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INFLUENCE OF FLY ASH (FA) AND BAMBOO LEAF ASH (BLA) ON STRENGTH AND DURABILITY ENHANCEMENT OF M40 GRADE CONCRETE

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Abstract:

Demand for cement has surged because of the rapid urbanization and infrastructure development. To solve this serious dilemma, the construction sector is increasingly turning to supplementary cementitious materials (SCMs) which can partially substitute Portland cement in concrete compositions. These solutions need lower processing temperatures or leverage industrial by-products, thereby dramatically reducing the overall embodied carbon of concrete while maintaining or even improving performance qualities. By incorporating supplemental materials, the industry may achieve considerable emissions reductions without necessitating a total redesign of existing concrete technology, making it a feasible approach toward decarbonizing the built environment. To address these issues and promote sustainable construction methods, this study examines the combined use of Fly Ash (FA) and Bamboo Leaf Ash (BLA) as partial replacements for cement in M40-grade concrete.

This research demonstrates that the thorough combination of Fly Ash with Bamboo Leaf Ash satisfies M40 grade requirements while advancing trash valorisation, lowering cement usage, and lowering carbon emissions, therefore improving sustainable and resilient concrete technology for modern structural applications. After 7, 14, and 28 days, concrete samples were tested to determine their strength. Their long-lasting performance was examined using tests including how far carbonation had penetrated for durability and various mixes of materials.

While Bamboo Leaf Ash—a well-known pozzolanic by-product from thermal power plants—was kept at 10% by weight of cement in all altered mixtures, Fly ash, a well-known pozzolanic by-product from thermal power plants, was added at progressively higher levels of 0%, 3%, 6%, 9%, 12%, and 15% by weight of cement. The made concrete mixtures were: 0% BLA + 0% FA, 3% BLA + 10% FA, 6% BLA + 10% FA, 9% BLA + 10% FA, 12% BLA + 10% FA, and 15% BLA + 10% FA.

Keywords— M40 grade, Fly Ash (FA), Bamboo Leaf Ash (BLA), partial cement replacement, mechanical properties, durability, sustainable construction, agro-waste utilization

I. INTRODUCTION

1.1 THE HISTORICAL EVOLUTION OF SUBSTITUTE MATERIALS USED AS PROXIES IN CONCRETE:

Environmental, economic, and performance-related factors make cement replacement in concrete a highly relevant topic in modern construction. One of the leading causes of greenhouse gas emissions, the production of Ordinary Portland Cement (OPC) necessitates large amounts of fossil fuels and limestone, and it emits around one tonne of CO_2 for every tonne of cement that is manufactured. Reducing energy consumption, conserving natural raw materials, and minimizing CO_2 emissions are all possible outcomes of partially substituting cement with supplemental cementitious materials (SCMs). The technical side of things shows that cement substitution makes concrete last longer by making it less porous, less prone to thermal cracking because the heat of hydration is lower, and more resistant to chemical attacks such salt and sulphate ingress. Furthermore, by transforming agricultural and industrial refuse into valuable building materials, the

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utilization of waste-derived materials aligns with sustainable development goals.

Three linked factors—sustainability, performance, and economy—make it absolutely vital to replace part of cement with supplementary cementitious materials (SCMs) such as fly ash, slag, or silica fume. From an environmental point of view, the production of cement is a major cause of CO_2 emissions. It accounts for about 8% of the total worldwide. This is mostly due to the energy-intensive process of making clinker. Substituting industrial leftovers for cement significantly reduces concrete's carbon footprint, guides trash from landfills, and preserves natural limestone. Beyond sustainability, these replacements sometimes boost concrete's long-term performance; they improve workability, lower heat of hydration (hence minimizing cracking in big pours), raise ultimate strength over time, and boost resilience against chemical attacks, hence enabling longer-lasting buildings. Economically, even though some SCMs need rigorous quality checks, they are often cheaper than pure Portland cement, which reduces the cost of materials. As a result, replacing cement is more than simply an environmental decision; it's a calculated one to build infrastructure that is more robust, affordable, and resistant to future changes.

1.2 WHAT DO YOU MEAN BAMBOO LEAF ASH (BLA)?

Bamboo Leaf Ash (BLA) is a finely powdered material obtained by controlled burning of dried bamboo leaves, followed by grinding of the resulting ash. It is considered an agro-waste–based supplementary cementitious material (SCM) due to its high silica content and pozzolanic properties. Derived from bamboo leaves, Bamboo Leaf Ash is a pozzolanic, environmentally friendly material that can partially replace concrete in building, therefore fostering sustainable construction and enhanced durability when properly processed and ratioed

1.3 WHAT IS FLY ASH?

Power stations produce fly ash, a fine powder, by burning coal and other fuels with a high carbon content. The name "fly cinder" describes it somewhat. Fly ash can have different composition and characteristics depending on the fuel type and burning technique. This material is extensively utilized in building, especially as an additional ingredient that reinforces and lengthens the durability of concrete. Incorporating fly ash into ecologically friendly construction materials improves their sustainability by reducing the quantity of cement created from limestone.

1.4 CALCINATION OF BAMBOO LEAVES INTO ASH:

Fig 1: Bamboo Leaf Ash (BLA) production from Leaf to Ash

II. LITERATURE REVIEW

Driven by the necessity to reduce environmental consequences connected with cement manufacture, including high CO2 emissions and energy usage, recent studies on the use of supplementary cementitious materials (SCMs) such as fly ash and bamboo leaf ash (BLA) as partial substitutes for cement in concrete have attracted a lot of interest. A byproduct of coal combustion, fly ash is a proven SCM. It usually replaces 20–30% of cement to increase long-term compressive strength, lower permeability, and make it more resistant to chloride penetration and sulfate attack. It works as well as or better than rice husk ash when it comes to being a pozzolan. Research shows that replacing 10–20% BLA increases compressive strength by 18% at 28 days, cuts chloride penetration by 71%, and improves workability, therefore it is practically useful for areas with a lot of bamboo where there is not much fly ash. In general, including fly ash and BLA enhances more environmentally friendly building methods without sacrificing quality.Antonio et al (2014): CCA can be used up to 10%; it retains structural stability; it enhances compressive strength and workability in mixtures (when solely using CCA).

- Sell Jr. et al. investigated bamboo leaf ash calcined at 600 °C as a cement replacement in concrete. The study reported improved

compressive strength at 15% replacement, along with reduced water absorption and chloride ion penetration. These improvements were attributed to pore refinement caused by secondary calcium silicate hydrate formation. The authors concluded that bamboo leaf ash enhances both strength and durability characteristics of concrete. (Journal of Building Engineering, Vol. 97, 2024, DOI: 10.1016/j.jobe.2024.110986)

- Huang presented a comprehensive review on the development and application of bamboo leaf ash in concrete technology. The paper summarized previous experimental findings related to workability, strength, durability, and sustainability. The author emphasized that bamboo leaf ash can reduce cement consumption and environmental impact while maintaining acceptable mechanical performance. The review also identified gaps related to standardization and long-term durability. (Frontiers in Science and Engineering, Vol. 5, Issue 3, 2025, DOI: 10.54691/gj9wn206)

- V. Sameer Kumar., Ahmed Vali, D., Venkata Prakash, M., & Chand Basha, S. (2023). (Vol. 10, Issue 2, pp. 1–2) The workability of the control specimen of SCC, as well as the SCC that included Alccofine and Fly Ash, was found to be within the limitations allowed by the Indian Code, according to the findings of a battery of tests. This verifies the mix design of the SCC. It seems that the addition of Alccofine and Fly Ash improves the workability of the SCC, since this tendency was also seen in other evaluation techniques. Using a compression testing equipment, we measured the concrete's average compressive strength at7,14, and 28 days. According to the results, as compared to regular concrete, the average compressive strength is much higher, reaching its peak at a 25% Alccofine replacement level. Additionally, the average split tensile strength was also tested at 7, 14, and 28 days, with the maximum value reported at a combination of 20% Fly Ash, 20% Alccofine, and 1% superplasticizer. Similarly, the average flexural strength at these intervals was measured, with the highest value again observed at the same mix proportions of 20% Fly Ash, 20% Alccofine, and 1% superplasticizer. https://www.ijrar.org/papers/IJRAR23B1720.pdf

- Mohd Allauddin , Vanam Sameer Kumar International Research Journal of Modernization in Engineering Technology and Science Volume:07/Issue:03/March-2025 Emphasizing the main ideas taken from the previous conversations and results, this article closes: Fly Ash (FA) and Recycled Paper Cinder (RPC) may effectively replace cement, retaining FA at a constant 10% while altering RPC in increments of 0%, 4%, 8%, 12%, 15%, and 20% in M30 Solid, the results show. Examining the compressive, ductile, and flexural properties reveals that 12% RPC and 10% FA replacement yields the optimum strength. After 28 days, the greatest compressive strength recorded is 38.69 MPa. 3.09 MPa is the highest tensile strength reached after 28 days. ➢ After 28 days, the flexural strength maximum reported is 6.19 MPa. Including recovered waste RPC, this concrete is regarded as green concrete. https://doi.org/10.56726/IRJMETS69930

- Shaik Imran, Vanam Sameer Kumar IJPREMS Vol. 05, Issue 04, April 2025, pp : 177-185 Based on the foregoing considerations and developments, this essay can be concluded by concentrating on the following points: The result clearly shows that the substitution of FC & GHA both are replaced in place of cement by maintaining FC as constant with 10% and GHA with ascending follows from 0%, 3%, 6%, 9%, 12% & 15% in M35 Solid. Based on results as considered the compressive quality, ductile quality & flexural quality attained maximum strength at percentage of replacing 9%GHA+10%FC. The maximum Compressive strength quality gained for 28 days is 43.55 MPa. The maximum Tensile strength quality gained for 28 days is 4.59 MPa. The maximum Compressive strength quality gained for 28 days is 8.41 MPa. It

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can be referred as green concrete due to the replacement of agro based waste GHA. https://www.doi.org/10.58257/IJPREMS39569

- V.SAMEER KUMAR Journal of Engineering Sciences Vol 16 Issue 04,2025 The value of slump cone value decreases with increase in the percentage of drug waste Powder and bottom ash from 0%Drug waste power+0%Bottom ash to 6%drug waste powder+10% bottom ash in M30 grade concrete. The values of compaction factor increase with increase in the percentage of biomedical waste powder and bottom ash in M30 grade concrete. The maximum value of compressive strength was observed at 3%Drug waste power+10%Bottom ash for 3days, 7days, 28days curing period The maximum value of split tensile strength was observed at 3% Drug waste power+10% Bottom ash for 7days and 28days curing period in M30 Grade Concrete. DOI:10.15433.JES.2025.V16I4.43P.50 21.

III. METHODOLOGY

The Methodology summarizes the replacements for cement mentioned in this paper:

- Analyzing Fly Ash (FA) employment at a consistent ratio of 10% with Bamboo Leaf Ash (BLA) at levels ranging from 3% to 15%, maintaining 3% frequency.
- Checking the compressive strength of 150 mm x 150 mm x 150 mm cubes.
- Examining the tensile strength of cylinders with a diameter of 150 mm and a height of 300 mm.
- Evaluating the bending strength of beams 500 x 100 x 100 mm.
- Using carbonation test for 28 days, ascertain the durability test on concrete cubes.

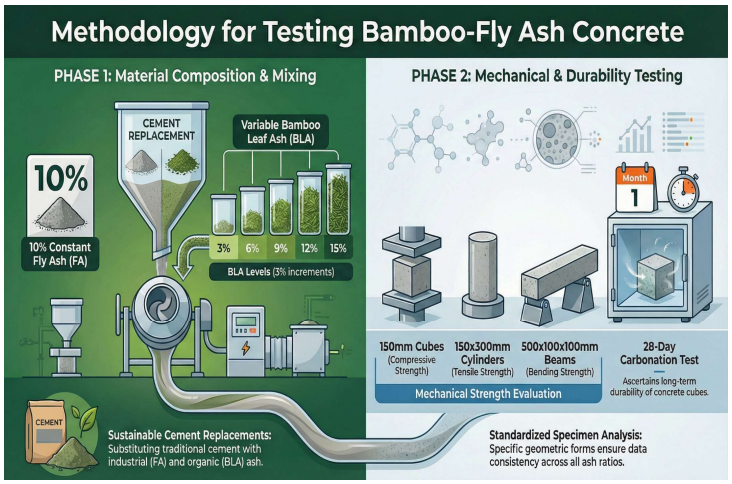

Fig 2: Steps involved in methodology of with respect to proxies

IV. RESULTS

Table no 1 Slump Cone values

Mix % Replacement	Slump value in mm
0%FA + 0%BLA	75
10%FA + 3%BLA	79
10%FA + 6%BLA	82
10%FA + 9%BLA	87
10%FA + 12%BLA	72
10%FA + 15%BLA	66

Graph no 1 Slump Cone values

Table no 2: Mix proportion of M40

Grade	**M40**
Proportion	**1:2.18:3.01**
W/C ratio	**0.39**

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Cement	**375**
Fine Aggregate	**820.01**
Coarse Aggregate	**1130.07**
Water	**153**

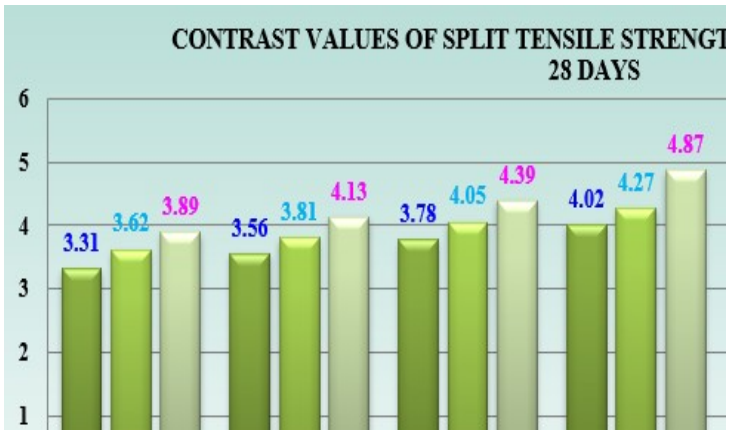
Table no 3 Test results of Compressive Strength at 7 days, 14 days & 28 days:

Mix % Replacement	7 days in Mpa	14 days in Mpa	28 days in Mpa
0%FA + 0%BLA	33.67	38.72	45.92
10%FA + 3%BLA	34.35	39.37	46.53
10%FA + 6%BLA	35.39	40.28	47.48
10%FA + 9%BLA	36.48	41.21	48.78
10%FA + 12%BLA	32.28	37.78	44.16
10%FA + 15%BLA	31.25	36.08	42.12

Graph no 2 Compressive Strengths at 7,14 & 28 days

Table no 4 Test results of Split Tensile Strength at 7 days, 14 days & 28 days:

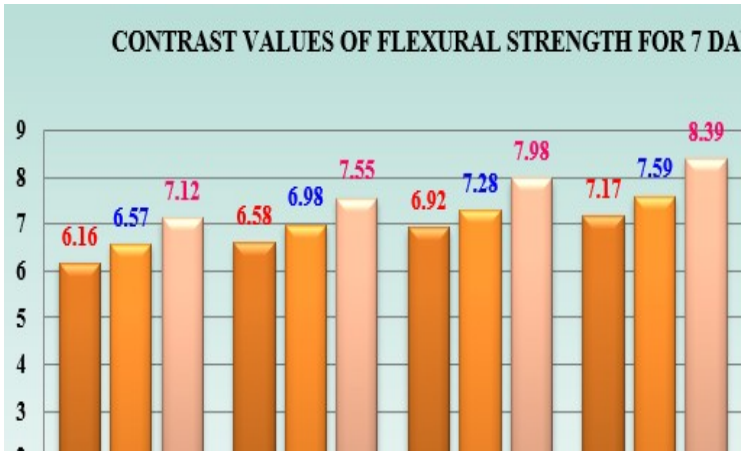
Mix % Replacement	7 days in Mpa	14 days in Mpa	28 days in Mpa
0%FA + 0%BLA	3.31	3.62	3.89
10%FA + 3%BLA	3.56	3.81	4.13
10%FA + 6%BLA	3.78	4.05	4.39
10%FA + 9%BLA	4.02	4.27	4.87
10%FA + 12%BLA	3.18	3.45	3.62
10%FA + 15%BLA	2.75	2.95	3.13



Graph no 3 Split Tensile Strength at 7,14 & 28 days

Table no 5 Test results of Flexural Strength at 7 days, 14 days & 28 days:

Mix % Replacement	7 days in Mpa	14 days in Mpa	28 days in Mpa
0%FA + 0%BLA	6.16	6.57	7.12
10%FA + 3%BLA	6.58	6.98	7.55
10%FA + 6%BLA	6.92	7.28	7.98
10%FA + 9%BLA	7.17	7.59	8.39
10%FA + 12%BLA	5.89	6.12	6.89
10%FA + 15%BLA	5.17	5.59	6.45



Graph no 4 Flexural Strengths at 7,14 & 28 days

Table no 6 Test results of Carbonation Depth at 7 days

Mix % Replacement	Carbonation Depth (mm) for 7 days
0%FA + 0%BLA	2.6
10%FA + 3%BLA	2.3
10%FA + 6%BLA	1.9
10%FA + 9%BLA	1.7
10%FA + 12%BLA	2.2
10%FA + 15%BLA	2.7

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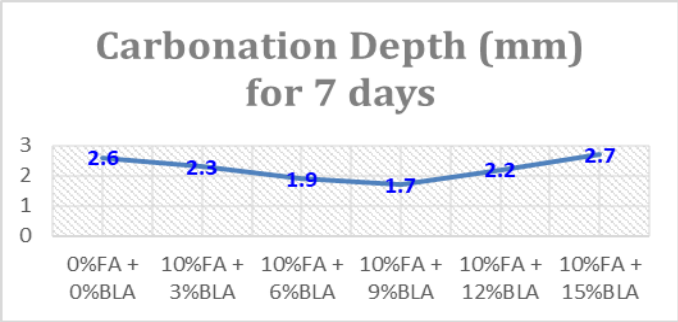
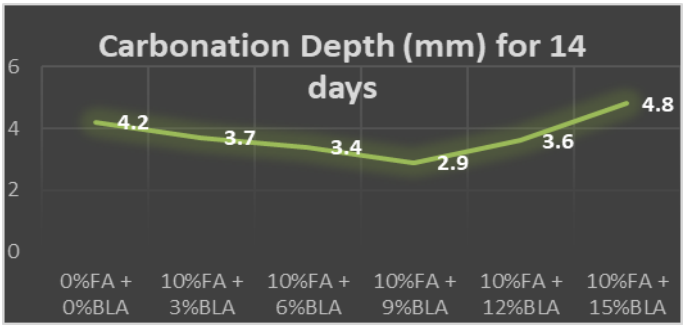


Graph no 5 Carbonation Depth at 7 days

Table no 7 Test results of Carbonation Depth at 14 days

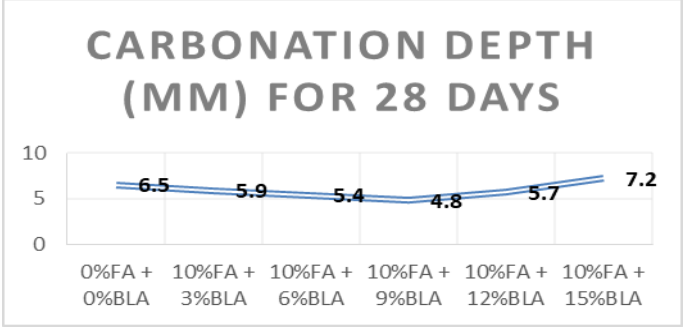
Mix % Replacement	Carbonation Depth (mm) for 14 days
0%FA + 0%BLA	4.2
10%FA + 3%BLA	3.7
10%FA + 6%BLA	3.4
10%FA + 9%BLA	2.9
10%FA + 12%BLA	3.6
10%FA + 15%BLA	4.8



Graph no 6 Carbonation Depth at 14 days

Table no 8 Test results of Carbonation Depth at 28 days

Mix % Replacement	Carbonation Depth (mm) for 28 days
0%FA + 0%BLA	6.5
10%FA + 3%BLA	5.9
10%FA + 6%BLA	5.4
10%FA + 9%BLA	4.8
10%FA + 12%BLA	5.7
10%FA + 15%BLA	7.2



Graph no 7 Carbonation Depth at 28 days

V. CONCLUSION

Emphasising the main ideas taken from the previous conversations and results, this article closes:

- ✓ Fly Ash (FA) and Bamboo Leaf Ash (BLA) may effectively replace cement, retaining FA at a constant 10% while altering BLA in increments of 0%, 3%, 6%, 9%, 12%, and 15% in M40 Solid, the results show.
- ✓ Examining the compressive, ductile, and flexural properties reveals that 9% BLA and 10% FA replacement yields the optimum strength.
- ✓ After 28 days, the greatest compressive strength recorded is 48.78 MPa.
- ✓ 4.87 MPa is the highest tensile strength reached after 28 days.
- ✓ After 28 days, the flexural strength maximum reported is 8.39 MPa.
- ✓ The Durability test results of Carbonation on concrete show their Depth of carbonation as 1.7 mm, 2.9 mm & 4.8 mm for the mix replacement of 9% BLA + 10% FA has their best for 7 days, 14 days & 28 days respectively.
- ✓ Including recovered waste BLA, this concrete is regarded as green concrete

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