

Performance Evaluation Of Self-Curing Concrete With Euphorbia Cactus Extract And Polypropylene Fibres

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ABSTRACT

Concrete is utilized extensively in modern infrastructure because of its power and versatility, yet proper curing remains a significant challenge, especially in arid climates and complex structures. This study investigates a novel self-curing concrete incorporating Euphorbia cactus extract—a natural hydrogel known for its water retention properties—combined with polypropylene fibres to enhance both curing efficiency and mechanical performance. The cactus gel, introduced in varying dosages (1%, 3%, 5%, and 7% by weight of cement), serves as an internal curing agent, gradually releasing moisture during hydration and reducing reliance on traditional water-curing methods. Polypropylene fibres (0.5% by weight of cement) are added to improve tensile strength, crack resistance, and ductility. A comprehensive experimental program evaluates workability, compressive strength as well as split tensile strength and flexural strength of the modified mixes, comparing them with conventionally cured control specimens. Durability is also assessed through sulfuric acid resistance tests. All tests are conducted on 28-day-old specimens without external curing for the self-curing variants. The results highlight the synergistic benefits of cactus gel and fibres in producing sustainable, durable concrete, making it suitable for resource-limited environments. This bio-based approach promotes eco-friendly construction practices and supports the development of green materials, with potential for future research into plant-based and fibre-reinforced composites.

Keywords: Self-curing concrete, Euphorbia cactus extract, Polypropylene fibres, Internal curing, Sustainable construction, Mechanical properties of concrete

1. INTRODUCTION

Concrete, composed comprising fine and coarse particles, water, and cement, is the foundation of modern construction because of its resilience, strength, and versatility. Even though it's widely used, one major challenge in concrete application is achieving proper curing, which is vital for strength development and durability. Traditional curing methods, which rely heavily on external water application, often fall short in arid or water-scarce regions. To address this, self-curing concrete has emerged as an innovative solution, capable of internally retaining moisture and reducing reliance on external curing processes. One natural agent that has shown promise in this context is Euphorbia cactus extract, or cactus gel. Known for its exceptional water retention, the cactus gel acts as a natural internal curing agent, releasing moisture gradually to support ongoing hydration and reduce shrinkage and cracking. In parallel, polypropylene fibres, synthetic materials commonly used to enhance concrete, are introduced to enhance mechanical attributes like tensile power and crack opposition. When combined, cactus gel and polypropylene fibres create a synergistic effect that enhances both curing efficiency and structural performance. This research evaluates This modified concrete's workability, compressive, tensile, and flexural strengths, along with its acid resistance and durability. The study ultimately supports the use of sustainable, plant-based, and fibre-reinforced materials to produce high-performance, eco-friendly concrete for modern infrastructure.

With growing global demand for sustainable construction, natural additives in concrete are being explored to enhance performance and reduce environmental impact. Traditional concrete poses ecological challenges due to cement-related CO₂ emissions and high water usage during curing. Natural additives, such as Euphorbia cactus gel, offer internal curing by retaining moisture, improving hydration, and reducing shrinkage and cracking. Additionally, plant-based fibres like jute or bamboo improve tensile strength and crack resistance. While natural materials face challenges like variability and durability concerns, combining them with synthetic fibres like polypropylene provides a balance between eco-friendliness and performance, paving the way for greener and more resilient construction.

2. OBJECTIVES

- To study the effect of *Euphorbia cactus* extract (cactus gel) as a natural self-curing agent in concrete.
- To investigate how polypropylene fibers affect the self-curing concrete's mechanical characteristics..
- To study Concrete's workability, compressive strength, split tensile strength, and flexural strength modified with cactus gel and polypropylene fibres.
- To study the internal moisture retention and curing efficiency of concrete incorporating cactus gel compared to conventional curing methods.
- To investigate the amended concrete's overall resilience to cracking and durability. mix under different curing conditions.

3. LITERATURE REVIEW

A study published in *SciELO Brazil* assessed the efficiency of 2900 psi concrete confinement employing *Euphorbia tortilis* excerpt as a natural additive. Concrete mixes with varying concentrations (1% to 9%) of the extract were prepared, and We tested the strength of the material's ability to squeeze, split, and stretch. sorptivity over periods up to 90 days. The findings showed that the addition of the extract led to decreased fluidity due to polysaccharides acting as viscosity-modifying agents, improved consistency, and reduced water requirements. Notably, the modified concrete exhibited increased strength properties (compressive, tensile, and flexural) by 10% to 40% after 28 days, along with decreased water absorption and enhanced durability.

El-Dieb et al. (2012) examined cement mixes' internal curing of concrete including water-soluble polymers. As selfcuring agents, polyacrylamide (PAM) and polyethylene glycol (PEG) have been used both singly and in combination. Cement was partially substituted with silica fume to improve the hydration effect. Results including mass loss, moisture transport, and water retention were examined with and without mineral and self-curing additive in a variety of combinations. Test findings demonstrated that a mixture of PEG and PAM with 8% silica fume delivers superior qualities compared to a traditional mix.

Using a variety of shrinkage-reducing admixtures, Subramaniaii et al. (2015) attempted to lessen the autogenous shrinkage in low w/c concrete. The four additional components used in place of some of the cement were fly ash, metakaolin, GGBS, and micro silica. They found that concrete treated with ethyl propyl polyoxy ethylene ether at a dosage of 0.025% that substitutes individual fly ash and metakaolin for cement reduced shrinkage by 40%.

In their 2016 study, Madduru et al. attempted to determine how internal curing agents affected self-compacting mortars. Two kinds of curing agents—liquid paraffin wax and polyethylene glycol (molecular weights 200 and 4000)—have been employed. 0%, 0.10%, 0.50%, and 100% curing agent dosages were used, depending on the cement's weight. The self-compacting mortar mix was also used in two distinct design combinations (1:1 for w/c = 0.34 and 1:3 for w/c = 0.5). Properties such as durability, compressive strength, workability, and water retention were examined and contrasted with mortar specimens under wet curing and no curing techniques. The findings showed that, in comparison to alternative curing regimes, self-compacting mortar with internal curing agents exhibits a superior C-S-H gel matrix.

Shanmugavel et al. (2020) examined the effects of cactus extract biopolymers on Cement paste for environmentally friendly concrete. Their research demonstrated that the inclusion of The viscosity of the concrete mix was increased using cactus extract, improving workability. Infrared spectroscopy using Fourier transform (FT-IR) and additional microstructural analyses revealed that polysaccharides in the extract improved water retention, reducing early drying and shrinkage cracks. The modified concretes showed enhanced mechanical properties and durability, suggesting that cactus extract is an eco-friendly, cost-effective additive for sustainable cement composites.

González-Calderón and Torres-Acosta (2021) investigated the efficacy of *Opuntia ficus-indica* (OFI) mucilage as a natural corrosion inhibitor for steel reinforcement in mortars exposed to CO₂-rich environments. Steel-reinforced mortar prisms containing varying concentrations of OFI mucilage (1.5% to They were exposed for more than 14 years (95 percent by water mass replacement). The study found that Adding OFI mucilage significantly reduced Cracking brought due by corrosion, with corrosion-inhibiting efficiencies ranging from 40% to 90%, depending on the concentration used. This suggests that OFI mucilage can enhance the longevity of materials made of cement in aggressive environments.

A study published in PMC (2022) explored the process of removing mucilage from OFI fruit peel and its application when treating water as a natural coagulant processes. The mucilage exhibited effective coagulation properties, reducing turbidity and chemical oxygen demand in treated water. This research highlights the potential of OFI mucilage in environmental applications beyond construction materials.

Velumani et al. (2023) explored the durability aspects of M25 grade concrete infused with an extract from cacti as a bio-admixture. By replacing water with varying percentages (1% to 9%) of cactus extract, they conducted tests on water absorption, porosity, sorptivity, drying shrinkage, rapid carbonation, and resistance to acidic and alkaline environments. The

study found that cactus-infused concrete exhibited enhanced fluidity, strength, and durability, with optimal improvements observed at specific extract concentrations. Scanning Electron Microscopy (SEM) analyses indicated that polysaccharides and fats in the cactus extract contributed to a denser microstructure, thereby improving durability properties by up to 30%.

Mohanraj and Krishnasamy (2024) investigated the incorporation of *Euphorbia tortilis* cactus (ETC) extract into reinforced concrete beams. Their study revealed that beams with ETC exhibited a ductile response, with initial crack loads increasing by up to 47.9%. Additionally, these beams showed reduced crack widths, enhanced stiffness, and significantly higher energy absorption compared to control beams, highlighting the potential of ETC as a sustainable additive for improving load-carrying capacity and ductility in concrete structures.

4. METHODOLOGY

The methodology for this research is designed to evaluate the functionality of self-curing concrete using Euphorbia cactus extract (cactus gel) and polypropylene fibres. This section outlines the detailed procedures for material selection, mix design, preparation of specimens, testing procedures, and data analysis. The methodology is divided into several key steps, including materials used, mix design, preparation, and testing procedures.

A. Material Used:

- **Cement Ordinary Portland Cement (OPC) 53 Grade:** IS 12269:2013-compliant Ordinary Portland Cement (OPC) 53 Grade is utilized. in this study for its high early strength and efficient hydration, making it suitable for rapid strength development in concrete. Its superior compressive strength and durability provide a reliable base for evaluating the effects of Euphorbia cactus extract and polypropylene fibres on concrete performance.
- **River Sand, a fine aggregate that complies with Zone II:** Zone II river sand that complies with IS: 383-2016 is used as the fine aggregate in this study due to its moderate grading, which enhances workability and ensures a uniform concrete mix. The sand is cleaned to remove impurities and tested for specific gravity to maintain proper water-cement ratio and support effective cement hydration.
- **Crushed granite is a coarse aggregate with a maximum size of 20 mm.:** Coarse aggregate, consisting of Crushed granite that is no larger than 20 mm is utilized in this study because it has a high compressive strength, is durable, and resistance to weathering. Crushed granite is preferred over natural gravel because its angular particles provide better interlocking, enhancing the concrete's strength and stability. The aggregate is properly graded, cleaned of impurities, and tested for specific gravity as per IS: 2386 (Part III) – 1963 to ensure it meets the required standards for concrete production.
- **Water: Potable Water :** Water is essential in concrete mixing as it initiates the hydration process between cement and aggregates, forming the hardened structure of concrete, and in this study, clean potable water is used. The cement-to-water ratio is carefully controlled to ensure proper feasibility, strength, and durability, while avoiding impurities that could disrupt the hydration process.
- **Self-Curing Agent: Euphorbia Cactus Extract (Cactus Gel) :** This study introduces Euphorbia cactus extract, particularly from *Euphorbia tirucalli*, as a self-curing agent due to its high mucilage content that enables prolonged water retention, making it suitable for reducing dependence on external water curing in water-scarce regions. The cactus gel is extracted, filtered, and incorporated into the concrete mix at 1%, 3%, 5%, and 7% by cement weight in order to assess its impact on internal curing, hydration, and overall concrete performance.
- **Polypropylene Fibres :** Polypropylene fibres, added at 0.5% by weight of cement, are synthetic monofilament fibres (0.04 mm diameter, 12 mm length) used in concrete to enhance tensile strength and reduce shrinkage cracking. Their inclusion improves structural integrity by interlocking within the cement matrix, thereby minimizing microcracks and increasing durability without significantly affecting workability.

B. Mix Design

Based on performance metrics from trial testing, the final mix proportions are selected to deliver optimal results for M25 concrete enhanced with cactus extract and polypropylene fibres. The mix design that yielded the best strength and durability includes:

- 395.75 kg of cement
- 186 liters of water
- 691.507 kg of fine aggregate
- 1233.4 kg of coarse aggregate

- 19.79 kg of cactus extract (5% by weight of cement)
- 1.98 kg of polypropylene fibres (0.5% by weight of cement)

This final mix provides superior compressive strength, flexural strength, and resistance to environmental degradation compared to conventional M25 concrete, validating the benefits of natural self-curing agents and synthetic fibres.

C. Preparation of Material

- **Cactus Gel Preparation :** Euphorbia cactus stems are cleaned, peeled, blended, and filtered to obtain the gel, which is stored in airtight containers for use in the concrete mix.
- **Concrete Mixing Procedure :** The concrete ingredients (cement, sand, aggregations) are dry blended, after which the addition of polypropylene fibres. A water solution with cactus gel is then prepared and incorporated into the dry mixture. The resulting mixture is thoroughly blended until uniform consistency is achieved.
- **Casting and Demoulding :** The prepared concrete is cast into standard moulds, compacted, and demoulded after 24 hours. The specimens are then allowed to cure, utilizing the self-curing properties of the cactus gel.

This preparation process ensures that the concrete mix achieves the necessary hydration, strength, and durability while minimizing water usage for external curing, making it an efficient and eco-friendly solution for concrete production.

D. Test Conditions

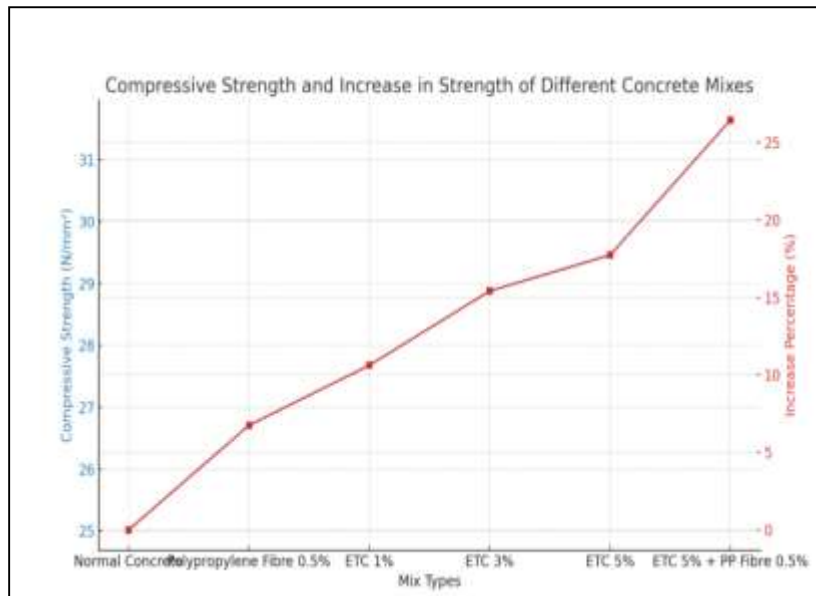
- **Compressive Strength Test:** Evaluates the concrete's ability to withstand axial loads by applying a compressive force to cube specimens and measuring the load at failure.
- **Flexural Strength Test:** Measures the concrete's resistance to bending by applying a two-point load to beam specimens and calculating the flexural strength.
- **Acid Resistance Test:** Assesses the durability of concrete in a 5% sulfuric acid solution by measuring weight loss, inspecting for visible damage, and testing strength loss after 28 days of exposure.

These tests allow a comprehensive assessment of the self-curing concrete's mechanical execution, crack resistance, and durability under various environmental conditions. The results provide valuable insights into the feasibility of using Euphorbia cactus gel and polypropylene fibres to enhance concrete's sustainability and performance in practical applications.

5. RESULTS AND DISCUSSIONS

Table 1: The standard deviation of the average compressive strength of polypropylene and etc concrete

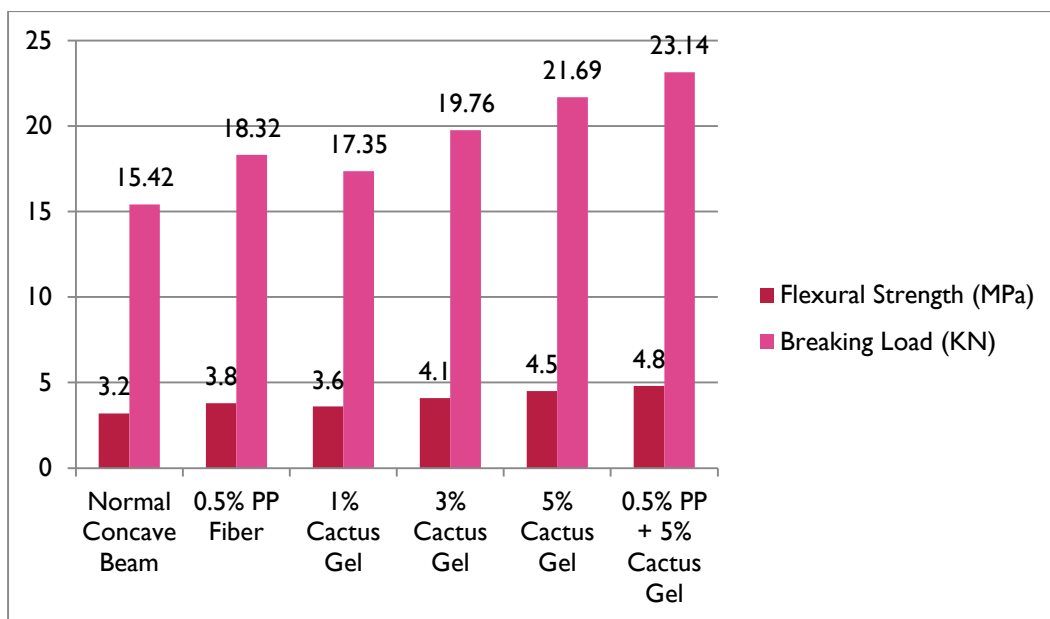
Grade	Mix Index	Compressive Strength (N/mm ²) For 28 Days	Increase percentage of Compressive strength at 28 days	Crushing value at 28 days in N/mm ² (X)	Average Strength (Y)	Deviation (X-Y)	Standard Deviation $\sigma = \sqrt{\frac{\sum (X-Y)^2}{N-1}}$
M25	NORMAL CONCRETE	25.02	-	25.02	28.23	- 3.22	0.0089
	POLYPROPYLENE FIBRE 0.5%	26.71	6.75	26.71	28.23	- 1.92	
	ETC 1%	27.68	10.63	27.68	28.23	- 0.82	
	ETC 3%	28.88	15.42	28.88	28.23	0.78	
	ETC 5%	29.46	17.74	29.46	28.23	1.98	
	ETC 5% + PP FIBRE 0.5%	31.64	26.45	31.64	28.23	3.18	



Graph 1: Compressive strength and increase in strength of different concrete mixes

Table 2: Standard variation of ETC and polypropylene concrete's average flexural strength

Sr. No.	Sample Name	Beam Dimensions (mm)	Span Length (mm)	Flexural Strength (MPa)	Breaking Load (N)	Breaking Load (KN)
1	Normal Concave Beam	150 x 150 mm	700 mm	3.2	15428	15.42
2	0.5% PP Fiber	150 x 150 mm	700 mm	3.8	18321	18.32
3	1% Cactus Gel	150 x 150 mm	700 mm	3.6	17357	17.35
4	3% Cactus Gel	150 x 150 mm	700 mm	4.1	19767	19.76
5	5% Cactus Gel	150 x 150 mm	700 mm	4.5	21696	21.69
6	0.5% PP + 5% Cactus Gel	150 x 150 mm	700 mm	4.8	23142	23.14

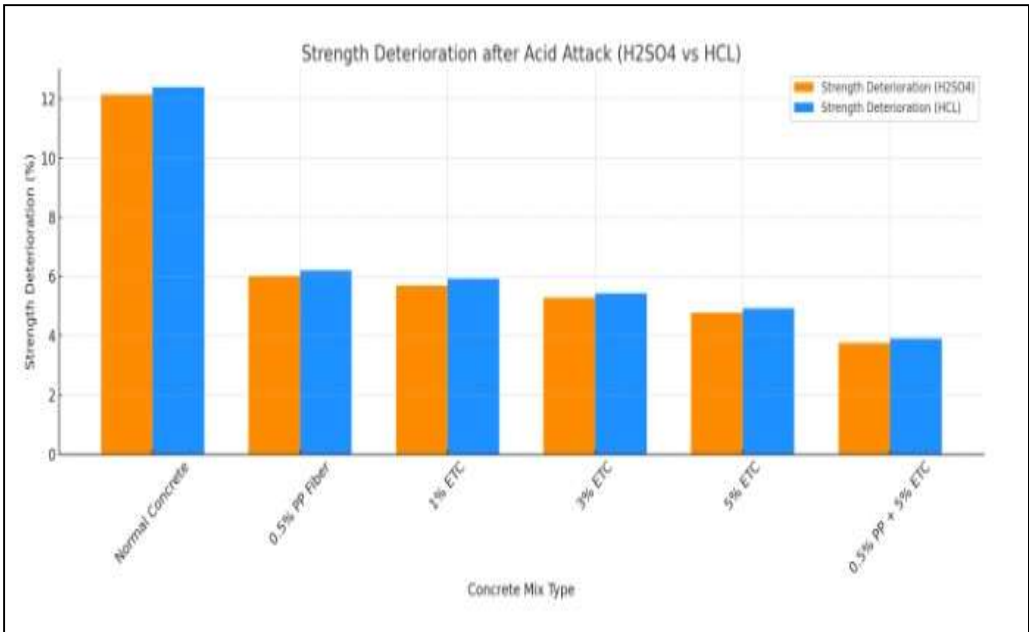


Graph 2: Flexural Strength Comparison of ETC & Polypropylene Concrete

The flexural strength of the concrete increased progressively with higher percentages of Euphorbia cactus gel, demonstrating its effectiveness as a natural internal curing agent. Polypropylene fibres also contributed significantly to the strength, particularly when used in combination with the cactus gel. The optimal performance was observed in the mix containing 5% Euphorbia cactus extract and 0.5% polypropylene fibres, which showed the highest flexural strength among all tested combinations. These findings highlight the potential of combining natural and synthetic materials to enhance the mechanical performance of self-curing, eco-friendly concrete, making it a promising solution for sustainable construction.

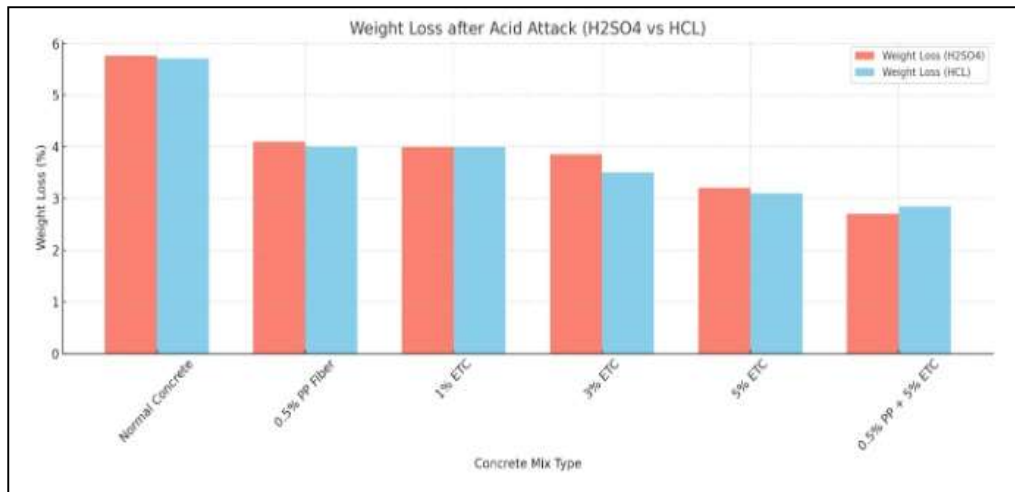
Table 3: Acid Test Result

Grade	Mix Index Normal	Weight Loss (%)		Initial Compressive Strength 28 Days N/mm ²	Strength of Concrete after acid attack N/mm ²		Strength Deterioration factor in (%)	
		H2SO4	HCL		H2SO4	HCL	H2SO4	HCL
(M25)	NORMAL CONCRETE	5.765	5.711	25.02	21.98	21.92	12.15	12.39
	0.5 % PP FIBER CUBE	4.105	4.012	26.71	25.11	25.05	6.00	6.21
	1 % ETC	4.002	4.006	27.68	26.10	26.04	5.70	5.92
	3 % ETC	3.860	3.506	28.88	27.35	27.31	5.29	5.43
	5 % ETC	3.210	3.100	29.46	28.05	28.01	4.78	4.92
	0.5 % PP + 5 % ETC	2.701	2.845	31.64	30.45	30.40	3.76	3.91

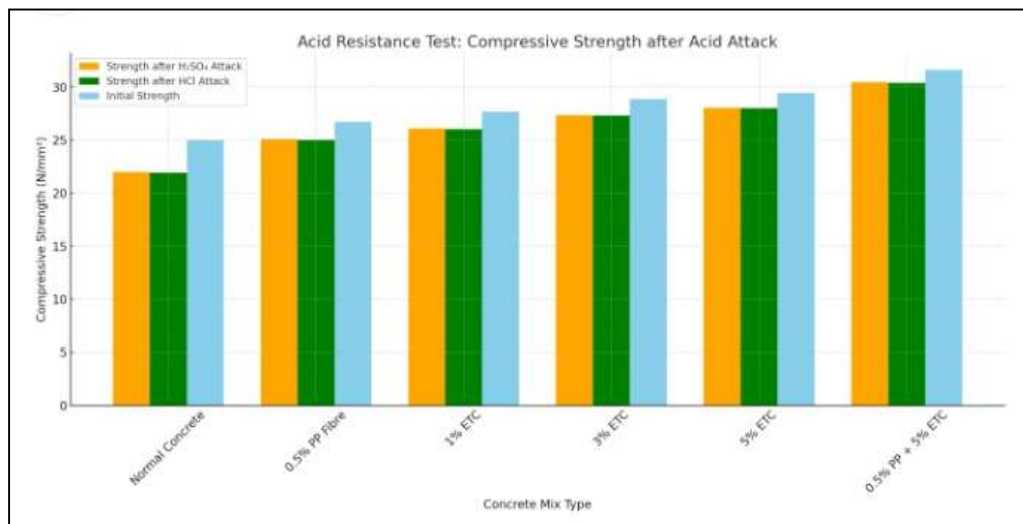


Graph 3: Strength Deterioration After Acid Attack

(h2so4 vs hcl)



Graph 4: Weight Loss After Acid Attack (h₂so₄ vs hcl)



Graph 5.: Acid Resistance Test: Compressive Strength After Acid Attack

The acid Concrete's resilience in harsh chemical conditions is assessed using a resistance test. For 28 days, concrete samples in this investigation were subjected to 5% sulfuric acid (H₂SO₄) and 5% hydrochloric acid (HCl). The test measured weight loss, residual compressive strength, and strength deterioration to determine acid resistance. The results provide insight into how Euphorbia cactus gel (ETC) and polypropylene fibres improve durability under acidic exposure.

The inclusion of Euphorbia cactus extract (ETC) and polypropylene fibres significantly improved the acid attack concrete's resilience. The combination containing 5% ETC and 0.5% polypropylene fibres exhibited the best durability performance when exposed to both sulfuric and hydrochloric acid, indicating strong resistance to chemical degradation. ETC not only facilitated self-curing but also enhanced chemical resistance by promoting a denser and less permeable microstructure. While the addition of polypropylene fibres alone was effective in improving durability, their combination with ETC produced notably superior results, showcasing the synergistic benefits of natural and synthetic additives in enhancing how well concrete performs throughout time under aggressive environmental circumstances.

6. CONCLUSION

This study looked into the development of self-curing concrete using Euphorbia cactus extract (ETC) and polypropylene fibres, aiming to enhance mechanical strength and durability while promoting sustainable construction practices. The incorporation of ETC, a natural hydrogel, significantly improved internal moisture retention, enabling better hydration and reducing shrinkage and microcracking. Increasing the cactus gel content up to 5% showed significant increases in compressive and flexural strength by weight of cement, indicating its effectiveness as a natural alternative to

traditional water curing, especially in water-scarce environments.

Polypropylene fibres, added at a rate of 0.5% by cement weight improved the concrete's tensile and flexural performance by bridging cracks and improving toughness. The combination of 5% ETC and 0.5% fibres yielded the highest mechanical performance, with compressive strength reaching 31.64 N/mm² and flexural strength 15.10 N/mm², demonstrating a synergistic effect. Durability tests under acidic conditions confirmed improved acid resistance and reduced weight loss in the modified mixes because to the low permeability and thick matrix. The eco-friendly nature of ETC and the durability of polypropylene fibres support sustainable concrete production. Overall, this study presents an innovative, practical solution for constructing durable infrastructure in challenging environments, laying the groundwork for further research into bio-based self-curing systems.

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