Study on Polymer Mycelium Composite Coating for Capillary Action Prevention in Buildings

Anu George[1], Arya Nandanan[2], Hana Mehaboob[3], Mohammad Fadil[4], Naajiya Kamarudeen[5]

[1]*Assistant Professor, Department of Civil Engineering, IES College of Engineering, Kerala, India*
[2,3,4,5]*Student, Department of Civil Engineering, IES College of Engineering, Kerala, India*
Email_id: anugeorge023@gmail.com, aryanandanan0372@gmail.com, naajikamaru04@gmail.com, hanamehaboob2@gmail.com

Abstract

Capillary rise of water through porous concrete and masonry materials is a major cause of dampness, deterioration, and reduction in service life of buildings. This study presents the development and performance evaluation of a sustainable polymer–mycelium composite coating intended to prevent capillary action in building components. The composite coating was developed using oyster mushroom mycelium as a bio-based filler, chicken feather fibers as reinforcement, and polymeric additives such as polyvinyl alcohol, polytetrafluoroethylene, silicone emulsion, acrylic polymer, and polyurethane to enhance adhesion, hydrophobicity, flexibility, and durability. Experimental investigations were carried out on concrete specimens to assess water absorption, surface wettability, adhesion strength, skid resistance, and fungal resistance. In addition, a numerical simulation study was conducted using ANSYS software to analyze capillary water transport in concrete and to validate the experimental findings. The results indicate that the developed polymer–mycelium composite coating significantly reduces water ingress and improves resistance to capillary action, demonstrating its potential as an eco-friendly and effective moisture-protection solution for buildings.

***Keywords*: Capillary action, Bio-composite coating, Mycelium, Waterproofing, Sustainable construction.

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1. Introduction

Moisture ingress due to capillary action is a common durability problem in buildings, especially in foundations, walls, bathrooms, and roof slabs. Concrete and masonry materials possess interconnected pore structures that allow water to rise vertically against gravity. This phenomenon results in dampness, efflorescence, fungal growth, corrosion of reinforcement, and degradation of structural components over time.

Traditional waterproofing systems are generally based on synthetic chemical products, which may have limitations related to environmental impact, cost, and long-term sustainability. In recent years, bio-based materials and waste-derived composites have gained attention in the construction sector as environmentally responsible alternatives. Mycelium-based materials have emerged as promising bio-composites due to their lightweight nature, biodegradability, and ability to form interconnected networks. Chicken feathers, a poultry industry waste, contain keratin and exhibit inherent hydrophobic characteristics, making them suitable as reinforcement in composite materials.

This study focuses on the development of a polymer–mycelium composite coating using bio-based and waste materials combined with polymeric binders to prevent capillary water rise in buildings. The study emphasizes experimental evaluation supported by numerical simulation to establish the effectiveness of the proposed coating.

1.2 Objectives of the study

- To develop a sustainable polymer–mycelium composite coating for capillary action prevention.
- To utilize bio-based and waste materials such as mycelium and chicken feathers in construction applications.
- To experimentally evaluate the water resistance and durability performance of the developed coating.
- To numerically analyse capillary water transport in concrete using ANSYS software.
- To validate the numerical results with experimental observations.

1.3 Scope of the study

- The study focuses on the development of a polymer–mycelium composite coating for preventing capillary water rise in concrete.
- The scope includes the use of bio-based and waste materials such as oyster mushroom mycelium and chicken feathers to promote sustainability in construction.
- Experimental investigations are limited to laboratory-scale tests conducted on concrete specimens with and without the composite coating.
- The performance of the coating is evaluated through water absorption, contact angle, adhesion strength, skid resistance, and fungal resistance tests.
- The study includes a numerical investigation using ANSYS software to analyse capillary water transport in concrete and to study the effect of the coating layer on moisture movement.
- The numerical analysis is restricted to a two-dimensional transient study under controlled boundary conditions.
- The application scope of the developed coating is limited to moisture-prone building areas such as foundations, bathrooms, and roof slabs.
- Long-term field performance, structural load-bearing behaviour, and chemical degradation effects are beyond the scope of this study.

2. Materials used

2.1 Mycelium

Oyster mushroom mycelium was used as the primary bio-based filler in the composite coating. The mycelium was cultivated under controlled conditions and thermally inactivated prior to use to ensure material stability and durability.

Figure 1: Mycelium

2.2 Chicken Feathers

Chicken feathers were collected, cleaned, dried, and shredded into fine fibers. These fibers act as reinforcement in the composite coating and contribute to crack resistance and hydrophobic behaviour due to their keratin content.

Figure 2: Chicken feathers

2.3 Polyvinyl Alcohol (PVA)

Polyvinyl alcohol was used as the main binder to provide adhesion between the coating and the concrete substrate. It also improves film formation and flexibility.

Figure 3: Polyvinyl Alcohol (PVA)

2.4 Polytetrafluoroethylene (PTFE)

PTFE was incorporated to enhance the hydrophobicity of the coating owing to its low surface energy and water-repellent characteristics.

Figure 4: Polytetrafluoroethylene (PTFE)

2.5 Silicone Emulsion

Silicone emulsion was added to improve pore sealing and reduce water absorption at the microstructural level.

Figure 5: Silicone Emulsion

2.6 Acrylic Polymer

Acrylic polymer was used to improve weather resistance, flexibility, and aging performance of the coating.

Figure 6: Acrylic Polymer

2.7 Polyurethane

Polyurethane was added to enhance elasticity and crack-bridging ability, thereby improving long-term durability.

Figure 7: Polyurethane

2.8 Natural Gum

Natural gum was used as a thickening and plasticizing agent to improve workability and uniformity of the composite mixture.

Figure 8: Natural Gum

3. Methodology

3.1 Preparation of Composite Coating

A 10% PVA solution was prepared by dissolving polyvinyl alcohol in water under controlled heating. Thermally inactivated mycelium and shredded chicken feathers were gradually added to the solution and mixed thoroughly. PTFE, silicone emulsion, acrylic polymer, polyurethane, and natural gum were subsequently incorporated, and the mixture was mechanically stirred until a homogeneous coating paste was obtained.

3.2 Use of Pre-Casted Concrete Specimens

In the present study, concrete cubes that had been cast and cured prior to the commencement of the experimental program were utilized. The use of pre-casted and well-cured concrete specimens is considered appropriate for durability and moisture-transport investigations, as such studies primarily depend on the stabilized pore structure of concrete rather than early-age hydration behaviour. Fully matured concrete provides consistent and repeatable results for capillary action and water absorption tests.

3.3 Specimen Selection and Preparation

Concrete cubes of size 150 × 150 × 150 mm were selected from previously cast specimens. The cubes had been cured for a sufficient period to ensure complete hydration. Prior to testing, the specimens were visually inspected to ensure the absence of surface cracks or defects.

The concrete surfaces were cleaned using a dry brush to remove dust, loose particles, and surface contaminants. The specimens were then allowed to air-dry under laboratory conditions to achieve a uniform initial moisture condition.

3.4 Surface Conditioning

To ensure consistency during moisture-related testing, the selected concrete cubes were oven-dried at 105 ± 5°C until a constant mass was achieved. This step ensured the removal of free moisture and allowed the capillary absorption tests to be conducted from a defined dry reference state. After oven drying, the specimens were cooled to room temperature in a desiccator to prevent moisture reabsorption from the atmosphere.

3.5 Application of Bio-Composite Coating

After surface conditioning, a set of concrete cubes was coated with the prepared polymer–mycelium composite coating. The coating was applied uniformly using a brush, ensuring complete coverage of the exposed surfaces. The thickness of the applied coating was maintained uniformly across all specimens.

The coated specimens were allowed to cure under ambient laboratory conditions for 24–48 hours to ensure proper film formation and adhesion to the concrete substrate.

4. Experimental Investigation

4.1 Water Absorption Test

Water absorption tests were conducted to evaluate the resistance of coated and uncoated concrete specimens to water ingress. The test was performed in accordance with IS 2645:2003.

4.2 Contact Angle Test

Contact angle measurements were carried out to assess the surface wettability of the coating. Higher contact angle values indicate improved hydrophobic performance.

4.3 Adhesion Strength Test

Adhesion strength between the coating and concrete substrate was determined as per IS 101 (Part 5). Adequate adhesion is essential for long-term performance.

4.4 Skid Resistance Test

Skid resistance was evaluated using the British Pendulum Test in accordance with ASTM E303 to assess the suitability of the coating for floor and roof applications.

4.5 Fungal Resistance Test

Fungal resistance testing was conducted as per IS 15462:2004 to examine the resistance of the coating against microbial growth in moist conditions.

4.6 Study on capillary action using ANSYS Software

In addition to experimental investigations, a separate numerical study was conducted using ANSYS software to understand the mechanism of capillary water transport in concrete and to study the influence of the polymer–mycelium composite coating on moisture movement. The objective of this study was not only to validate experimental results but also to visualize capillary rise behaviour and moisture distribution within the concrete matrix.

A two-dimensional model representing a vertical section of a concrete specimen was developed. The concrete was modelled as a porous medium, while the coating layer was represented as a thin, low-permeability barrier at the exposed surface. Material properties such as porosity, permeability, and surface wettability were adopted from experimental observations. Gravity effects were included to simulate realistic capillary rise conditions.

The analysis was carried out as a transient study to capture the time-dependent movement of water through the concrete pores. The numerical results provided saturation contours and capillary rise profiles, enabling a comparative study between uncoated and coated concrete conditions. The ANSYS-based study clearly demonstrated a reduction in moisture penetration and capillary rise in the presence of the polymer–mycelium composite coating, thereby supporting the experimental findings.

5. Expected Results and Discussions

The experimental results showed that uncoated concrete specimens exhibited significant water absorption and capillary rise. In contrast, the polymer–mycelium composite coated specimens demonstrated a substantial reduction in water uptake and improved hydrophobic behaviour. Adhesion strength and skid resistance values satisfied the recommended limits, indicating suitability for practical application. The numerical analysis results obtained from ANSYS showed good agreement with experimental trends, thereby validating the performance of the developed coating.

6. Conclusion

This study demonstrates that the polymer–mycelium composite coating effectively reduces capillary action in concrete and enhances resistance to moisture ingress. The use of bio-based and waste materials contributes to environmental sustainability while achieving satisfactory performance characteristics. The numerical analysis using ANSYS successfully supported the experimental findings. The developed coating shows promising potential for application in moisture-prone areas of buildings such as foundations, bathrooms, and roof slabs.

7. Reference

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