

Experimental Investigation on Concrete with *Prosopis Juliflora* Ash and Basalt Fiber Bar Reinforcement

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Abstract: The increasing environmental concerns caused by global warming and the rising costs of cement production due to quarrying have created a pressing need to explore alternative materials. To address this challenge, extensive research has been carried out to identify suitable replacements for cement. This research work is aimed to investigate the strength of concrete with partial replacement of cement with *Prosopis juliflora* ash (PJA) and compare it with conventional concrete. The grade of concrete is M30. Incorporating *Prosopis juliflora* ash can potentially reduce the overall consumption of cement in the country while promoting sustainable construction practices. The primary objective of this research is to evaluate the influence of *Prosopis juliflora* ash as a partial replacement for cement on the compressive, split tensile, and flexural strength of concrete. In this investigation, *Prosopis juliflora* ash (locally known as Seemaikaruvelam) was used to replace cement in varying proportions of 10%, 20% and 30%. Based on the experimental results, the mix containing 20% *Prosopis juliflora* ash exhibited optimal strength characteristics. The findings of this study highlight the potential of *Prosopis juliflora* ash as an eco-friendly and cost-effective alternative material for sustainable construction.

Keywords: Concrete, *Prosopis Juliflora* Ash, Basalt Fiber

1. Introduction

Global warming has emerged as one of the most critical environmental challenges of the 21st century. Among the major contributors to anthropogenic greenhouse gas emissions is the cement industry, which is responsible for approximately 8% of global carbon dioxide (CO₂) emissions. In response to growing environmental concerns and the global push toward sustainable development, there is an increasing focus on identifying and incorporating alternative materials that can partially or wholly replace conventional cement in construction. Sustainable construction practices are guided by three primary pillars: environmental sustainability, economic feasibility, and social responsibility. Within this context, the present study investigates the partial replacement of cement with *Prosopis juliflora* ash, a biomass-derived waste material, and the incorporation of basalt fiber as a reinforcing agent in concrete. *Prosopis juliflora*, often considered an invasive species, offers potential for value-added utilization when processed into ash, thus contributing to waste management and sustainability goals.

1.1 Literature review

- [1] Govindasami. S et al, "An experimental study on flexural behaviour of *Prosopis juliflora* ash concrete", International Journal of Civil Engineering and Technology (IJCIET) Volume 11, Issue 04, April 2020. This study is on partial replacement of cement by *Prosopis juliflora* and its characteristic behavior in concrete. M30 concrete was prepared. The investigation include casting of specimens for each proportions to obtain its compressive strength, split tensile strength by testing cylindrical concrete specimen of standard size and flexure behavior by prism of size 100 mm x 100 mm x 500 mm. The compressive, split tensile and flexural strength of *juliflora* concrete was found to be more efficient than the conventional concrete at 20% *juliflora* ash. Thus, from this study it is found

that there is a way to use the juliflora ash in an economical way in concrete to increase the strength of concrete and to reduce the cost of construction.

- [2] Leema Margret A, et al, "Influence of utilizing Prosopis juliflora ash as cement on mechanical properties of cement mortar and concrete", Global NEST Journal, Vol 26, No 1, Global NEST, 14.11.2023. To generate additional calcium silicate hydrate (C-S H) gel, calcium hydroxide, which is a byproduct of cement hydration, is utilized, was allowed to react with PJA to measure its pozzolanic activity. Due to its extremely fine structure, PJA covers more gaps and has superior pore structure, which enhances strength due to decreased permeability. The creation of CSH gel increases the crushing strength in M30 grade when PJA is used in place of cement up to 30% enhanced PJA addition leads to higher aluminium and silica content and enhanced compressive strength. It proved that waste wood from burning operations may be used as cement ash to make environmentally friendly mortar and concrete. Consequently, Prosopis Juliflora 21 Ash (PJA) can find application in construction contexts as a substitute for up to 30% of cement in both mortar and concrete.
- [3] Lapko Wiejska St., et al, "Experimental and Theoretical Analysis of deflections of concrete beams reinforced with basalt rebar", Springer nature, 14 April 2014, Volume 15. This paper presents a comparative analysis of experimental and theoretical deflections of simply supported beams reinforced with BFRP rebar (Basalt Fiber 25 Reinforced Polymers). The tested BFRC model beams have been made of concrete class C30/37 and reinforced with flexural basalt bars of 8 mm in diameter with the characteristic identified in strength tests in tension. During the investigation of model beams there were registered beam deflection, concrete strains and width cracks, as well as critical forces. It has been shown that much lesser cross-sectional stiffness of basalt BFRP bars produces higher deflections and crack widths compared to the beams reinforced with steel bars of the same cross-section. The results of theoretical analysis of BFRC beam deflections on the basis of the known formulas showed some significant discrepancies compared to experimentally obtained deflections, especially for lower level of loading forces. The results clearly show that basalt rebar having full resistance against corrosion may be good alternative for the reinforcement of concrete structures, like RC bridge girders subjected to environmental attack.

1.2 Prosopis Juliflora Ash

Given its high silica and mineral content upon combustion, Prosopis juliflora ash (PJA) has shown promising potential as a supplementary cementitious material (SCM). When finely ground, the ash may exhibit pozzolanic properties, contributing to the strength and durability of concrete. It enhances mechanical properties when used in combination with reinforcements like basalt fiber.

1.3 BFRP Rebars

Basalt fiber is revered for its exceptional **mechanical, thermal, and chemical properties**, which make it a competitive alternative to traditional reinforcement materials like steel and fiberglass. This contributes to reduced structural weight.

1.3.1 Density- 2700 kg/m³

1.3.2 Modulus of elasticity- 89-110 Gpa

1.3.3 Tensile strength- >2800 Mpa

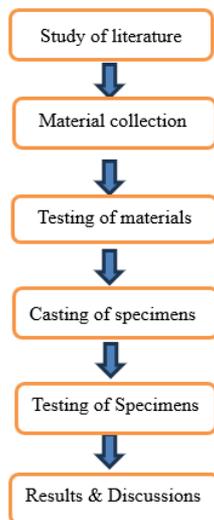
1.3.4 Average lifespan- >100 years

1.4 Objective

- To minimize the disposal problem of the Prosopis plant.
- To study if Prosopis ash usage reduces the production cost of binding material(cement).

- To investigate the comparative strength properties of conventional concrete with concrete where the cement is replaced by the ash of *Prosopis juliflora* plant.
- To study the tensile strength of basalt fiber bar.

1.4 Methodology



2 Mix Design

The mix design as per IS 10262:2009. The code permits the use of supplementary materials such as chemical and mineral admixtures. All mixes were proportioned in order to achieve a design compressive strength of M₃₀ concrete after 28 days. A control mix was produced with design mixes incorporating *Prosopis juliflora* ash as a partial replacement for cement in proportions of 10, 20 and 30%.

3 Material preparation

3.1 Cement

In this work, Ordinary Portland Cement has been used. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation. The cement thus procured was tested for physical properties in accordance with the IS: 4031-1988. Tests on Cement i) Specific Gravity ii) Initial and Final Setting Time iii) Fineness of Cement iv) Consistency test v) Soundness.

3.2 Fine aggregate

The fine aggregate used was locally available sand without any organic impurities and conforming to IS: 383 – 2016. Tests on Fine aggregate i) Fineness modulus ii) Specific gravity. M-Sand of grading zone III was used.

3.3 Coarse aggregate

The aggregate which pass through 75 mm IS sieve and retain on 4.75 mm IS sieve are known as coarse aggregate. In this research, aggregate of 20 mm maximum size was used. Tests on Coarse aggregate i) Fineness modulus ii) Specific gravity iii) Impact value.

3.4 *Prosopis Juliflora* ash

The specific gravity of *Prosopis* ash was found to be less than that of cement. Specific gravity of *Prosopis* ash is 1.65. The suitable range of specific gravity of *juliflora* ash is 1.6 to 2.8.

4. Experimental investigation

The most common of all checks on hardened concrete is that the compressive strength test. This thesis work is based on IS: 10262 – 2019. Four different proportions of concrete mix (replacement of 10%, 20%, 30% by weight of cement) including the control mixture were prepared with water to binder ratio of 0.5. The tests are applied once seven & twenty eight days of casting of concrete.

4.1. Curing

Curing of cement concrete is defined as the process of maintaining the moisture and temperature conditions of concrete for hydration reaction to normally so that concrete develops hardened properties over time. The hydration process requires water to carry on and releases heat.

4.2. Strength study

All tests were done with reference to IS 516 (Part1/Section1):2021. The tests conducted on cubes, cylinders and prisms are 1) Compressive strength test 2) Split tensile strength test 3) Flexural strength test.

5. Results And Discussion

5.1 Compressive strength test

The cubes with 150 mm sizes are used. Calibrated moulds of cast iron were used.

Mix ID	Compressive strength in N/mm ²	
	7 DAYS	28 DAYS
PJA 0%	19.80	30.81
PJA 10%	21.37	31.39
PJA 20%	22.38	32.11
PJA 30%	19.71	27.47

Table 1 Compressive strength results of M30 grade concrete

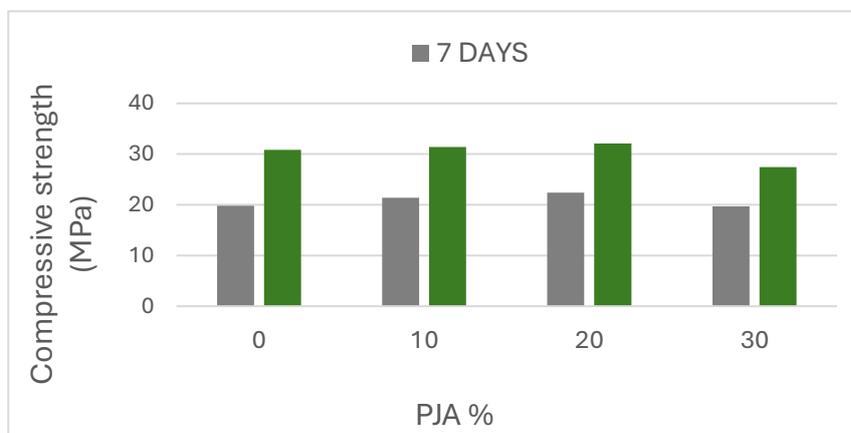


Figure 1 Graph for compressive strength results of M30 grade concrete

5.2 Split tensile strength test

This method consists of applying a diametric compressive force along the length of the cylindrical specimen. Test has been conducted on the specimen of size 150 mm in diameter and 300mm in length after the curing period of 7 and 28 days.

$$\text{Split tensile strength} = 2P / \pi DL \text{ (N/mm}^2\text{)}$$

(P = Ultimate load (N) D = Diameter of specimen (mm) L = Length of specimen (mm))

Mix ID	Split tensile strength in N/mm ²	
	7 DAYS	28 DAYS
PJA 0%	1.71	3.09
PJA 10%	2.03	3.14
PJA 20%	2.22	3.23
PJA 30%	1.67	2.72

Table 2 Split tensile strength results of M30 grade concrete

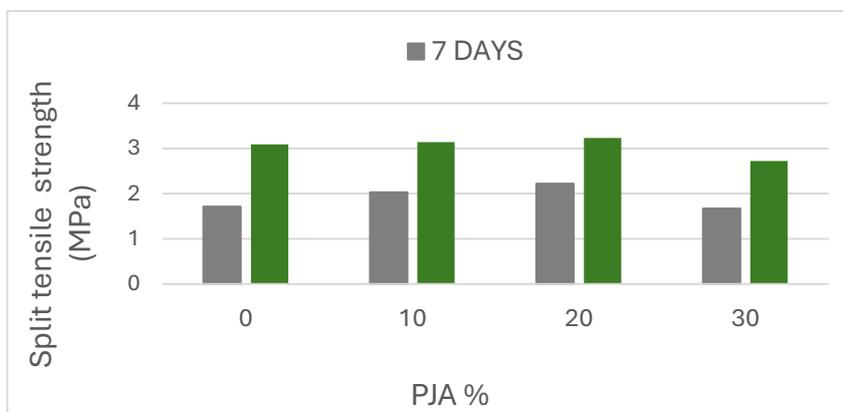


Figure 2 Graph for split tensile strength results of M30 grade concrete

5.3 Flexural strength test

This test is performed to determine the flexural strength or modulus of rupture of concrete. It measures the ability of a concrete beam or prism to resist failure in bending. The test is conducted on a prism specimen of standard size 100 mm × 100 mm × 500 mm after 28 days of curing.

$$\text{Flexural strength (Modulus of rupture) } f_b = PL/bd^2$$

(P = Ultimate load at failure (N) L = Span length between supports (mm) b = Breadth of specimen (mm) d = Depth of specimen (mm))

Mix ID	Flexural strength in N/mm ²	
	7 DAYS	28 DAYS
PJA 0%	3.10	4.74
PJA 10%	3.11	4.74
PJA 20%	3.27	5.06
PJA 30%	2.78	4.25

Table 3 Flexural strength results of M30 grade concrete

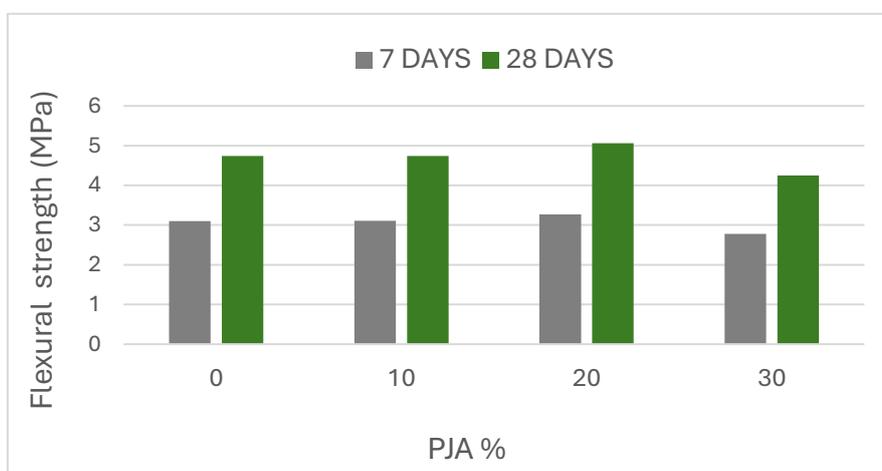


Figure 3 Graph for flexural strength results of M30 grade concrete

6. Conclusion

The following conclusions are drawn from the experimental investigation of Prosopis concrete with partial replacement of cement by Prosopis juliflora ash by 10%, 20% and 30%

- PJA replacement levels of about 20% in this study demonstrated the best performance. A 20% replacement provides the ideal ratio of PJA to portlandite (the free calcium hydroxide by-product) to maximize the pozzolanic reaction. This process converts the weak and permeable calcium hydroxide into a strong, cementitious C-S-H gel.
- With 20% PJA, the fine particles fill a significant number of voids in the cement paste, creating a denser and less permeable microstructure.
- The mechanical properties deteriorated after this point, with strength reductions of up to about at 30% replacement. The delayed hydration may be the cause of the decreased performance at higher PJA dosages. Excessive replacement can weaken the bond between the cement paste and aggregates, decreasing the overall bonding strength and reducing the effectiveness of the pozzolanic activity.

Cost of construction reduces notably up to ~Rs. 600/m³ of concrete with 20% PJA.

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