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STRENGTH STUDIES ON BANANA FIBER CONCRETE WITH ZEOLITE POWDER AND COPPER SLAG

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ABSTRACT

This research investigates the synergistic effects of incorporating industrial by-products and natural fibers to develop sustainable and enhanced concrete. The study systematically explores the partial replacement of *fine aggregate with copper slag* ***at varying percentages of 10%, 20%, 30%, 40%, and 50%. Simultaneously,*** *zeolite powder* ***is utilized as a partial replacement for*** *cement* ***at concentrations of 5%, 10%, 15%, and 20%. Furthermore, to improve the ductility and crack resistance of the concrete,*** *banana fibers* ***are introduced as an additive at 1%, 2%, and 3% by weight of cement. This multi-faceted approach aims to reduce the reliance on virgin materials, mitigate environmental impact by utilizing waste, and potentially enhance the mechanical and durability properties of concrete. The findings are expected to identify optimal replacement levels for each material, contributing to the development of eco-friendly and high-performance concrete suitable for diverse construction applications in India. This study addresses critical concerns regarding resource depletion and waste management in the construction industry.***

KEYWORDS: ***Copper slag, zeolite powder, Banana fiber, workability, Compressive Strength, Split Tensile Strength.***

1. INTRODUCTION

Concrete, an indispensable material in modern construction, is a composite made primarily from cement, water, and aggregates (fine and coarse). Its versatility, strength, and durability have made it the backbone of infrastructure worldwide, forming everything from buildings and bridges to roads and dams. However, the production of its key constituent, Ordinary Portland Cement (OPC), is highly energy-intensive and a significant contributor to global carbon dioxide emissions. Furthermore, the increasing demand for natural aggregates puts immense pressure on natural resources, leading to environmental concerns like riverbed erosion and depletion of sand reserves.

In response to these environmental and resource-related challenges, the construction industry is actively

seeking sustainable alternatives and innovative materials. This pursuit often involves the incorporation of industrial by-products as supplementary cementing materials or aggregate replacements, alongside the exploration of natural fibers for property enhancement. Copper slag, a by-product generated during the pyrometallurgical extraction of copper, possesses granular characteristics similar to fine aggregates, making it a promising candidate for partial replacement. Its utilization can mitigate landfill issues associated with its disposal while conserving natural sand. Similarly, zeolite powder, a naturally occurring or synthetically produced hydrated aluminosilicate mineral, exhibits pozzolanic properties. When used as a partial replacement for cement, it can react with calcium hydroxide released during cement hydration, forming additional cementitious compounds, thereby enhancing strength and durability while reducing cement consumption and its associated environmental footprint. Beyond strength and durability, concrete often lacks sufficient tensile strength and exhibits brittle failure.

To address this, the incorporation of banana fibers, a readily available natural cellulosic fiber, offers a sustainable solution. These fibers, extracted from the pseudostem of the banana plant, can improve the post-cracking behavior, ductility, and energy absorption capacity of concrete, transforming its brittle nature into a more ductile one. This research therefore aims to comprehensively investigate the combined efficacy of copper slag, zeolite powder, and banana fibers in developing a more sustainable, environmentally friendly, and mechanically enhanced concrete, contributing to a circular economy in the construction sector within India.

2. OBJECTIVES

1.To investigate the feasibility and effectiveness of utilizing copper slag as a partial replacement for fine aggregate in concrete, specifically at 10%, 20%, 30%, 40%, and 50% replacement levels.
2.To evaluate the influence of zeolite powder as a partial replacement for cement on concrete properties, at replacement percentages of 5%, 10%, 15%, and 20%.
3.To assess the impact of incorporating banana fibers into concrete at 1%, 2%, and 3% by weight, particularly on its mechanical and fresh properties.

4. To determine the optimal combination of copper slag, zeolite powder, and banana fibers that yields enhanced mechanical properties (e.g., compressive strength and split tensile strength) of concrete.

3. MATERIALS

3.1 Cement: Cement is a fine, powdery binding material that, when mixed with water, forms a paste capable of hardening and binding other materials together. It acts as the primary binder in concrete, reacting chemically with water in a process called hydration to form a solid, durable matrix. The most common type is Portland cement, crucial for the strength and integrity of concrete structures.
3.2 Fine Aggregate: Fine aggregate typically consists of sand, or finely crushed stone/slag, with particles generally passing through a 4.75 mm sieve. It fills the voids between coarse aggregates, contributing to the workability, density, and overall homogeneity of the concrete mix. It also helps in providing a smooth finish to the concrete surface.
3.3 Coarse Aggregate: Coarse aggregate refers to larger, inert granular materials like gravel or crushed stone, with particles retained on a 4.75 mm sieve. It provides volume, strength, and stability to the concrete, acting as the main skeletal framework within the cement paste. The size and shape of coarse aggregates significantly influence the concrete's mechanical properties.
3.4 Water: Water is a crucial component in concrete, serving as a reactant in the hydration process of cement, which leads to hardening. It also acts as a lubricant, enabling the mix to be workable and allowing for proper mixing and placement. The water-cement ratio is critical as it directly influences the concrete's strength and durability.

3.5Copper slag: Copper slag is a glassy, granular by-product generated during the smelting and refining of copper ores. Due to its similar physical properties to natural sand, it is often utilized as a partial or full replacement for fine aggregate in concrete. Its use helps reduce the environmental burden of waste disposal and conserves natural sand resources.

3.6Zeolite Powder: Zeolite powder is a finely ground aluminosilicate mineral, either natural or synthetic, possessing pozzolanic properties. When used as a partial replacement for cement, it reacts with calcium hydroxide to form additional cementitious compounds. This enhances concrete's long-term strength, reduces permeability, and contributes to a lower carbon footprint.

3.7 Banana fiber: Banana fiber is a natural cellulosic fiber extracted from the pseudostem of the banana plant, an agricultural waste product. When added to concrete in small percentages, it acts as a discontinuous reinforcement. It can improve the concrete's ductility, energy absorption, and resistance to cracking, particularly reducing its brittle nature.

4. EXPERIMENTAL INVESTIGATIONS

4.1**Compressive Strength Results:**Test specimens must be 15 by 15 by 15 cm in size, and the nominal maximum aggregate sizes of the concrete to be tested cannot be greater than 20 mm. 7 and 28 days are usually enough time to analyze the concrete sample.

Table 1: Compressive Strength Results of Concrete with Partial Replacement of Fine aggregate by Copper Slag.

S.No	% of Copper Slag	Compressive strength results, N/mm^2	
		7 days	28 days
1	0%	33.95	49.97
2	10%	35.69	52.41
3	20%	36.83	53.89
4	30%	37.07	55.94
5	40%	39.42	58.15
6	50%	36.19	52.53

Table 2: Compressive Strength Results of Concrete with Partial Replacement of cement by Zeolite Powder.

S.No	% of Zeolite Powder	Compressive strength results, N/mm^2	
		7 days	28 days
1	0%	33.95	49.97
2	5%	37.41	54.86
3	10%	40.14	58.09
4	15%	44.34	63.47
5	20%	43.16	61.68

Table 3: Compressive strength result by addition of Banana fiber in concrete

S.No	% of BF	Compressive strength results, N/mm^2	
		7 days	28 days
1	0%	33.95	49.97
2	1%	35.72	51.89
3	2%	37.87	54.13
4	3%	36.74	52.56

Table 4: Compressive strength of concrete for combined partial replacement of cement by 40% Copper Slag+ 15% of Zeolite powder and addition of 2% Banana Fiber.

S.No	Combined Replacements	Compressive strength results, N/mm^2	
		7 days	28 days
1	0%	33.95	49.97
2	40%CS+15%ZP+2 BF	48.88	69.93

4.2 Split Tensile Strength Test: The loading surfaces of the compression testing equipment are separated horizontally using a typical test cylinder of concrete specimen, measuring 300 mm by 150 mm in diameter. Up to the point where the cylinder fails at its vertical diameter, the compression force is applied consistently and symmetrically along its length.

Table 5: Split tensile Strength Results of Concrete with Partial Replacement of Fine aggregate by Copper Slag.

S.No	% of Copper Slag	Split tensile strength results, N/mm^2	
		7 days	28 days
1	0%	3.41	4.94
2	10%	3.52	5.12
3	20%	3.74	5.36
4	30%	3.88	5.64
5	40%	3.96	5.75
6	50%	3.63	5.27

Table 6: Split tensile Strength Results of Concrete with Partial Replacement of cement by Zeolite Powder.

S.No	% of Zeolite Powder	Split tensile strength results, N/mm^2	
		7 days	28 days
1	0%	3.41	4.94
2	5%	3.56	5.45
3	10%	3.85	5.72
4	15%	4.29	6.28
5	20%	4.22	6.11

Table 7: Split tensile strength result by addition of Pine apple leaf fiber in concrete

S.No	% of BF	Split tensile strength results, N/mm^2	
		7 days	28 days
1	0%	3.41	4.94
2	1%	3.52	5.13
3	2%	3.68	5.35
4	3%	3.57	5.29

Table 8: Split tensile strength of concrete for combined partial replacement of cement by 40% Copper Slag+ 15% of Zeolite powder and addition of 2% Banana Fiber.

S.No	Combined Replacements	Split tensile strength results, N/mm^2	
		7 days	28 days
1	0%	3.41	4.94
2	40%CS+15%ZP+2 BF	4.85	7.06

5. CONCLUSIONS

1. The Normal Concrete Compressive Strength Results for 7 and 28 days is 33.95 and 49.97 N/mm^2.
2. The optimum compressive strength results of concrete with a 40% partial replacement of fine aggregate by copper slag are 39.42 N/mm² at 7 days and 58.15 N/mm² at 28 days.
3. The optimum compressive strength results of concrete with a 15% partial replacement of cement by zeolite powder are 44.34 N/mm² at 7 days and 63.47 N/mm² at 28 days.
4. The compressive strength results of concrete with the addition of 2% Banana fiber are 37.87 N/mm² at 7 days and 54.13 N/mm² at 28 days.

5. The compressive strength results of concrete with a combined replacement using 40%copper slag as a partial replacement for fine aggregate, 15% of Zeolite powder as a partial replacement of cement and the addition of 2% Banana fiber are 48.88 N/mm² at 7 days and 69.93 N/mm² at 28 days.

6. The Normal Concrete Split tensile Strength Results for 7 and 28 days is 3.41 and 4.94 N/mm^2.

7. The optimum Split tensile strength results of concrete with a 40% partial replacement of fine aggregate by copper slag are 3.96 N/mm² at 7 days and 5.75 N/mm² at 28 days.

8. The optimum Split tensile strength results of concrete with a 15% partial replacement of cement by zeolite powder are 4.29 N/mm² at 7 days and 6.28 N/mm² at 28 days.

9. The Split tensile strength results of concrete with the addition of 2% Banana fiber are 3.68 N/mm² at 7 days and 5.35 N/mm² at 28 days.

10. The Split tensile strength results of concrete with a combined replacement using 40%copper slag as a partial replacement for fine aggregate, 15% of Zeolite powder as a partial replacement of cement and the addition of 2% Banana fiber are 4.85 N/mm² at 7 days and 7.06 N/mm² at 28 days.

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