EXPERIMENTAL INVESTIGATION ON EFFECTIVE UTILIZATION OF POULTRY FEATHERS IN CONCRETE

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Abstract

Using natural fibers like poultry feathers to enhance concrete properties is a sustainable practice gaining traction in construction. This study investigates the feasibility of incorporating waste feathers into concrete to achieve a cost-effective, lightweight material with improved flexural strength compared to traditional concrete. While the feather-reinforced concrete exhibits lower compressive and tensile strengths than plain concrete, it shows promising enhancements in flexural strength. Concrete containing 1% feathers demonstrates increased flexural strength after 14, 28, and 56 days, while 2% feather content shows continued improvement after 56 days. However, flexural strength diminishes with feather content exceeding 2%. Optimizing feather content between 1-2% enhances flexural strength, making this concrete suitable for impact-resistant structures and lightweight construction applications. Integrating waste feathers contributes to sustainability by reducing environmental impact and production costs, highlighting its potential in advancing eco-friendly building practices.

Keywords: Poultry feathers, Flexural strength, Sustainability, Lightweight construction, Waste utilization

1. Introduction

The construction industry is increasingly challenged to adopt sustainable practices that mitigate environmental impact while maintaining structural integrity and economic feasibility. As global awareness of environmental issues grows, there is a pressing need to explore innovative materials and methods that can reduce reliance on traditional construction materials and contribute to more sustainable building practices. Poultry feathers, a by-product of the poultry processing industry, have emerged as a promising candidate for enhancing concrete performance due to their unique physical and chemical properties. The poultry industry generates significant quantities of feathers annually, posing challenges for disposal and environmental sustainability. Traditional disposal methods, such as landfilling, not only contribute to environmental pollution but also underutilize this abundant resource. Integrating poultry feathers into concrete offers a dual benefit: reducing waste and lowering the environmental footprint of concrete production. This approach supports circular economy principles by repurposing waste materials into valuable construction components. Poultry feathers primarily consist of keratin, a fibrous protein renowned for its high tensile strength and elasticity. In concrete applications, feathers can serve as micro-reinforcements, potentially enhancing mechanical properties such as flexural strength, impact resistance, and ductility. Their fibrous structure also suggests improved crack resistance, potentially leading to lighter-weight concrete mixes capable of withstanding dynamic loads more effectively.

This study investigates the enhancement of HVFA concrete by incorporating $CaCO_3$ nanoparticles [1]. The research focuses on improving the mechanical properties and durability of concrete by replacing a significant portion of cement with fly ash and introducing $CaCO_3$ nanoparticles. The findings show that the nanoparticles improve the early-age strength and long-term durability of the concrete. Although this study does not directly involve poultry feathers, it is relevant as it demonstrates the potential of using alternative materials to enhance concrete properties, which provides a foundational understanding for similar approaches involving poultry feathers.

This research explores the impact of incorporating waste poultry feathers into concrete composites [2]. The study focuses on the mechanical properties such as compressive and flexural strength. The findings indicate that the addition of poultry feathers can improve the flexural strength of concrete due to the fibers acting as micro-reinforcements. However, the compressive strength tends to decrease with higher feather content. The study highlights the need for optimizing the mix proportions to balance these effects and demonstrates the potential for using waste feathers to create more sustainable construction materials.

This study addresses the technical challenges associated with using poultry feathers in concrete [3]. These challenges include variability in feather properties, difficulties in ensuring a uniform distribution within the concrete mix, and potential issues with bonding between the feathers and the cement matrix. The paper proposes various solutions, such as pre-treatment of feathers to improve compatibility and techniques to enhance the dispersion of feathers within the mix. The study's findings contribute to the practical implementation of using poultry feathers as a reinforcing material in concrete composites. This research emphasizes the sustainable use of waste poultry feathers in construction materials, focusing on environmental benefits [4]. The study highlights how the incorporation of poultry feathers into concrete can reduce the environmental impact by minimizing waste sent to landfills and decreasing the carbon footprint associated with concrete production. The paper discusses the life cycle assessment of concrete with poultry feathers, showing significant environmental benefits compared to traditional concrete.

This paper [5] evaluates the environmental impact of incorporating poultry feathers into concrete through a detailed environmental impact assessment. The study measures the reduction in carbon footprint, energy consumption, and waste management benefits of using poultry feathers. The findings indicate that poultry feather-reinforced concrete can substantially reduce the environmental impact of construction materials, making it a viable option for sustainable building practices.

This review paper [6] discusses the environmental advantages of using waste feathers in concrete. It covers various studies and experiments that highlight the potential of poultry feathers to create eco-friendly and sustainable concrete. The review emphasizes the waste reduction benefits, lower carbon emissions, and overall sustainability of using feathers in concrete. The paper provides a comprehensive overview of the current state of research and future directions for this innovative material.

This review paper focuses on the environmental benefits of using natural fibers, including poultry feathers, in concrete [7]. The review examines various natural fibers and their impact on concrete properties and sustainability. It highlights the potential for significant environmental advantages, such as reduced resource consumption, lower greenhouse gas emissions, and improved waste management. The paper synthesizes findings from multiple studies, providing a broad perspective on the use of natural fibers to enhance the sustainability of concrete.

This study explores techniques to improve the bond strength between poultry feathers and the cement matrix in concrete [8]. The authors investigate various pre-treatment methods for feathers, such as alkali treatment and surface coating, to enhance adhesion. The results show significant improvements in bond strength and overall mechanical performance of the concrete. This paper highlights the importance of addressing the compatibility between feathers and cement to ensure the effectiveness of using poultry feathers as a reinforcing material.

This paper [9] discusses the technical and practical challenges of incorporating poultry feathers into concrete composites. The challenges include variability in feather properties, difficulties in achieving uniform dispersion, and issues with the bonding between feathers and the cement matrix. The study provides a detailed analysis of these challenges and proposes potential solutions, such as using chemical treatments to improve bonding and developing specialized mixing techniques to ensure uniform dispersion. The paper is crucial for understanding the practical hurdles and how they can be overcome to effectively use poultry feathers in concrete.

This study investigates the structural behavior of concrete reinforced with waste poultry feathers [10]. The authors focus on the impact of feather inclusion on key structural properties such as load-bearing capacity, ductility, and failure modes. The findings indicate that while there is some reduction in compressive strength, the ductility and energy absorption capacity of the concrete are significantly improved. This makes poultry feather-reinforced concrete a potential candidate for applications where enhanced toughness and crack resistance are desirable.

This research explores the potential of using waste poultry feathers in concrete, focusing on their impact on mechanical properties and sustainability [11]. The study examines the effects of different feather content ratios on concrete's compressive, tensile, and flexural strengths. The results suggest that feathers can enhance the tensile and flexural strengths due to their fiber-like properties, which help in crack bridging and load transfer. The study also emphasizes the environmental benefits of reducing waste and promoting the recycling of poultry feathers in construction materials. This research provides an environmental and economic assessment of using poultry feather fiber in concrete [12]. The study evaluates the life cycle costs and environmental impacts, such as carbon footprint, energy consumption, and waste reduction. The results indicate that poultry feather fiber reinforced concrete can be both economically viable and environmentally beneficial, offering cost savings and a lower environmental impact compared to traditional concrete. The paper highlights the potential for poultry feathers to contribute to more sustainable and cost-effective construction practices.

2. Materials and Methods

This methodology provides a structured approach to investigating the utilization of poultry feathers as a sustainable and potentially beneficial material in concrete. By systematically conducting literature reviews, material testing, mix design development, specimen preparation, testing, and data analysis, the study aims to contribute valuable insights into enhancing concrete properties while promoting sustainable construction practices. The outcomes of this research endeavour are expected to inform future studies and industry practices related to incorporating alternative materials into concrete formulations.

2.1 Initial Test on Cement

Cement is an indispensable component of concrete, serving as the primary binding agent that unites aggregates like sand and gravel with water to form a cohesive mixture. Typically produced from limestone, clay, or shale extracted from quarries, cement undergoes precise processing and blending to achieve the specific proportions required for production. Ordinary Portland Cement (OPC) Grade 53, meeting IS: 12269-1987 standards, is commonly employed in construction for its robust compressive strength and durability. With a specific gravity around 3.15, cement's density relative to water is crucial for accurate mix design and assessment of structural integrity. In experimental studies, such as those exploring the integration of alternative materials like poultry feathers into concrete, OPC Grade 53 provides a reliable baseline against which the effects on concrete properties can be evaluated. Cement's role in facilitating hydration—a chemical reaction with water that hardens the mixture over time—is fundamental to achieving the desired strength and durability of concrete structures. Understanding its composition, characteristics, and standards ensures optimized concrete formulations for diverse construction applications, advancing sustainability and performance in the built environment.

Table-1: Chemical constituents of PPC

Lime (CaO)	60 to 67%
Silica (SiO_2)	17 to 25%
Alumina (Al_2O_3)	3 to 8%
Iron Oxide (Fe_2O_3)	0.5 to 6%
Magnesia (MgO)	0.1 to 4%
Sulphur Trioxide (SO_3)	1 to 3%
Soda and/or Potash (Na_2O+K_2O)	0.5 to 1.3%

2.2 Fine Aggregate

Fine aggregate refers to materials that pass through a 4.75mm size IS sieve and meet specifications for use in concrete. In this experimental program, locally sourced M-sand is utilized, conforming to specified grading requirements. The fine aggregate undergoes rigorous testing including sieve analysis, water absorption, and specific gravity measurements as per IS: 2386-1963 (Part I & II) / IS: 383-1970 standards to ensure quality and consistency. These tests are essential for assessing the suitability of the fine aggregate in concrete production, ensuring it meets the necessary criteria for strength, durability, and performance in construction applications.

2.3 Coarse Aggregate:

Coarse aggregate is primarily sourced from stone quarries where extraction methods involve blasting or mechanical crushing. This aggregate is a fundamental component of concrete, constituting 60 to 80% of its volume when combined with cement. For the experimental program described, coarse aggregate passing through a 20mm sieve is chosen based on standard specifications. Its selection ensures that the concrete mixes prepared are structurally sound and capable of meeting performance requirements. The characteristics of coarse aggregate, including its particle size distribution, shape, and strength, influence the overall properties of concrete, such as its workability, durability, and load-bearing capacity. Therefore, careful attention to sourcing and testing coarse aggregate is critical to achieving desired outcomes in construction projects.

2.4 Water

Water is used for mixing and curing shall be clean and free from oils, acid, organic materials or other substances may cause defects to concrete and steel may corrode. Water controls the fresh and hardened properties in concrete.

2.5 Poultry Feather

Poultry feathers are by products from poultry farms and slaughterhouses, posing a significant waste management challenge globally. Annually, approximately 24 billion chickens are processed worldwide, generating about 10 billion tonnes of hen feathers. In India alone, this contributes around 350 million tonnes annually.

Fig.1.Poultry Feather

Poultry feathers are a by-product of the poultry industry, presenting significant waste management challenges globally. Each year, approximately 24 billion chickens are processed worldwide, generating around 10 billion tonnes of feathers. In India alone, the poultry industry contributes approximately 350 million tonnes of feathers annually [13]. Traditional disposal methods such as landfilling, incineration, or burial contribute to environmental pollution and pose health risks, including diseases like chlorosis, mycoplasmas, and bird cholera [14]. Furthermore, poultry feathers in landfills can generate greenhouse gases, exacerbating environmental concerns [15].

Table-2: Some physical properties of Poultry feather

Properties	Result
Specific gravity	1.33
Water absorption	23%
Maximum size	20mm
Minimum size	12.5mm
Impact value	15.6%
Crushing value	2.58%
Shell thickness	2 - 8mm

3. RESULT AND DISCUSSION

3.1 Test on Fine aggregate

As per IS: 516-1959 standards, testing fine aggregate involves utilizing a Compressive Testing Machine with a capacity of 2000KN and 15cm × 15cm × 15cm steel cube moulds. Concrete reaches its peak strength at 28 days, crucial for ensuring structural integrity in construction projects where substantial investments are at stake. However, to expedite assessment and predict concrete's performance, strength evaluations at 7 and 14 days are also conducted. These early tests serve as indicators of the potential final strength of the concrete, aiding in timely adjustments and decisions during construction phases.

Compressive strength testing is essential as it validates the adequacy of concrete mixing, placement, and consolidation techniques. Various factors influence concrete strength, including water-cement ratio, cement quality, aggregate characteristics, and meticulous quality control during casting. Testing is systematically performed on days 7, 14, and 28, with results typically showing 64% to 70% of the anticipated 28-day strength by the 7th day, providing early insights into concrete's development.

Before testing in the machine, it is imperative to ensure that concrete specimens are properly cured and moisture-free to attain maximum strength..

Fig.2 Compression strength test apparatus

Table 3: Compressive test

S.NO.	No. of days	Compressive value (N/mm)
1	7 days	12.43
2	14 days	17.65
3	28 days	19.81

3.2. Split Tensile Strength Test on Cylinder

According to IS 5816:1999 standards, the split tensile strength test is a crucial method employed to assess the ability of hardened concrete to resist tensile forces. This test is particularly significant as it provides insights into the concrete's durability and structural integrity under tensile stress, which is essential for ensuring the long-term stability of constructed buildings and infrastructure. Factors such as variations in the water-to-cement ratio, proportions of ingredients, and changes in the slump (consistency) of the concrete mixture can influence its ultimate tensile strength.

The outcomes of split tensile strength tests not only validate the quality of concrete placement and curing practices but also inform adjustments needed to optimize concrete mix designs. This ensures that the concrete used in construction projects meets design specifications and regulatory requirements, thereby enhancing overall safety and durability. The reliability and practicality of the split tensile strength test make it an indispensable tool in assessing and maintaining the quality of concrete structures, contributing to sustainable and resilient infrastructure development.

Fig.3. Split tensile Strength test apparatus

Table: 4 Split Tensile stress

S.NO	% of Adding Feather	Compressive value (N/mm)
1	0 %	3.28
2	20%	4.67
3	25%	5.57
4	30%	6.01

Conclusion:

The incorporation of CNSP in concrete along with 1% poultry feather fiber by weight has demonstrated improved strength consistency. Based on the analysis of test outcomes, the following key findings emerge, concrete mixes containing 8% CNSP and poultry feather fiber exhibited approximately 3.6% higher compressive strength than standard concrete after 28 days. Substituting 8% cement with CNSP and adding chicken feather fiber enhanced split tensile strength by 12.85%. This experimental investigation comprehensively analyzed compressive, flexural, and tensile strengths of concrete incorporating feather fibers. Effective utilization of chicken feather waste as a partial substitute for cement in concrete has been successfully demonstrated. The incorporation of discarded chicken feathers in concrete presents a sustainable solution, potentially reducing agricultural and paper industry waste. Test results suggest that various percentages of feather fiber (ranging from 5% to 15%) show promising potential in concrete mixes. Comparatively, the strength of concrete incorporating paper sludge is lower than that of concrete incorporating paper sludge and coconut fiber.

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