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Experimental Investigation on Utilization of Cotton Waste in Concrete Along with Yarn Waste and Superplasticizer

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Abstract—Concrete is the primary structural material utilized in the global construction sector. However, the exponential accumulation of solid textile waste presents a critical environmental challenge requiring sustainable recycling strategies. This investigation focuses on evaluating the incorporation of cotton waste cloth, yarn waste, and chemical admixtures into M30 grade concrete. The inclusion of cotton cloth enhances internal stress redistribution, leading to an increase in flexural and split tensile strengths. Conversely, the introduction of raw cloth fibers disrupts cementitious matrix cohesion, causing a degradation in compressive performance. To counter this loss of strength, yarn waste is introduced as a densification agent to fill interstitial voids and enhance packed density. Furthermore, a high-range water-reducing superplasticizer (Ceraplast 300) is incorporated to significantly decrease the water-cement ratio, thereby densifying the microstructural hydration matrix and improving overall concrete durability. Experimental evaluation covers 7, 14, and 28-day curing regimes for compressive and flexural behaviors across multiple non-conventional mix proportions.

Key Words —Cotton Waste, Yarn Waste, Ceraplast 300 Superplasticizer, M30 Grade Concrete, Compressive Strength, Flexural Strength, Microstructural Cohesion, Sustainable Materials.

I. Introduction

The continuous growth of worldwide infrastructure development has driven concrete consumption to unprecedented levels. Concrete production requires immense quantities of natural aggregates, Portland cement, and fresh water. Simultaneously, rapid urbanization and industrial expansion generate vast volumes of industrial byproducts and solid municipal wastes. Among these, textile industry wastes—comprising garment manufacturing scraps, discarded cotton cloth, and synthetic yarn offcuts—present severe environmental hazards. Traditional disposal methods, including landfilling and open incineration, lead to ground pollution, soil degradation, and harmful greenhouse gas emissions. Consequently, incorporating textile waste into construction materials represents a sustainable solution that mitigates environmental pollution while providing low-cost material alternatives.

The inclusion of fibrous textile wastes in concrete matrices transforms brittle concrete behavior into a more ductile composite response. When subjected to mechanical loading, fibrous inclusions bridge micro-cracks, delaying macro-crack propagation and augmenting energy absorption capacities. However, raw cotton cloth scraps absorb free mixing water and disrupt aggregate interlock, leading to matrix honeycombing and diminished compressive strength. To solve this issue, yarn waste is integrated as fine interstitial reinforcement alongside a liquid superplasticizer (Ceraplast 300). The superplasticizer acts as a high-range water reducer, dispersing cement particles via electrostatic repulsion and steric hindrance. This allows for low

water-cement (W/C) ratios without compromising fresh workability.

1.1 Objectives

The primary objective of this experimental study is to formulate an eco-friendly M30 grade concrete mix incorporating cotton waste, yarn waste, and superplasticizer. Specific sub-objectives include:

- To design and evaluate cost-effective, sustainable non-conventional concrete mixes utilizing textile industrial wastes.
- To maintain ideal fresh workability and slump characteristics at reduced water-cement ratios using Ceraplast 300 superplasticizer.
- To analyze the mechanical properties (compressive strength, flexural strength, and split tensile strength) across standard 7, 14, and 28-day curing periods.
- To establish the optimal substitution levels of cotton waste and yarn waste that maximize flexural ductility while preserving compressive structural performance.
- To reduce environmental contamination and municipal waste disposal burdens associated with the textile manufacturing sector.

II. Literature Review & Theoretical Background

Fiber-reinforced concrete (FRC) has evolved significantly over recent decades. Fiber inclusion enhances tensile strain capacity, impact resistance, and crack control. Natural and synthetic textile fibers (cotton, polyester, nylon) act as crack arrestors under

mechanical stress. Recent studies highlight that natural cotton fibers possess high tensile strength but exhibit high water absorption due to their porous cellulose structure. When raw cotton fibers are introduced into cementitious mixes, they withdraw water required for cement hydration, resulting in poor workability and reduced compressive capacity.

To overcome hydration deficits, chemical admixtures such as polycarboxylate ether or sulfonated naphthalene formaldehydes (superplasticizers) are essential. Superplasticizers deflate cement flocs, releasing trapped water and ensuring complete hydration even at water-cement ratios below 0.40. Yarn waste, consisting of tightly spun threads, fills inter-aggregate voids within the concrete matrix, enhancing physical packing density. The synergistic combination of cotton cloth (flexural bridging), yarn waste (void filling), and superplasticizer (hydration enhancement) provides a technical foundation for non-conventional structural concrete.

III. Materials And Experimental Methodology

3.1 Material Characterization

The raw materials utilized in this experimental investigation were subjected to preliminary physical property tests in accordance with relevant Indian Standard (IS) specifications:

- Cement: Ordinary Portland Cement (OPC 53 Grade) conforming to IS 12269 with a specific gravity of 3.15

and normal consistency of 32%.

- Fine Aggregate: Locally available clean river sand conforming to IS 383 Zone II, possessing a specific gravity of 2.62 and a fineness modulus of 2.74.
- Coarse Aggregate: Crushed angular granite stones passing 20 mm sieve and retained on 10 mm sieve, conforming to IS 383 with a specific gravity of 2.68.
- Cotton Waste Cloth: Cleaned, pre-shredded cotton cloth pieces (aspect ratio optimized) acting as structural fiber inclusion.
- Yarn Waste: Industrial textile yarn offcuts utilized to reduce matrix voids and increase compact density.
- Superplasticizer: Ceraplast 300, a high-range liquid chemical admixture utilized to maintain fluid workability at reduced water content.
- Water: Potable mixing and curing water free from organic impurities, conforming to IS 456 requirements.

3.2 Mix Design & Batching

The target mix proportioning was conducted for M30 grade concrete per IS 10262:2019 guidelines. The control mix was designed for a characteristic compressive strength of 30 N/mm² at 28 days. Four non-conventional concrete formulations (Mix 1 to Mix 4) were prepared by introducing percentage additions of cotton waste, yarn waste, and Ceraplast 300 relative to cement mass.

Table 1: Mix Proportions for M30 Grade Non-Conventional Concrete

Mix ID	Cotton Waste (%)	Yarn Waste (%)	Ceraplast 300 (%)	W/C Ratio
Control (M0)	0.0%	0.0%	0.00%	0.45
Mix 1 (M1)	1.0%	1.0%	0.10%	0.43
Mix 2 (M2)	2.0%	2.0%	0.20%	0.41
Mix 3 (M3)	3.0%	3.0%	0.30%	0.39
Mix 4 (M4)	4.0%	4.0%	0.40%	0.38

3.3 Specimen Preparation & Testing Methodology

Standard steel molds were used to cast three distinct specimen geometries: 150 mm × 150 mm × 150 mm cubes (compressive strength), 100 mm × 100 mm × 500 mm prisms (flexural strength), and 150 mm diameter × 300 mm height cylinders (split tensile strength). Aggregates, cement, cotton waste, and yarn waste were initially dry-mixed for 2 minutes to achieve uniform fiber distribution. Water mixed with Ceraplast 300 was added gradually, followed by thorough mechanical mixing. Molds were filled in three layers, compacted mechanically on a vibrating table, and finished with smooth troweling. After 24 hours of ambient de-molding, specimens were immersed in curing tanks for 7, 14, and 28 days.

IV. Results And Discussion

4.1 Workability and Fresh Density

Slump cone tests revealed that increasing raw cotton cloth content reduces fresh slump due to fiber surface absorption. However, introducing Ceraplast 300 restored slump values from 65 mm (without admixture) up to 90 mm for Mix 1 and Mix 2, maintaining adequate placing workability. Yarn waste successfully occupied interstitial voids, yielding a maximum fresh wet density of 2410 kg/m³ in Mix 2.

4.2 Compressive Strength Evaluation

Compressive strength testing was conducted using a 2000 kN capacity Compression Testing Machine (CTM) at a uniform loading rate of 140 kg/cm²/min per IS 516. Test results for 7, 14, and 28 days are detailed in Table 2.

Table 2: Compressive Strength Performance of Control and Modified Concrete Mixes

Mix ID	Description	7 Days (N/mm ²)	14 Days (N/mm ²)	28 Days (N/mm ²)
Control	Conventional M30 Grade Concrete	19.8	27.2	31.3
Mix 1	1% Cloth + 1% Yarn + 0.1% Ceraplast 300	18.2	26.7	30.8
Mix 2	2% Cloth + 2% Yarn + 0.2% Ceraplast 300	15.1	22.4	30.2
Mix 3	3% Cloth + 3% Yarn + 0.3% Ceraplast 300	11.2	20.5	28.9
Mix 4	4% Cloth + 4% Yarn + 0.4% Ceraplast 300	10.9	19.1	28.4

As observed from Table 2, adding waste cloth introduces internal micro-planes that slightly reduce matrix cohesion, causing a minor decline in compressive strength compared to the control mix. However, the addition of yarn waste (filling voids) and Ceraplast 300 superplasticizer (permitting lower water-cement ratios) helps offset this loss. Mix 1 achieves a 28-day compressive strength of 30.8 N/mm² closely matching the 31.3 N/mm²

achieved by conventional control concrete.

4.3 Flexural Strength Evaluation

Flexural strength tests were conducted on 100 mm × 100 mm × 500 mm prisms under two-point loading in accordance with IS 516. The results demonstrate that flexible cotton waste fibers act as internal micro-reinforcement, enhancing crack-bridging capacities.

Table 3: Flexural Strength Performance of Control and Modified Concrete Prisms

Mix ID	Description	7 Days (N/mm ²)	14 Days (N/mm ²)	28 Days (N/mm ²)
Control	Conventional M30 Grade Concrete Prism	3.9	4.6	5.0
Mix 1	1% Cloth + 1% Yarn + 0.1% Ceraplast 300	3.9	4.7	5.2
Mix 2	2% Cloth + 2% Yarn + 0.2% Ceraplast 300	4.0	4.9	5.5
Mix 3	3% Cloth + 3% Yarn + 0.3% Ceraplast 300	4.2	5.1	5.7
Mix 4	4% Cloth + 4% Yarn + 0.4% Ceraplast 300	3.9	4.8	5.1

Flexural test results in Table 3 show a continuous improvement in tensile and flexural capacities up to Mix 3 (3% replacement). Mix 3 achieves a maximum 28-day flexural strength of 5.7 N/mm², representing a 14% increase over conventional concrete (5.0 N/mm²). Beyond 3% replacement (Mix 4), fiber agglomeration

occurs, leading to a minor drop in flexural resistance.

4.4 Split Tensile Strength Evaluation

Split tensile tests conducted on cylindrical specimens (150 mm × 300 mm) confirmed a trend consistent with the flexural performance. At 28 days, control concrete recorded a split tensile

strength of 3.15 N/mm². In contrast, Mix 3 recorded 3.65 N/mm², demonstrating that randomly oriented cotton cloth and yarn fibers effectively arrest splitting cracks under diametral line compression.

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V. Cost & Environmental Impact Analysis

A life-cycle cost assessment indicates that replacing raw cementitious volume with recycled textile waste reduces overall material procurement expenses. Because cotton waste and yarn waste are industrial byproducts available at nominal collection costs, aggregate/filler substitution yields direct savings. Moreover, diverting textile waste from landfills reduces methane emissions, lowers carbon footprints, and supports circular economic principles within civil engineering construction.

VI. Conclusion

Based on the comprehensive experimental investigation, the following conclusions are established:

- **Flexural & Tensile Enhancement:** Incorporating cotton waste cloth and yarn waste significantly improves flexural strength (up to 5.7 N/mm² in Mix 3) and split tensile strength due to fiber crack-bridging mechanisms.
- **Compressive Strength Optimization:** Although waste cloth alone reduces matrix cohesion, adding yarn waste (filling internal voids) and Ceraplast 300 superplasticizer (permitting lower water-cement ratios) mitigates compressive strength loss, yielding structural performance comparable to M30 control concrete.
- **Optimal Addition Threshold:** Mix 3 (3% cotton cloth, 3% yarn waste, and 0.3% Ceraplast 300) represents the optimal blend, maximizing tensile-flexural performance without excessive compressive degradation.
- **Environmental Sustainability:** Utilizing textile wastes in structural concrete provides an eco-friendly waste management alternative, reducing municipal landfill burdens while advancing sustainable construction.

VII. References

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