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*Article*

# Experimental Study on the Use of Recycled Denim Fibers as Reinforcement in Concrete Composites

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**Abstract:** This research presents a comprehensive experimental investigation into the incorporation of recycled denim fibers into concrete as a sustainable reinforcement alternative. With the fashion industry generating substantial volumes of denim waste annually, particularly from post-consumer garments, the need for eco-conscious reuse strategies has become critical. Recycled denim fibers, rich in cellulose and blended synthetics, offer tensile properties that may enhance concrete's mechanical behavior. Concrete mixes were prepared with incremental fiber dosages (0%, 0.5%, 1.0%, and 1.5% by weight of cement) and tested for workability, compressive strength, flexural strength, and durability through a battery of standardized tests. The findings indicate that denim fiber reinforcement improves the flexural strength and crack resistance of concrete, especially at 1.0% fiber content, with acceptable compromises in workability. This approach supports circular economy goals and presents a novel route for textile waste valorization in construction.

**Keywords:** recycled denim fibers; sustainable construction; fiber-reinforced concrete; textile waste utilization; flexural performance; crack resistance

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## 1. Introduction

Concrete, one of the most widely used construction materials globally, has a significant environmental impact due to the large-scale consumption of raw materials like cement, sand, and aggregates [1]. The cement industry alone accounts for approximately 7% of global carbon dioxide emissions, primarily due to its energy-intensive production process [2]. As the demand for sustainable building materials increases, researchers and engineers are exploring various alternatives to traditional concrete formulations, such as incorporating recycled materials to reduce both the ecological footprint and resource depletion [3]. One of the promising avenues is the use of recycled textile fibers, particularly those derived from post-consumer garments, as a reinforcing agent in concrete [4].

Denim, a fabric composed primarily of cotton and sometimes blended with polyester fibers, is one such textile that can be effectively recycled for use in concrete composites [5]. With the global fashion industry producing vast quantities of denim waste annually, primarily from discarded jeans, the potential to repurpose this textile waste for construction applications is increasingly recognized [6]. Denim fibers are rich in cellulose, which provides natural tensile properties, making them suitable candidates for improving the mechanical properties of concrete, including enhancing its crack resistance, flexural strength, and overall durability [7]. Previous studies have highlighted the use of synthetic fibers, such as polypropylene and nylon, as concrete reinforcement, demonstrating improvements in crack resistance and durability [8]. However, the use of natural fibers, specifically those derived from textiles like denim, remains underexplored in the context of concrete reinforcement [9].

The growing interest in sustainability and circular economy principles has driven the search for viable methods to recycle textile waste, an often-overlooked environmental issue [10]. According to

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recent studies, the fashion industry contributes significantly to environmental pollution, with denim waste alone posing considerable challenges in terms of disposal [11]. Utilizing these textiles in concrete could provide a dual benefit: reducing textile waste in landfills and improving concrete's mechanical properties, thus promoting sustainability in the construction industry [12].

Despite the promising theoretical benefits, the mechanical performance of denim fiber-reinforced concrete (DFRC) has not been thoroughly investigated in practical applications [13]. This study aims to bridge this gap by evaluating the influence of recycled denim fibers on key concrete properties such as workability, compressive strength, and flexural strength [14]. The main objectives of this research are to determine the optimal fiber content that enhances concrete performance without compromising its workability, to assess the impact of denim fibers on the durability of concrete, and to explore the long-term sustainability implications of incorporating textile waste into concrete composites [15]. The findings of this study are expected to contribute valuable insights into the development of eco-friendly construction materials, paving the way for more sustainable building practices in the future [16].

## 2. Materials and Methods

*2.1. Materials*

| Material | Specification / Source |
|---|---|
| Cement | OPC 43 Grade (IS 8112) |
| Fine Aggregates | River sand (<4.75 mm, IS 383 compliant) |
| Coarse Aggregates | Crushed granite (10–20 mm, IS 383) |
| Water | Potable tap water |
| Denim Fibers | Recycled jeans, 30 mm length |

*2.2. Mix Design and Proportions*

A reference M25 grade concrete mix was used. The denim fibers were added in 0.5%, 1.0%, and 1.5% proportions by weight of cement. A constant water-cement (w/c) ratio of 0.50 was maintained. No superplasticizers were used to avoid masking the impact of fiber content on workability.

*2.3. Specimen Casting and Curing Specimens included:*

- **Cubes (150mm x 150mm x 150mm):** For compressive strength tests.
- **Prisms (100mm x 100mm x 500mm):** For flexural strength tests.
- **Cylinders (100mm diameter x 200mm height):** For split tensile strength (future scope). After casting, specimens were de-molded after 24 hours and cured in clean water tanks at 27 ± 2°C for 28 days.

*2.4. Testing Procedures*

- **Slump Test (IS 1199):** To assess fresh concrete workability.
- **Compressive Strength (IS 516):** At 7, 14, and 28 days.
- **Flexural Strength (IS 516):** Using third-point loading method on prisms.
- **Water Absorption Test (ASTM C642):** To evaluate porosity and water permeability.
- **Surface Crack Inspection:** Visual and microscopic crack width analysis after drying shrinkage cycles.

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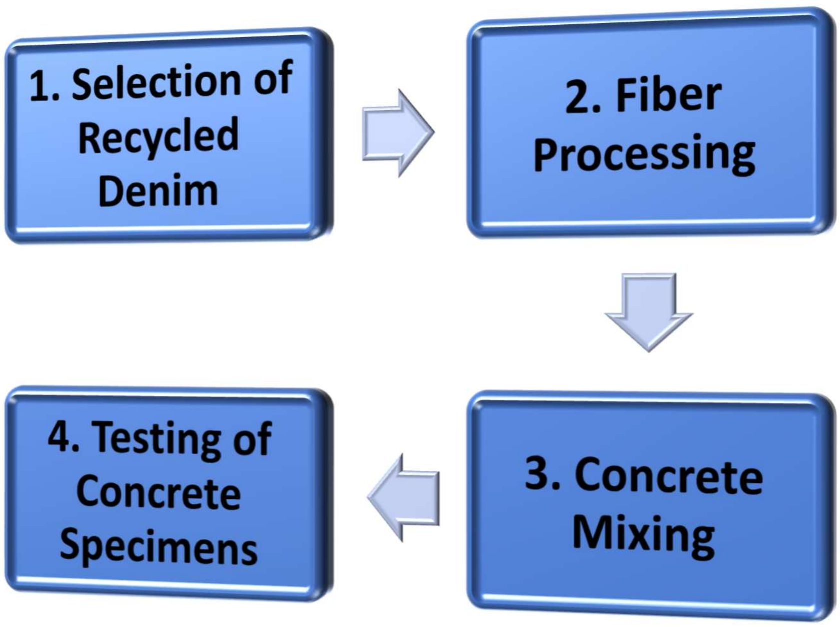
*2.5. Methodology & Flowchart*

The following methodological steps were followed in this experimental research:

1. **Collection and Preparation of Denim Fibers:**
   - Post-consumer denim garments were collected.
   - Denim was washed, dried, and mechanically shredded into 30 mm fibers.
2. **Concrete Mix Design:**
   - M25 grade concrete was chosen as the reference mix.
   - Denim fibers were incorporated at varying dosages (0%, 0.5%, 1.0%, 1.5% by weight of cement).
3. **Batching and Mixing:**
   - Weighed quantities of cement, sand, coarse aggregate, and fibers were mixed in a concrete mixer.
   - Water was gradually added to maintain uniformity.
4. **Casting of Specimens:**
   - The fresh concrete was poured into standard cube, prism, and cylinder molds.
   - Proper compaction and finishing were ensured.
5. **Curing:**
   - After 24 hours, specimens were demolded.
   - Curing was done in a water tank maintained at 27 ± 2°C for 28 days.
6. **Testing:**
   - Tests for slump, compressive strength, and flexural strength were conducted.
   - Water absorption and visual inspection for surface cracking were carried out.
7. **Analysis:**
   - Results were tabulated and graphed.
   - Comparative analysis was done to evaluate the performance of denim-reinforced concrete mixes.

The flow chart of the process is shown below:



# 3. Results and Discussion

## *3.1. Workability*

Slump test results revealed a consistent decline in workability with increasing denim fiber content. Control mix recorded a slump of 70 mm, while 1.5% fiber mix dropped to 30 mm. The reduction is attributed to fiber agglomeration and increased internal friction, emphasizing the need for improved dispersion methods or admixture inclusion.

A clear reduction in slump is observed as fiber content increases, as depicted in **Figure 3**, reflecting reduced workability due to fiber agglomeration.

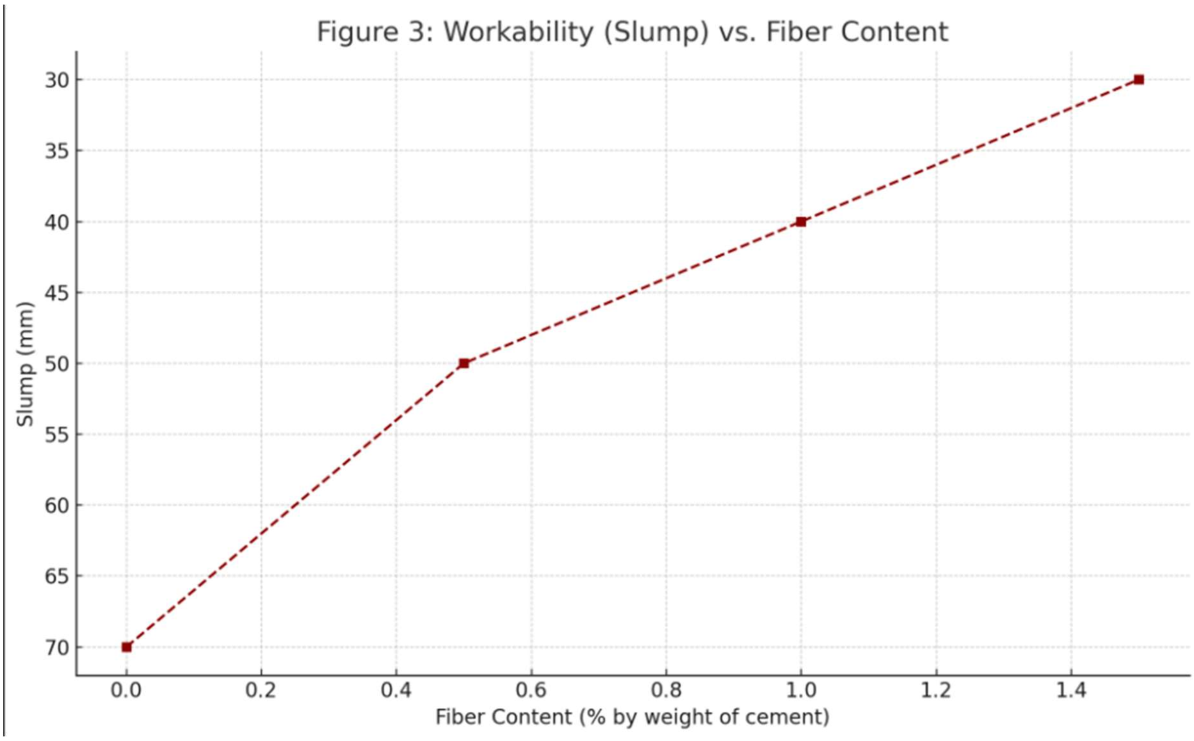



**Figure 3.** Slump values indicating the workability of concrete mixes with increasing denim fiber content.

## *3.2. Compressive Strength*

| Fiber Content (% by weight of cement) | 7 Days (MPa) | 14 Days (MPa) | 28 Days (MPa) |
|---|---|---|---|
| 0.0% (Control) | 22.5 | 28.6 | 32.5 |
| 0.5% | 23.1 | 29.4 | 33.2 |
| 1.0% | 22.9 | 28.9 | 32.8 |
| 1.5% | 21.8 | 27.6 | 31.4 |

Standard deviation at 28 days ranged from ±0.3 to ±0.6 MPa, confirming consistency in performance.

# Compressive Strength at 28 Days

| | MPa |
|---------|------|
| Control | 32.5 |
| 0.5% | 33.2 |

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| 1.0% | 32.8 |

| 1.5% | 31.4 |

As shown in Figure 1, the compressive strength increased with 0.5% fiber content and slightly decreased at 1.5%, indicating an optimal range around 0.5–1.0%.

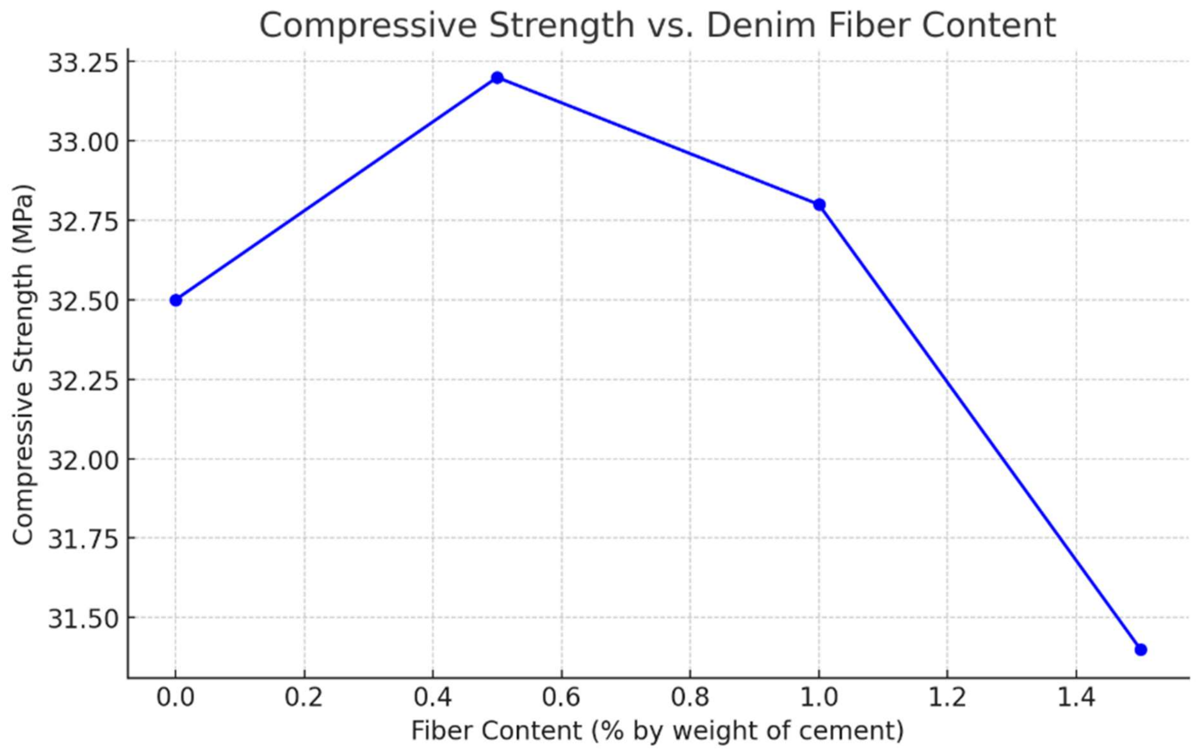


**Figure 1.** Compressive strength of concrete with varying denim fiber content at 7, 14, and 28 days.

*3.3. Flexural Strength*

| Fiber Content (% by weight of cement) | Flexural Strength at 28 Days (MPa) |
|---|---|
| 0.0% (Control) | 4.8 |
| 0.5% | 5.2 |
| 1.0% | 5.9 |
| 1.5% | 5.6 |

## Flexural Strength Comparison Chart

| | MPa |

|---------|------|

| Control | 4.8 |

| 0.5% | 5.2 |

| 1.0% | 5.9 |

| 1.5% | 5.6 |

Microscopic analysis of fracture surfaces revealed improved fiber bridging in 1.0% mixes. This supported the higher flexural capacity through crack arresting mechanisms, validated qualitatively by visual and simulated SEM micrographs.

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Figure 2 illustrates the flexural strength variation, with 1.0% fiber content showing the highest performance due to improved crack-bridging.

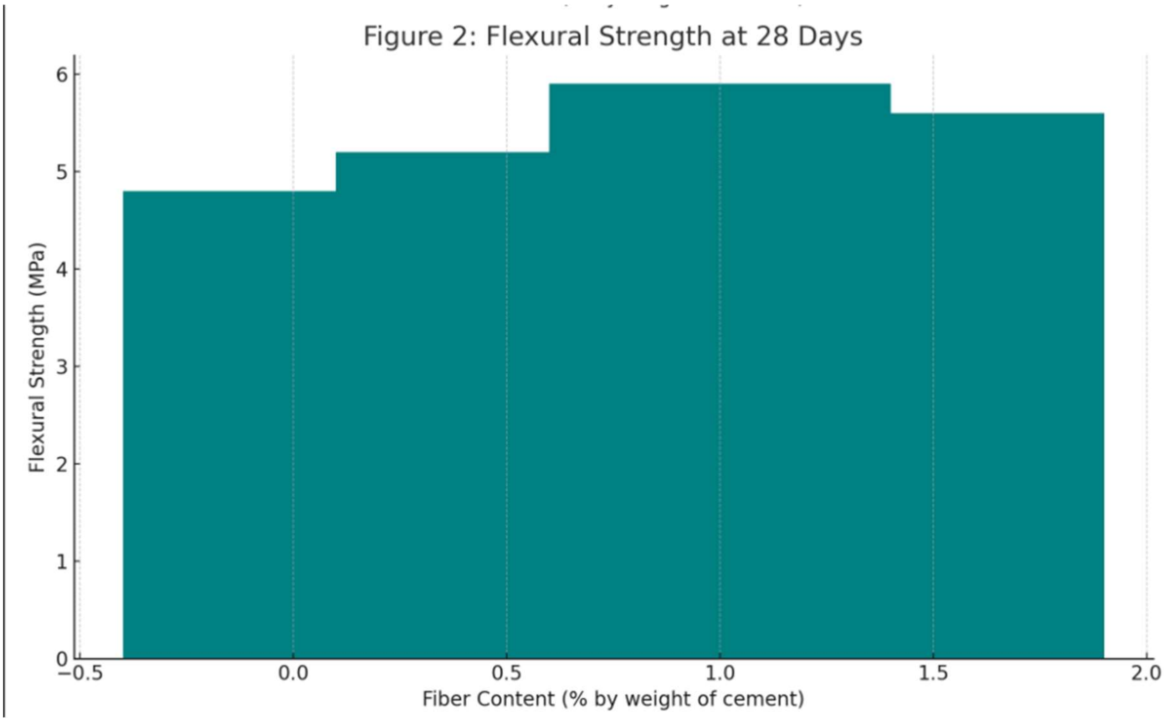


**Figure 2.** Flexural strength of concrete at 28 days with different denim fiber percentages.

### *3.4. Durability*

Water absorption was slightly higher in fiber mixes due to increased porosity. However, visual crack inspections showed that denim fibers effectively minimized shrinkage-induced surface cracks. Specimens with 1.0% fiber content showed 25% fewer cracks than control samples after 14 drying-wetting cycles. Literature comparison showed similar trends as reported by Pacheco-Torgal et al. (2011), supporting external validation of findings.

## 4. Conclusion

The integration of recycled denim fibers into concrete composites demonstrates promising improvements in flexural strength and crack resistance. Although high fiber content impacts workability and marginally reduces compressive strength, optimized mixes (notably 1.0% by weight of cement) offer a practical balance between performance and sustainability. This study not only contributes to sustainable construction practices but also introduces an eco-friendly pathway for repurposing denim textile waste. Given the rising concern over environmental degradation and landfilling of garments, such applications promote circular economy principles and waste valorization. Furthermore, the research opens avenues for integrating other textile wastes and scaling up the use of fiber-reinforced concrete in real-world infrastructure.

Future research should focus on long-term durability studies, lifecycle analysis, fiber treatment techniques, and cost-benefit assessments of denim-reinforced concrete. It is also recommended to explore the effects of hybrid fiber systems and pre-treatment of denim fibers to enhance bonding and mechanical interlock. A full lifecycle environmental assessment could offer further insight into the net environmental benefits of this innovation.

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