Ultra pulse velocity for conventional concrete for 28 days is 4349 m/s.
10. At 40% replacement of cement with Copper slag the Ultra pulse velocity for 28 days is 4736m/s.
11. At 1.0% addition of banana fibre the Ultra pulse velocity for 28 days is 4629 m/s.
12. At 40%CS+1% BF the combined replacement of concrete the Ultra pulse velocity for 28 days is 4796 m/s.

REFERENCES

1. Patil, M. V. (2026). Properties and effects of copper slag in concrete. *DigitalXplore Journal of Engineering*, 12(4), 66-70.
2. Rohini, I., & Padmapriya, R. (2023). Properties of bacterial copper slag concrete. *Buildings*, 13(2), 290-298.
3. Sharma, R. K., & Chaurasia, A. K. (2020). Study of copper slag as replacement of fine aggregate in concrete. *International Journal of Structural Engineering*, 8(3), 83-89.

4. Fadaee, M., & Nécira, B. (2018). Compressive and tensile properties of self-consolidating concrete made with copper slag as part of cement. *CSCE General Conference Proceedings*, 4(2), 252-258.
5. Jyothi, S. V. L., Sai, V. J., & Narasimhulu, M. (2022). Partial replacement of fine aggregate with copper slag. *RGM Journal of Civil Engineering Technology*, 15(1), 20-25.
6. Mithun, B. M., & Narasimhan, M. C. (2016). Performance of alkali-activated slag concrete mixes incorporating copper slag as fine aggregate. *Journal of Cleaner Production*, 112(1), 837-844.
7. Al-Jabri, K. S., Hisada, M., & Al-Oraimi, S. K. (2015). Influence of using copper slag as fine aggregate on the properties of cement mortars and concrete. *Construction and Building Materials*, 43(3), 331-338.
8. Khanzadi, M., & Behnood, A. (2017). Mechanical properties of high-strength concrete incorporating copper slag as a coarse aggregate. *Construction and Building Materials*, 23(5), 2183-2188.
9. Thomas, B. S., & Gupta, R. C. (2019). Long term properties of concrete with copper slag as a partial replacement of fine aggregate. *Journal of Structural Concrete*, 20(4), 1421-1430.
10. Srinivasu, K., & Ramana, N. V. (2021). Ultrasonic pulse velocity and strength structural parameters of copper slag blended concrete. *Journal of Sustainable Construction Papers*, 9(2), 112-117.
11. Al-Massri, G., Ghanem, H., Khatib, J., & Elkordi, A. (2025). Influence of adding banana fibers on the mechanical properties and volume stability of mortar for paving block applications. *Journal of Natural Fibers*, 22(1), 152-160.
12. Ganesan, V., Chohan, J. S., Subburaj, G. S., & Panneerselvam, H. (2024). Experimental analysis of mechanical properties of banana fibre/eggshell powder-reinforced hybrid epoxy composite. *MDPI Engineering Proceedings*, 61(1), 18-24.
13. Devi, T. M., Shijagurumayum, C., & Thokchom, S. (2022). An experimental study on banana fibre reinforced GGBS concrete. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, 14(1), 52-57.
14. Afraz, A., & Ali, M. (2021). Effect of banana fiber on flexural properties of fiber reinforced concrete for sustainable construction. *The 1st International Conference on Energy, Power and Environment*, 12(1), 63-69.
15. Gairola, P. S., Tyagi, Y., & Gupta, N. (2022). Mechanical properties evaluation of banana fibre reinforced polymer composites: A review. *Acta Innovations*, 42(5), 59-70.
16. Ali, M., & Pathan, A. K. (2022). Strength assessment of sustainable structural concrete reinforced with varying percentages of banana fiber. *Journal of Building Engineering*, 45(2), 104-112.
17. Logeshwar, K., & Jameel, M. A. (2022). Structural performance of natural banana fiber concrete blended with agricultural wastes. *International Journal of Concrete Structures*, 16(3), 341-348.
18. Pathan, S. I., & Jhumarwala, F. A. (2022). Compressive and flexural strengths of high-strength green concrete utilizing banana fibers. *Journal of Sustainable Built Environment*, 11(2), 89-95.
19. Ayyadurai, M., Muthuchamy Maruthai, R., & Muthu, K. (2024). Mitigating shrinkage and micro-crack failures in concrete elements using modified natural banana fibres. *Materials and Structures Journal*, 57(2), 201-209.
20. Jordan, W., & Shih, Y. F. (2019). Evaluation of pseudo-stem banana fibre as macro and micro-reinforcement inclusions in structural concrete. *Journal of Reinforced Plastics and Composites*, 38(4), 175-182.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details