International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

# Utilizing Fish Scales as a Bio-Admixture to Enhance Concrete Properties

***[1]Dineshkumar V ,[2]Kirubakaran M,[3] Srinivasan P, [4]Naveen S***

[1 2 3 4]UG Student Civil Engineering, AVS Engineering College, Salem-636003.

**ABSTRACT:**

This research examines the use of fish scales as a natural additive in concrete to improve its performance characteristics. The study involved testing concrete mixes with fish scales incorporated at 2% and 3% of the cement weight and comparing them to standard concrete. Key aspects assessed included workability, compressive strength, and tensile strength at various curing stages. The findings showed that adding fish scales reduced the concrete's workability due to higher water absorption needs. While compressive strength initially declined at early curing periods (7 and 14 days), the mix containing 2% fish scales reached similar strength levels to conventional concrete by the 28th day. Notably, the tensile strength of concrete improved consistently as the proportion of fish scales increased, with the 3% mix achieving the best results. The study concludes that fish scales serve as a beneficial reinforcement material for improving tensile strength, although their impact on early compressive strength limits their use in some structural applications. However, their effectiveness in enhancing tensile properties and their role in promoting sustainable use of fish waste suggest potential for use in lightweight or non-load-bearing construction components.

## Introduction

Concrete stands as the world's most extensively used construction material, valued for its adaptability, longevity, and economic efficiency. Nonetheless, traditional concrete inherently possesses limitations, particularly its minimal tensile strength, which typically necessitates steel reinforcement. The construction sector is continuously seeking innovative and sustainable alternatives to enhance concrete's performance and minimize its environmental impact.

Fish scales, a considerable byproduct of the fishing industry, are frequently discarded as waste, raising environmental concerns. These scales are a rich source of biopolymers, including collagen, calcium carbonate, and chitin. Their distinct characteristics, such as biocompatibility and biodegradability, have led to their investigation in various applications, including biopolymers, composite materials, and medical devices. This interest is further heightened by their unique structural and chemical composition, particularly the presence of hydroxyapatite, a compound that acts as a cementing agent.

This project aims to assess the practicality of incorporating fish scales into concrete as a novel additive. The key objectives of this investigation are:

- To analyze how fish scales influence the fresh properties of concrete, with particular attention to its workability.
- To evaluate the effect of fish scales on the hardened properties of concrete, specifically examining its compressive and split tensile strength at different curing periods (7, 14, and 28 days).
- To conduct a comparative assessment between the performance of fish scale-modified concrete and conventional concrete to identify its potential uses and limitations.

## Literature review

- Authors: P. Chandra Sekhar, Dr. N. Victor Babu (P.G. Student, Professor)
- Affiliation: Baba Institute of Technology and Sciences, Visakhapatnam, Andhra Pradesh, India.

### Overview of Relevant Studies:

- Nirmalraj et al. (2018) conducted a study on the creation of reinforced composites by blending natural waste fish scales and chicken quills with epoxy resin (Araldite LY 556) and its corresponding hardener (HY951) in specific ratios. Their findings indicated improved elasticity and hardness, making these composites suitable for low-load applications.

- Zhu et al. (2017) investigated fish scales as protective materials, drawing insights from natural organisms to inspire new armor designs. These bio-inspired materials offer enhanced penetration resistance, flexibility, light weight, transparency, and breathability. A single fish scale, approximately 200–300μm thick, features a rigid outer layer supported by a softer, cross-linked collagen fibril network. Puncture tests with a sharp needle demonstrated superior resistance compared to polystyrene and polycarbonate, common engineering polymers for light packaging or protective gear. Under a cutting force, the scale undergoes a two-phase failure process: initially, the hard outer layer splits in a distinct cross-like pattern, forming four "folds." The collagen layer then resists the needle's advancement, acting as a retaining film under biaxial strain. This second phase of penetration is remarkably stable, requiring significant additional force to eventually sever the collagen layer. This combination of a hard layer with controlled failure and a soft, extensible support layer is key to the individual scales' penetration resistance.

- Manikandan et al. (2017) explored the extraction of gelatin and collagen from fish scales. The authors detailed the thermal, physical, mechanical, biodegradable, and cytocompatible properties of these extracts, which can be characterized using micro-computed tomography analysis. They suggest the potential use of these materials as natural, synthetic, biodegradable components in tissue engineering.

- Prasad et al. (2017) focused on fish scales as a source of biopolymeric films, derived from what is often considered biological waste. These fish scale-derived polymeric films have applications in sealing or bolting internal fixation devices. Their paper describes the preparation of biofilms using a twin-screw mixing and solvent casting method. They highlight the use of poly(lactic acid) (PLA), a biodegradable polymer, and hydroxyapatite (HAp), a bioceramic also known as bone material, which promotes new bone growth near fracture sites. The authors discuss the blend of PLA and HAp in creating these biopolymers.

- Ololade et al. (2017) identified fish scales as an abundant source of biopolymers, comprising 30–40% protein (collagen), 30–50% calcium and potassium carbonate, and 20–30% chitin. These valuable components can be extracted, suggesting that fish waste has significant potential for various industries. Their research included experimental investigations into pharma remedial mixes.

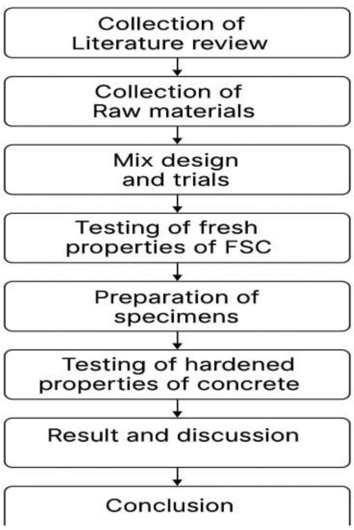
- Das et al. (2017) investigated the scales of Labeo rohita (Rohu fish), confirming their rich source of gelatin/collagen. This gelatin is extensively used as a biopolymer in various sectors, showcasing high potential biopolymer properties. Analytical methods such as scanning electron microscopy (SEM), UV-vis spectroscopy, X-ray diffraction (XRD) for determining crystalline structure and surface morphology, and Fourier transform infrared spectroscopy (FTIR) for structural characterization were employed.

- Bora et al. (2016) conducted a study on fiber polymer composites utilizing fish scales. They noted that India's fish production yields approximately 95.7 lakh tons annually, with 7.34 lakh tons of fish scales produced each year. The authors prepared various composites using fish scales with Lap bull L12 resin and K6 hardener. The fish scales used were biodegradable, suggesting applications in construction for improved degradation properties.

- Sridhar et al. (2015) investigated the application of fish scales as a natural fiber. Fish scales were blended with vinyl ester scraps at various proportions, specifically 5% to 30% by weight (FS5%, FS10%, FS15%, FS20%, FS25%, FS30%). Composites of fish scale and vinyl ester were prepared in corresponding ratios (5:95, 10:90, 15:85, 20:80, 25:75, and 30:70) by manual weighing and compounding. Mechanical tests, including flexural and tensile strength properties, were performed on all samples according to their respective proportions.

- Olatunji et al. (2014) discussed the limitations of silicon-fabricated microneedles, noting that their rigid/solid nature can cause significant damage to the epidermis when puncturing the skin surface. To address this, they proposed using fish scales as a biopolymer to develop microneedles. This approach would reduce manufacturing costs, as these microneedles are biocompatible and biodegradable. The authors concluded that fish scale biopolymers have the ability to penetrate and degrade into the skin, making them suitable candidates for transdermal applications.

## Methodology



The research process for this study was systematically structured into the following key phases:

- Literature Review Compilation: This initial phase involved comprehensive research into existing scholarly articles, established theories, and relevant data pertaining to the study's subject matter. This systematic review was crucial for synthesizing current knowledge, identifying research gaps, and establishing a robust theoretical framework for the investigation.
- *Raw Material Acquisition:* This step encompassed the careful collection of all necessary components required for the experimental work. In the context of concrete, this included procuring cement, various aggregates (such as sand and gravel), water, and any specialized admixtures relevant to the project.
- *Raw Material Characterization:* Following collection, each raw material underwent thorough testing to verify its adherence to specified quality parameters and standards. This rigorous evaluation was fundamental to ensuring the consistency and reliability of subsequent experimental outcomes.
- *Mix Design and Optimization:* This phase focused on developing and refining the optimal proportions of the raw materials to achieve the desired characteristics in the final product, such as the strength and workability of the concrete. This process typically involved conducting multiple trial mixes to meticulously fine-tune the material ratios.
- *Fresh Concrete Property Assessment (for Fish Scale Concrete - FSC):* This stage involved evaluating the characteristics of the concrete mixture before it underwent hardening. For concrete, this included conducting standard tests for workability (slump), air content, and unit weight, all of which are critical factors influencing its placement and compaction.
- *Specimen Fabrication:* Once the concrete mixture was in its fresh state, it was carefully cast or molded into specific geometries and dimensions (specimens) designed for subsequent testing of its hardened properties. These specimens typically included cubes or cylinders for concrete strength evaluations.
- *Hardened Concrete Property Evaluation:* After the fabricated specimens had undergone an appropriate curing period, they were subjected to testing to ascertain their mechanical and durability characteristics. This commonly involved assessing compressive strength, split tensile strength, and occasionally other durability-related performance indicators.
- *Data Analysis and Interpretation:* This crucial phase involved systematically analyzing the experimental data, interpreting the significance of the results, and discussing their broader implications. This often included comparing findings with existing literature, providing explanations for any unexpected observations, and highlighting key insights derived from the study.
- *Conclusion Formulation:* The concluding phase involved summarizing the primary findings of the research, confirming whether the initial objectives were successfully met, and drawing overarching inferences from the entire study. This section also provided an opportunity to suggest avenues for future research.

## IV Materials and Methods

### *4.1 Constituent Components*

The experimental investigation incorporated the following essential materials:

- Cement: Ordinary Portland Cement (OPC) of grade 53, produced in compliance with IS 12269-1987, was systematically utilized across all concrete formulations. Comprehensive testing confirmed its properties were well within established limits, including a normal consistency of 32%, an initial setting time of 40 minutes, a final setting time of 4 hours, a fineness of 6%, and a specific gravity of 3.164.
- Fine Aggregate (Manufactured Sand - M-Sand): Manufactured sand, sourced locally and conforming to grading zone II as stipulated by IS:383-2016, served as the fine aggregate. Prior to use, it was sieved through a 4.75mm sieve and thoroughly washed to remove any impurities. Its specific gravity was determined to be 2.352 g/cc, with no detectable moisture content, and it was classified under grading zone I.
- Coarse Aggregate: Crushed aggregates, featuring a maximum particle size of 12.5 mm and adhering to IS: 383-2016 standards, were employed. These aggregates underwent rigorous washing and drying procedures. Characterized as crushed type with a maximum size of 12.5 mm, their specific gravity was recorded as 2.9450 g/cc.
- Water: Potable tap water from the laboratory, demonstrating a pH value between 6 and 8 and meeting the requirements of IS: 456-2000, was consistently used for both the mixing and curing processes.
- Fish Scales (Additive): Fish scales, collected from discarded fish waste, were integrated into the concrete as an admixture. These scales are recognized as a rigid biopolymer, comprising 30-40% protein (collagen), 30-50% calcium and potassium carbonate, and 20-30% chitin. Laboratory measurements indicated a specific gravity of 0.9, a translucent appearance, and the absence of moisture.

### *4.2 Concrete Mixture Design and Specimen Preparation*

- The design of the concrete mixtures adhered to the guidelines outlined in IS: 10262-2009 for M30 grade concrete. Key design stipulations included a maximum nominal aggregate size of 20 mm, a minimum cement content of 340 kg/m$^3$, and a maximum water-cement ratio of 0.55.
- For standard concrete, the proportion of cement, fine aggregate, and coarse aggregate was precisely set at 1:2.05:3.29, incorporating a water content of 197 litres/m$^3$.
- In the case of concrete modified with fish scales (FSC), two distinct percentages of fish scales were incorporated into the mix.
- A total of 27 cubic specimens were cast for the experimental program. These specimens underwent a controlled curing process for 7, 14, and 28 days before being subjected to mechanical testing.

### *4.3 Experimental Testing Procedures*

The following standardized tests were meticulously conducted on the prepared concrete specimens:

- *Workability Test (Slump Cone Test):* The slump cone test, performed strictly in accordance with ASTM C143 standards, was employed to quantitatively assess the workability of the fresh concrete mixtures.

- *Compressive Strength Test:* Concrete cubes were subjected to compressive strength evaluation using a Universal Testing Machine (UTM) at predetermined curing intervals of 7, 14, and 28 days. These tests followed the precise guidelines stipulated in ASTM C39, with a continuous load applied at an approximate rate of 140 kg/cm$^2$/min.

- *Split Tensile Strength Test:* Concrete cylinders were tested for their split tensile strength as per ASTM C496/C496M–17, at curing durations of 7, 14, and 28 days. The load was applied diametrically across the specimens until the point of failure.

## V Results and Discussion

### *5.1 Concrete Workability with Fish Scale Inclusion*

The slump cone test findings consistently revealed a reduction in concrete mix workability directly proportional to the amount of fish scales added. This decline in slump value is attributed to the increased water demand of the mix, a consequence of the fish scales' presence. For instance, incorporating 2% fish scales led to a 36.40% decrease in workability compared to the control (normal) concrete. This observation is in agreement with existing research, which suggests that fibrous additives and admixtures typically increase water absorption, thereby reducing concrete's workability.

### *5.2 Compressive Strength Evaluation*

Compressive strength defines concrete's capacity to withstand crushing or compressive forces. This characteristic is paramount in structural engineering, as concrete elements are primarily designed to resist such axial loads.

- ***Definition:*** It signifies the peak axial compressive load that a concrete specimen can sustain before exhibiting failure, typically through cracking or significant deformation.
- ***Measurement:*** This property is commonly expressed in units of pressure, such as pounds per square inch (psi) in the US system, or megapascals (MPa), equivalent to N/mm$^2$, within metric frameworks prevalent in India and globally.

### *5.3 Split Tensile Strength Assessment*

Split tensile strength, also known as indirect tensile strength or the Brazilian tensile strength test, provides an indirect method for evaluating the tensile resistance of concrete.

Concrete is inherently weak when subjected to direct tensile forces. To circumvent this, the split tensile test involves horizontally positioning a cylindrical concrete specimen between the loading platens of a compression testing machine. A compressive load is then applied diametrically along the cylinder's length until it splits along its vertical diameter. This applied compressive force generates tensile stresses perpendicular to the load's direction, ultimately causing the specimen to fail due to tension.

The split tensile strength is calculated using a formula that correlates the applied load at failure with the cylindrical specimen's dimensions, providing an indirect measure of the concrete's capacity to withstand tensile stress before cracking. This test is frequently employed in design to understand a concrete member's ability to resist cracking induced by factors such as shrinkage, temperature fluctuations, or shear forces.

## VI Conclusion

This experimental study investigated the potential of incorporating fish scales as an admixture to enhance concrete properties. The findings reveal that while adding fish scales reduces concrete workability due to increased water demand, a 2% inclusion achieved comparable 28-day compressive strength to conventional concrete. However, early strength (at 7 and 14 days) was lower, and a 3% addition negatively impacted 28-day compressive strength.

### *Key Improvements and Applications*

Crucially, the addition of fish scales significantly enhanced the tensile strength of concrete. Both 2% and 3% mixes showed improved tensile performance, with the 3% mix exhibiting the highest tensile strength, indicating a reinforcing effect.

Although not ideal for all general building constructions due to the initial lower compressive strength, concrete with fish scales and its superior tensile properties make it a promising material. It could be valuable for lightweight structures, non-structural components like floor slabs and ribs, or applications where improved crack resistance is desired.

### *Sustainable Innovation*

Furthermore, utilizing fish scales, an abundant bio-waste, contributes to sustainable waste management and offers an environmentally friendly construction material. This research highlights a promising avenue for sustainable innovation in the construction industry.

## VII REFERENCES:

### *Academic Works on Fish Scale Applications*

This collection of academic references explores various facets of fish scales, primarily focusing on their material properties and diverse applications across different fields. The studies highlight the potential of this natural resource in sustainable innovation.

#### Fish Scale Composites and Mechanical Behavior

Several papers delve into the mechanical characteristics of materials reinforced with fish scales. This includes:

- Research on characterizing fish scale-reinforced composites (e.g., Sridhar et al., 2015; Satapathy et al., 2012).
- Investigations into the inherent mechanical performance of teleost fish scales themselves (e.g., Zhu et al., 2011).

#### Extraction and Nature of Fish Scale Components

Other works focus on isolating and understanding the core components of fish scales:

- Studies detailing the extraction and characterization of gelatin derived from fish scales (e.g., Das et al., 2017; Manikandan et al., journal of Bioactive and Compatible Polymers).
- Research exploring the properties of fish scale biopolymers (e.g., Olatunji and Denloye, 1984).

#### Innovative Applications of Fish Scale-Derived Materials

The versatility of fish scales extends to advanced material science and biomedical engineering:

- The use of powdered fish scale to strengthen novel composite cements (e.g., Shiqun et al., 2013).
- Development of specialized materials like microneedles crafted from fish scale biopolymer (e.g., Olatunji et al., 2014).
- Creation of hydroxyapatite reinforced polymeric bio-films derived from fish scales, with potential for internal fixation devices (e.g., Siddharth Mohan Bhasney et al., 2017).
- Exploration of engineered fish scale gelatin as a suitable biomaterial for tissue *engineering* (e.g., Manikandan et al., journal of Bioactive and Compatible Polymers).

These references collectively underscore the growing interest in fish scales as a valuable and sustainable raw material for developing new materials and technologies.