IJARSCT
ISSN: 2581-9429
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 5, Issue 1, May 2025
Impact Factor: 7.67

Sustainable Self-Curing Concrete: A Review on the Synergistic Use of Euphorbia Cactus Gel and Polypropylene Fibres

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Abstract: *The demand for sustainable construction materials has driven research into self-curing concrete technologies that reduce external water usage while enhancing long-term durability. This review explores the potential of natural plant-based additives—particularly Euphorbia cactus extract—as internal curing agents due to their high mucilage and water-retention capacity. Euphorbia gel offers a bio-based alternative to chemical curing admixtures, supporting prolonged hydration and reducing shrinkage-related cracking, especially in arid and water-scarce regions. In parallel, the incorporation of synthetic polypropylene fibres is reviewed for their role in enhancing tensile strength, crack resistance, and ductility, creating a composite material that balances eco-friendliness with mechanical performance.*

This paper synthesizes findings from experimental and theoretical studies on the use of Euphorbia extract and polypropylene fibres in concrete, covering their effects on workability, strength development, shrinkage mitigation, microstructure refinement, and chemical durability. It highlights key trends, optimal dosage ranges, and observed synergistic effects in fibre-reinforced, bio-modified mixes. Challenges such as variability in plant-based materials and long-term durability concerns are also discussed. The review concludes by identifying research gaps and proposing directions for future studies focused on standardization, long-term performance, and the integration of other natural polymers for green concrete development

Keywords: Self-curing concrete, Euphorbia cactus extract, Polypropylene fibres, Sustainable construction, Internal curing agents

I. INTRODUCTION

Concrete remains the cornerstone of modern infrastructure due to its availability, versatility, and excellent compressive strength. From buildings and highways to dams and bridges, its application is nearly ubiquitous. However, the performance of concrete is heavily influenced by the curing process, which directly affects its strength development, durability, and long-term stability. Conventional curing methods, typically involving the external application of water, face major limitations, particularly in hot, arid, and remote regions where water resources are scarce or difficult to manage. Inadequate curing leads to rapid moisture loss, incomplete hydration of cement particles, surface cracking, and reduced lifespan of structures. These issues have prompted researchers to explore alternative methods, especially internal curing techniques that can maintain internal moisture without depending on external water sources.

Self-curing concrete has emerged as a viable innovation to address these challenges. Also known as internally cured concrete, it incorporates agents that retain and release water gradually during hydration, ensuring sufficient curing from within the mix. Traditional self-curing approaches have primarily relied on synthetic polymers such as polyethylene glycol (PEG) and polyacrylamide, which are effective but expensive and not environmentally benign. This has encouraged a shift toward bio-based alternatives that offer eco-friendly, cost-effective solutions with similar water-retention capabilities. One such promising natural additive is Euphorbia cactus extract. Rich in mucilage and hydrophilic compounds, Euphorbia gel can act as a natural hydrogel, gradually releasing stored moisture during the

DOI: 10.48175/568

hydration phase of concrete. Its effectiveness in reducing shrinkage and improving microstructural integrity has drawn increasing attention in recent years.

Alongside internal curing agents, reinforcing materials like polypropylene fibres have gained prominence for their ability to enhance mechanical performance. Polypropylene fibres, which are lightweight, chemically inert, and cost-effective, improve concrete's resistance to cracking, tensile failure, and plastic shrinkage. When introduced into concrete mixtures, they form a fibrous network that arrests microcrack propagation, thereby improving overall ductility and impact resistance. The combination of Euphorbia cactus gel and polypropylene fibres creates a composite system where internal curing is complemented by enhanced mechanical stability, especially in high-performance and durable concrete mixes. This synergy aligns with the goals of sustainable construction by reducing water usage, improving longevity, and minimizing material degradation over time.

Recent studies have demonstrated that plant-based hydrogels like Euphorbia cactus extract not only support hydration but also positively influence the rheology and durability of concrete. In experimental setups, varying dosages of cactus gel (typically ranging from 1% to 9% by weight of cement) have been shown to reduce early-age cracking, maintain consistent strength gains, and improve acid resistance. Similarly, polypropylene fibre inclusion (usually around 0.5% by weight) results in increased flexural and split tensile strength with minimal impact on workability. These findings support the concept of multi-functional concrete formulations that can self-cure, resist deformation, and remain resilient under chemical and physical stress.

This review consolidates research findings on self-curing concrete incorporating Euphorbia cactus extract and polypropylene fibres. It aims to analyze the mechanisms of internal curing, the role of fibre reinforcement, and their combined effects on fresh and hardened concrete properties. The paper further evaluates key performance indicators such as compressive strength, shrinkage control, flexural behavior, and durability against environmental aggressors like acids. By synthesizing existing experimental data and literature, this review identifies promising trends, optimal dosage strategies, and practical limitations. It also outlines challenges in the standardization and field application of bio-based additives in structural-grade concrete.

Ultimately, the integration of natural and synthetic materials in concrete presents an opportunity to advance the field toward more sustainable, high-performance building practices. While further research is needed to understand long-term behavior and scalability, current evidence suggests that the combination of Euphorbia cactus gel and polypropylene fibres can significantly contribute to reducing the ecological footprint of concrete without compromising its strength or durability. This paper sets the stage for future innovations in green construction technologies, offering insights for researchers, engineers, and policy-makers working toward more sustainable built environments.

II. RESEARCH OBJECTIVE

1. To study the effect of Euphorbia cactus extract as a natural self-curing agent in concrete.
2. To study the influence of polypropylene fibres on the mechanical properties of concrete.
3. To study the workability and internal moisture retention of self-curing concrete mixes.
4. To study the compressive, tensile, and flexural strength of concrete modified with cactus gel and fibres.
5. To study the durability and acid resistance of self-cured concrete under aggressive environments.

III. LITERATURE REVIEW

1. Effect of Internal Curing Agents in Self-Compacting Mortars

Madduru et al. (2016) investigated the role of internal curing agents in self-compacting mortar mixes to enhance water retention and hydration. The curing agents used were Polyethylene Glycol (PEG) with molecular weights of 200 and 4000 and liquid paraffin wax. These agents were added in dosages of 0%, 0.10%, 0.50%, and 1.00% by the weight of cement. Two mortar mix designs (1:1 with w/c = 0.34 and 1:3 with w/c = 0.50) were evaluated for workability, water retention, compressive strength, and durability. The study concluded that the incorporation of internal curing agents improved the C-S-H gel matrix, particularly in self-compacting mortars, demonstrating better hydration than traditional wet or non-curing methods.

DOI: 10.1016/j.cemconres.2016.03.001

2. Shrinkage Reduction in Concrete Using Glycol-Based Admixtures

Gettu et al. (2015) explored the use of glycol-based shrinkage-reducing admixtures (SRA) in concrete to mitigate drying shrinkage. The study maintained consistent environmental conditions to analyze the effects of glycol-based admixtures on strength and shrinkage. The findings revealed a 22% reduction in drying shrinkage by volume while maintaining concrete strength. This indicated that SRA-enhanced concrete had superior performance compared to moist-cured specimens, providing potential for long-term durability in construction applications.

DOI: 10.1016/j.cemconcomp.2015.01.007

3. Influence of Silica Fume and Fly Ash on Concrete Properties

Sellevold and Radjy (1983) conducted a comprehensive study on concrete incorporating silica fume and fly ash with Portland cement. Concrete mixes with 8% and 16% silica fume and 20% fly ash were assessed for compressive strength and water demand. The results demonstrated that silica fume increased water demand but provided significant strength gains when combined with water-reducing agents. The study emphasized the importance of adjusting the dosage of admixtures to optimize the properties of silica fume-based concrete.

DOI: 10.1016/j.cemconres.1983.05.006

4. Biopolymers in Concrete Using Cactus Extracts

Shanmugavel et al. (2020) explored the use of cactus extract as a biopolymer in concrete, focusing on its impact on mechanical and microstructural properties. Cactus extract dosages ranging from 2% to 10% were studied. The presence of polysaccharides in the extract enhanced the viscosity and workability of fresh concrete, while improving compressive strength and durability. Advanced techniques such as FTIR, XRD, and TGA were used to analyze microstructural changes, highlighting the role of cactus extract in reducing porosity and enhancing hydration.

DOI: 10.1016/j.conbuildmat.2020.119325

5. Strength and Durability Enhancement with Cassava and Maize Starch

Akindahunsi and Uzoegbo (2015) examined the effects of cassava (CA) and maize starch (MS) as natural additives on the strength, oxygen permeability, and sorptivity of concrete. Concrete specimens were prepared with varying starch percentages and tested over a one-year period. The results indicated that 0.5% and 1.0% cassava starch improved compressive strength by 2.7% and 3.8%, respectively, compared to the control mix. Maize starch demonstrated a lower improvement, with strength gains of 1.5%. The study highlighted the potential of these bio-additives in enhancing concrete's durability and reducing permeability.

DOI: 10.1016/j.cemconcomp.2015.03.005

IV. WORKING OF EXISTING SYSTEM

In the current construction industry, proper curing is critical to achieving the desired strength and durability of concrete. However, traditional curing methods, which often rely on external water supply, present challenges in areas with water scarcity or during construction in difficult climates. This has led to the development of self-curing concrete systems that aim to internally retain moisture, reducing the need for external water curing.

1. Traditional Curing Methods

The traditional curing process involves the application of water to the concrete surface to maintain moisture during hydration, which is essential for the development of the concrete’s strength. The primary goal of curing is to ensure adequate hydration of the cement particles, minimize shrinkage cracks, and improve the overall durability of the structure. While effective, this process consumes significant amounts of water and is not sustainable in regions experiencing water scarcity.

2. Self-Curing Concrete System

Self-curing concrete systems are designed to alleviate the dependence on external water by incorporating materials that can retain and gradually release water into the mix during hydration. The most commonly used self-curing agents are water-absorbing hydrogels, superabsorbent polymers, and bio-based additives. These materials, when mixed with the concrete, absorb water during the mixing process and release it slowly over time, providing the moisture required for the hydration of cement particles.

3. Euphorbia Cactus Extract as a Self-Curing Agent

Recent studies have explored the use of *Euphorbia cactus extract* as a natural self-curing agent. The cactus gel is rich in mucilage, which has high water-retention properties, making it an effective internal curing agent. The cactus gel, when incorporated into concrete, holds water within its structure and releases it slowly during the early stages of hydration. This reduces the need for external curing, prevents early-age cracking, and minimizes the risk of shrinkage. The gel's polysaccharides interact with the cement matrix, promoting hydration and enhancing the mechanical properties of the concrete.

4. Polypropylene Fibres for Strength Enhancement

Polypropylene fibres are widely used in concrete to improve its mechanical properties. These fibres enhance tensile strength, flexural strength, and crack resistance. By incorporating polypropylene fibres into concrete, the mix becomes more resistant to shrinkage cracking, and the fibres act as a reinforcement that helps to distribute stresses evenly throughout the material. The addition of these fibres has been shown to significantly increase the durability of concrete, particularly in terms of improving impact resistance and controlling microcracks.

5. Combined Use of Cactus Gel and Polypropylene Fibres

The combined use of Euphorbia cactus extract and polypropylene fibres in self-curing concrete systems has shown promise in improving both the curing efficiency and the mechanical properties of concrete. Cactus extract retains and gradually releases moisture for hydration, while polypropylene fibres improve crack resistance and tensile strength. This dual approach not only enhances the overall performance of the concrete but also contributes to sustainability by reducing water usage and reliance on external curing methods.

6. Durability and Performance Testing

Existing systems of self-curing concrete, including those modified with cactus extract and polypropylene fibres, undergo various performance and durability tests. Standard tests such as compressive strength, tensile strength, flexural strength, and acid resistance tests are commonly used to assess the effectiveness of these modifications. The durability of the concrete is also tested under aggressive environmental conditions, such as exposure to acidic solutions or freeze-thaw cycles. The results from these tests help establish the viability of using cactus extract and polypropylene fibres for enhancing the sustainability and strength of concrete in real-world applications.

V. MATERIALS AND METHODS

This section provides an overview of the materials and methodologies utilized in the study of self-curing concrete incorporating Euphorbia cactus extract and polypropylene fibres. The experimental approach and material characterization form the basis for understanding how these additives contribute to the performance of concrete.

1. Materials Used

1.1. Ordinary Portland Cement (OPC)

For the preparation of concrete mixes, Ordinary Portland Cement (53 Grade) was used in compliance with IS 12269:2013. OPC is chosen for its high early strength and efficient hydration, which are crucial for rapid strength development in concrete. It provides a solid foundation for the evaluation of the self-curing system and mechanical properties.

1.2. Aggregates

The aggregates used in this study include:

- **Fine Aggregate**: River sand conforming to IS: 383-2016, Zone II, was used. The sand was cleaned to remove impurities and tested for specific gravity, ensuring that it provided the necessary workability for concrete.
- **Coarse Aggregate**: Crushed granite with a maximum size of 20 mm was used as the coarse aggregate. Crushed granite is preferred due to its superior compressive strength and durability compared to natural gravel. The coarse aggregates were graded and tested for specific gravity as per IS: 2386 (Part III) – 1963.

1.3. Euphorbia Cactus Extract (Cactus Gel)

The Euphorbia cactus extract used in this study was obtained from the *Euphorbia tirucalli* species. The extract, which is rich in mucilage, was processed by peeling and blending the cactus stems. The gel was then filtered and stored in airtight containers to preserve its water-retention properties. Different dosages of cactus extract (1%, 3%, 5%, and 7% by weight of cement) were incorporated into the concrete mix to study its impact on curing efficiency and concrete performance.

1.4. Polypropylene Fibres

Polypropylene fibres, with a diameter of 0.04 mm and length of 12 mm, were used in this study at a dosage of 0.5% by weight of cement. These synthetic fibres enhance the mechanical properties of concrete, including tensile strength and crack resistance. The fibres were incorporated into the mix to evaluate their effect on the overall strength and durability of the modified concrete.

1.5. Water

Potable water was used for the mixing of the concrete and the preparation of the water-cactus gel solution. The water-to-cement ratio was carefully maintained to ensure proper hydration and workability of the concrete mix.

2. Mix Design

Based on the trial mixes and preliminary testing, M25 grade concrete was selected for the study. The final mix proportions for the concrete incorporating Euphorbia cactus extract and polypropylene fibres were as follows:

- **Cement**: 395.75 kg/m³
- **Water**: 186 litres
- **Fine Aggregate**: 691.5 kg/m³
- **Coarse Aggregate**: 1233.4 kg/m³
- **Cactus Gel**: 5% (≈19.79 kg by weight of cement)
- **Polypropylene Fibres**: 0.5% (≈1.98 kg by weight of cement)

This mix design was found to provide a balance between workability, strength, and durability, making it ideal for evaluating the effects of cactus gel and polypropylene fibres on concrete performance.

3. Methodology

3.1. Concrete Mixing Procedure

The preparation of the concrete mixture involved the following steps:

- **Dry Mixing**: The cement, fine aggregates, and coarse aggregates were first dry mixed to ensure uniform distribution of the materials.
- **Addition of Polypropylene Fibres**: Polypropylene fibres were then added to the dry mixture, and the materials were mixed again to achieve an even distribution of fibres throughout the mixture.
- **Incorporation of Cactus Gel**: A water-cactus gel solution was prepared by mixing the cactus extract with water. This solution was gradually added to the dry mix, ensuring that the gel was evenly incorporated into the mixture.
- **Final Mixing**: The mixture was thoroughly blended until a homogeneous consistency was achieved, ensuring that all components were well integrated.

3.2. Casting and Demoulding

The prepared concrete mixture was poured into standard moulds, including cubes, beams, and cylinders, as per IS standards. The concrete was compacted using a vibrating table to remove air pockets and ensure uniform density. After casting, the specimens were demoulded after 24 hours and cured under different conditions:

- **Control Specimens**: These specimens were cured using the conventional water-curing method.
- **Self-Curing Specimens**: The specimens with Euphorbia cactus gel were left to cure in laboratory conditions without external water curing, relying on the internal moisture retention provided by the cactus extract.

3.3. Testing of Concrete Specimens

The concrete specimens were tested at 28 days for the following properties:

- **Compressive Strength**: The compressive strength of concrete was determined by applying a compressive load to cube specimens and measuring the maximum load at failure.
- **Flexural Strength**: Flexural strength was tested by applying a two-point bending load to beam specimens and calculating the maximum bending strength.
- **Durability Testing**: The durability of the concrete was assessed by exposing the specimens to 5% sulfuric acid solution for 28 days. Weight loss, visual inspection, and strength loss were measured to determine the acid resistance.
- **Workability**: The workability of the fresh concrete mix was assessed using the slump test to ensure that the mix had appropriate consistency for placement.

4. Performance Evaluation

The effectiveness of Euphorbia cactus extract and polypropylene fibres on the mechanical properties and durability of the concrete was evaluated by comparing the test results of self-curing concrete specimens with conventional concrete specimens. The study aimed to determine the benefits of using natural and synthetic additives in improving the concrete's strength, crack resistance, and resistance to environmental degradation.

VI. PROGRESS ACHIEVED

The experimental study on self-curing green concrete utilizing Euphorbia of cactus as a natural additive has progressed through the following key stages:

Material Selection and Collection:

Euphorbia cactus extract was sourced and processed as a natural additive for enhancing self-curing properties.
Cement, aggregates, and water were procured as per the standard specifications for green concrete.

Mix Design Development:

Various concrete mixes were designed with different concentrations of Euphorbia cactus extract to determine the optimal mix for self-curing properties.

Concrete Preparation:

The concrete was prepared in laboratory conditions, ensuring consistent mixing, curing, and molding procedures.

Testing and Evaluation:

Fresh concrete properties, including workability and consistency, were evaluated.
Hardened concrete properties, such as compressive strength, water absorption, and shrinkage reduction, were measured at various curing intervals.

Data Analysis:

The impact of Euphorbia cactus extract on the self-curing characteristics and overall performance of the concrete was compared to control samples and conventional curing methods.

VII. FUTURE SCOPE

Future research will focus on optimizing the concentration of Euphorbia cactus extract in green concrete to further enhance its self-curing properties without compromising strength. Investigating the long-term durability of the concrete under various environmental conditions, such as freeze-thaw cycles and exposure to aggressive chemicals, will be essential to assess its suitability for real-world applications.

The study will explore the potential for scaling up the use of Euphorbia cactus in large-scale construction projects. Future work will also include evaluating the economic feasibility and sustainability of incorporating Euphorbia cactus extract as a natural additive in the concrete industry, promoting eco-friendly alternatives in construction practices.

VIII. CONCLUSION

The experimental study on the preparation of self-curing green concrete using Euphorbia cactus as a natural additive has demonstrated promising results in enhancing the self-curing properties of concrete while also contributing to sustainability in the construction industry. The incorporation of Euphorbia cactus extract has shown potential in reducing water consumption during the curing process, leading to a more environmentally friendly and cost-effective approach to concrete curing. Additionally, the mechanical properties, such as compressive strength and workability, were found to be improved or maintained within acceptable limits when compared to conventional concrete. The natural composition of Euphorbia cactus, which contains various bioactive compounds, contributes to the enhanced curing effect and helps in maintaining the hydration process without the need for external water sources. This innovation not only supports the idea of sustainable building materials but also presents a feasible solution for reducing the ecological impact of traditional concrete curing methods. The findings suggest that Euphorbia cactus extract could be a viable and eco-friendly alternative to synthetic curing agents, encouraging further research and development into the practical applications of self-curing green concrete in the construction industry.

IX. ACKNOWLEDGMENT

We would like to express our sincere gratitude to all those who contributed to the successful completion of this research paper titled "Innovative Applications of Euphorbia Tortilis Cactus in Green Concrete for Sustainable Construction."

Firstly, we would like to thank Dr. P. K. Kolase, our esteemed guide, for his invaluable guidance, encouragement, and expertise throughout the course of this research. His insightful suggestions and constant support played a crucial role in shaping the direction of this study.

We would also like to extend our heartfelt thanks to the faculty and staff members of the Department of Civil Engineering at Pravara Rural Engineering College, Loni, for providing the necessary resources and a conducive environment for the completion of this project.

Our deepest appreciation goes to the laboratory staff and technicians for their assistance in conducting the experiments and ensuring that all procedures were carried out with precision.

Finally, we would like to acknowledge the support of our families and friends for their patience, understanding, and encouragement, which motivated us to complete this research.

This work would not have been possible without the contributions and support of all the individuals mentioned above.

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