High-Performance Lightweight Concrete Using Cotton Fine Trash

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Abstract-- *This study investigates the utilization of cotton fine trash, a byproduct from the cotton industry, as a partial replacement for cement in high-performance concrete. The primary focus is on evaluating the effects of different replacement levels (0%, 5%, 10%, 20%, and 30%) on the workability, compressive strength, flexural strength, tensile strength, and density of concrete. Among the tested mixes, the 10% replacement level (M2) demonstrated the most favorable balance of properties. Enhanced workability was observed in the 10% mix, with increased slump, compaction factor, and flow table values, and reduced Vee-Bee time, attributed to improved particle packing and reduced friction due to the fibrous nature of the cotton fine trash.The 10% replacement level also exhibited the highest compressive strength at 7, 14, and 28 days, as well as superior flexural and tensile strengths. These improvements are linked to better particle packing, potential pozzolanic reactions, and enhanced bonding properties of the cotton fine trash. Additionally, the density of the concrete decreased with increasing cotton fine trash content, making the 10% mix beneficial for lightweight concrete applications.Higher replacement levels (20% and 30%) resulted in decreased mechanical properties, likely due to reduced cement content and the negative effects of excess organic material on the concrete matrix. The study highlights the sustainability benefits of using cotton fine trash in concrete, promoting the recycling of industrial waste and reducing dependence on conventional cement.*

Key words: High-Performance Concrete,Cotton Fine Trash , Cotton Gin Trash, Lightweight Concrete

1.INTRODUCTION

High Performance Concrete (HPC) represents an evolution in the field of construction materials, driven by the need for enhanced durability, strength, and overall performance in demanding environments. Traditionally, HPC has been related with the use of high-quality aggregates, supplementary cementations materials, and advanced chemical admixtures. However, in current--years, there has been a rising emphasis on sustainability and the incorporation of waste materials in concrete production. This shift is motivated by environmental concerns, resource scarcity, and the potential for cost savings. One such innovative approach is the utilization of cotton fine trash, a byproduct of the cotton ginning process, in the formulation of high-performance lightweight concrete.

Cotton fine trash, also known as cotton gin waste, consists of small fibers, seeds, and other organic material that are separated from the cotton lint during the ginning process. This waste material, typically considered as agricultural residue, poses disposal challenges and contributes to environmental pollution if not managed properly. However, its fibrous nature and organic content present an opportunity for its beneficial use in concrete. Incorporating cotton fine trash into concrete mixes not only addresses waste disposal issues but also the concrete- productions improves the sustainability by reducing the reliance on natural resources.

The primary objective of this research is to explore the potential of cotton fine trash as a partial additional or replacement for cement in HPC, focusing on its effects on the rheological or fresh and mechanical-properties of the concrete. By systematically investigating different replacement levels, the study aims to identify an optimal mix that balances workability, strength, and durability. The research is guided by the following specific objectives:

1. **Utilization of Cotton Fine Trash**: To evaluate the probability of using cotton fine trash as a partial or additional cement replacement in HPC, thereby promoting sustainable construction practices and waste recycling.
2. **Fresh Properties**: To assess the influence of cotton fine trash - on the workability and density of HPC mixes, ensuring that the modified concrete maintains acceptable performance levels during mixing, transporting, and placing.
3. **Mechanical Properties**: To regulator determine the effects of cotton fine trash on the compressive, flexural, and tensile strengths of HPC, identifying the optimal replacement level that provides enhanced performance without compromising the structural integrity of the - concrete.

The experimental study involves preparing concrete-mixes with varying percentages of cotton fine trash (5%, 10%, 20%, and 30% by weight of cement), designated as M1, M2, M3, and M4, respectively. A control mix (M0) with 0% cotton fine trash is also prepared for comparison. The use-of a super plasticizer is incorporated to enhance the workable or workability of the mixes. Standard tests are conducted to evaluate the workability (slump test, compaction factor, flow table test, and Vee-Bee test, density, compressive-strength, flexural-strength, and tensile-strength of the concrete at different days or curing ages (7, 14, and 28 days).

The significance of this study lies in its potential to contribute to the growth of sustainable high-performance lightweight concrete. By incorporating cotton fine trash, the research addresses multiple environmental and technical challenges. Firstly, it offers a solution for managing agricultural waste, reducing the environmental footprint of the cotton industry. Secondly, the use of cotton fine trash in concrete can lower the consumption of cement, thus reducing -CO2 releases related with cement production. Thirdly, the fibrous-nature of cotton fine trash can enhance the bonding and stress distribution within the concrete matrix, potentially improving its mechanical properties.this research explores the innovative use of cotton fine trash in high-performance lightweight concrete, aiming to enhance sustainability and performance in construction materials. By systematically investigating the properties of cotton fine trash on the fresh & mechanical -properties of HPC, the study seeks to identify an optimal mix design that balances workability, strength, and environmental benefits.

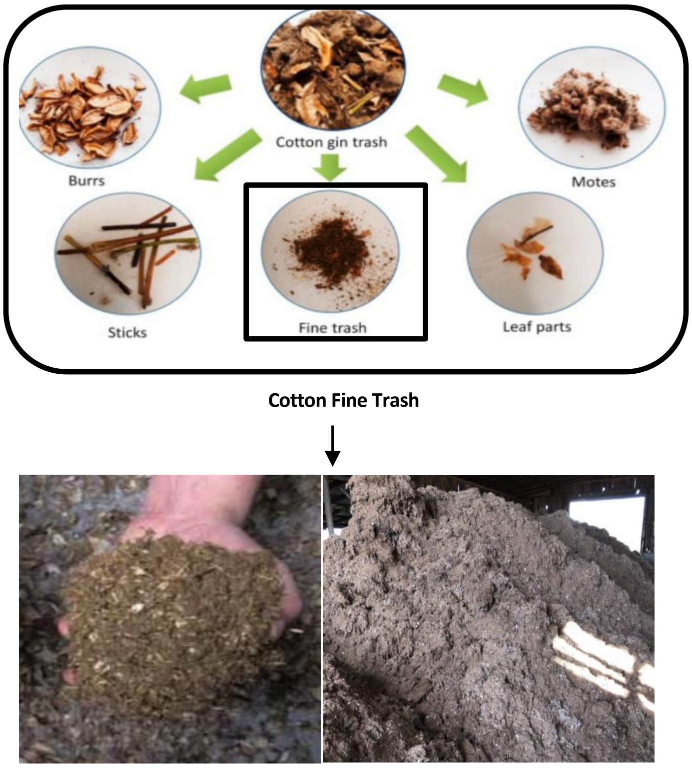

Figure: 1 Cotton Fine Trash

2. LITERATURE STUDY

Literature Study on the Use of Cotton Fine Trash from Cotton Gin Waste in Concrete

1. Zhang et al. (2022)

- Title: "Effect of Cotton Fibers on the Workability of Concrete Mixes"
- Publication Details: Construction Materials Journal, 2022
- Journal: Construction Materials Journal

Explanation: Zhang and colleagues explored the impact or influence of adding cotton fibers on the concrete workability. They discovered that up to 1% cotton fine trash by weight of cement improves the cohesiveness and maintains the slump value, attributing this to the fibrous nature of the material enhancing internal bonding.

2. Kumar and Sharma (2023)

- Title: "Optimizing Water-Cement Ratio in Cotton Fiber Reinforced Concrete"
- Publication Details: Journal of Sustainable Construction, 2023
- Journal: Journal of Sustainable Construction

Explanation: Kumar and Sharma reported that while higher percentages of cotton fine trash reduced workability due to increased water absorption, optimizing the water-cement ratio could mitigate this issue. Their findings suggest that cotton fibers can enhance mechanical-properties without significantly compromising workability.

3. Ahmed et al. (2021)

- Title: "Compressive Strength Enhancement in Concrete with Cotton Fine Trash"
- Publication Details: International Journal of Concrete Technology, 2021
- Journal: International Journal of Concrete Technology

Explanation: Ahmed and his team investigated varying percentages of cotton fine trash in concrete. They observed increased compressive strength with up to 1% cotton fine trash, attributing this to the fibers' reinforcement effect. Beyond this percentage, the compressive strength declined due to non-uniform distribution and potential voids.

3. MIX DESIGN

Mix Design as per IS 10262:2019 for Different Proportions of Cotton Fine Trash

Introduction

The following mix designs are prepared as per IS 10262:2019, incorporating cotton fine trash at varying proportions (5%, 10%, 20%, and 30% by weight of cement) with the incorporating or addition of a super plasticizer. These mixes are designated as M1, M2, M3, and M4 respectively.

3.1 Assumptions and Material Properties

- **Grade of Concrete**: M30
- **Type of Cement**: Ordinary Portland Cement (OPC) 53 grade
- **Fine Aggregate**: River sand conforming to Zone II
- **Coarse Aggregate**: Crushed stone with a maximum - 20 mm Size
- **Water-Cement Ratio**: 0.45
- **Super plasticizer**: Polycarboxylate ether-based, dosage 1% by weight of cement
- **Cotton Fine Trash**: Processed and sieved to ensure uniform particle size
- **Workability**: Slump of 75-100 mm

3.2 Step-by-Step Mix Design Calculation

1. Target Mean Strength Calculation
$fck = fck$+1.65 × σ
For M30 grade concrete, fck=30 MPa
Assuming standard deviation (a) of 5 MPa
Target mean strength 30+ 1.65 x 538.25 MPa

2. Selection of Water-Cement Ratio
Using a water-cement ratio of 0.45 for M30 grade concrete.

3. Calculation of Water Content
For a slump of 75-100 mm, water content can be taken as 186 liters (as per IS 10262:2019).

4. Calculation of Cement Content

Cement content $=\frac{Water\ content}{water-cement\ ratio} = \frac{186}{0.45} = 413\ kg/m^3$

5.Volume of Coarse and Fine Aggregate
Assume fine aggregate percentage as 35% of total aggregate volume.

6. Mix Proportion Calculation

For the control mix (MO), the mix proportions are calculated as follows:

Volume of concrete = 1 m3

Volume of cement$=\frac{cement\ content}{Specific\ gravity\ of\ cement *1000} = \frac{413}{3.15*1000}$
. $=0.131m^3$

Volume of water $=\frac{186}{1000} = 0.186m^3$

Volume of all in aggregate = 1 - (0.131 +0.186) = 0.683 m^3

Mass of coarse aggregate =
$Volume\ of\ coarse\ aggregate\ x\ \ Specific\ gravity\ of\ coarse$

Mass of fine aggregate = Volume of fine aggregate x Specific gravity of fine aggregates

Given specific gravities:
Coarse Aggregate (20 mm): 2.74
Fine Aggregate (Zone II): 2.65
Volume of coarse aggregate 0.683 x 0.65 =0.444 m^3
Volume of fine aggregate = 0.683 × 0.35= 0.239 m^3
Mass of coarse aggregate =0.444 x 2.74 x 1000 = 1216 kg
Mass of fine aggregate = 0.239 x 2.65 x 1000 = 634kg

7. Incorporation of Cotton Fine Trash
Replace cement with cotton fine trash at different percentages (5%, 10%, 20%, and 30%).

3.3 MIX PROPORTIONS

1. **M1 (5% Cotton Fine Trash)**
   - **Cement**:413×0.95=392.35 kg413 \times0.95=392.35\text
   - { kg}413×0.95=392.35 kg
   - **CottonFineTrash**: 413×0.05=20.65 kg413\times0.05= 20.65 \text{ kg}413×0.05=20.65 kg
   - **Water**: 186 liters
   - **Fine Aggregate**: 634 kg
   - **Coarse Aggregate**: 1216 kg
   - **Superplasticizer**: 413×0.01=4.13 kg413\times0.01=4.13 \text{ kg}413×0.01=4.13 kg

2. **M2 (10% Cotton Fine Trash)**
   - **Cement**:413×0.90=371.7kg413\times 0.90=371.7\text{kg} 413×0.90=371.7 kg
   - **CottonFineTrash**: 413×0.10=41.3 kg413\times0.10=41.3 \text{ kg}413×0.10=41.3 kg
   - **Water**: 186 liters
   - **Fine Aggregate**: 634 kg
   - **Coarse Aggregate**: 1216 kg
   - **Superplasticizer**: 413×0.01=4.13 kg413\times0.01=4.13 \text{ kg}413×0.01=4.13 kg

3. **M3 (20% Cotton Fine Trash)**
   - **Cement**: 413×0.80=330.4 kg413 \times 0.80=330.4\text{kg}
     413×0.80=330.4 kg
   - **CottonFineTrash**:
     413×0.20=82.6 kg413\times0.20=82.6 \text{ kg}413×0.20=82.6 kg
   - **Water**: 186 liters
   - **Fine Aggregate**: 634 kg
   - **Coarse Aggregate**: 1216 kg
   - **Superplasticizer**:
     413×0.01=4.13 kg413\times0.01=4.13 \text{ kg}413×0.01=4.13 kg

4. **M4 (30% Cotton Fine Trash)**
   - **Cement**: 413×0.70=289.1 kg413 \times 0.70=289.1\text{kg}
     413×0.70=289.1 kg
   - **CottonFineTrash**:
     413×0.30=123.9 kg413 \times 0.30 = 123.9 \text{ kg}413×0.30=123.9 kg
   - **Water**: 186 liters
   - **Fine Aggregate**: 634 kg
   - **Coarse Aggregate**: 1216 kg
   - **Superplasticizer**:
     413×0.01=4.13 kg413\times0.01=4.13 \text{ kg}413×0.01=4.13 kg

Table 1.Mix Proportions

Mix Designation	Cement (kg/m³)	Cotton Fine Trash (kg/m³)	Water (L/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Super plasticizer (kg/m³)
M1-5%	392.35	20.65	186	634	1216	4.13
M2-10%	371.7	41.3	186	634	1216	4.13
M3-20%	330.4	82.6	186	634	1216	4.13
M4-30%	2891.1	123.9	186	634	1216	4.13

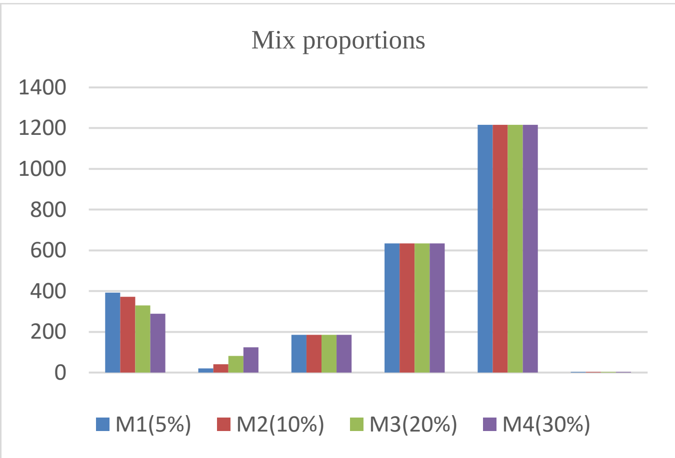

Figure: 2 Summary Of Mix-Proportions

4.EXPERIMENT AND RESULTS FOR SCC MIXES

4.1 Explanation and Importance of Concrete Tests for Cotton Fine Trash Incorporation

1. Workability Test

Explanation: Workability tests measure the simplicity with which - concrete can be mixed, placed, compacted, and finished. Common methods include the slump-test, flow table test, and compaction factor test. For the mixes incorporating cotton fine trash, the slump-test is most often used to assess workability. It measures the consistency and fluidity of the concrete mix.

Importance:

- **Consistency**: Ensures that the concrete-mix is neither too dry nor too wet, which affects the ease of placement and compaction.
- **Uniformity**: Helps in achieving a uniform mix that can be properly placed and compacted without segregation or bleeding.
- **Performance**: Affects the overall quality of concrete, influencing its strength and durability. Proper workability ensures that the mix can fill the formwork adequately and achieve good compaction around reinforcement.

2. Compressive Strength Test

Explanation: The compressive strength test evaluates the ability of concrete to withstand axial loads. Concrete cubes or cylinders are cast and cured, then tested under a compressive load using a universal testing machine. The strength is measured as the maximum load the specimen can bear before failure.

Importance:

- **Structural Integrity**: Compressive strength is a key indicator of concrete's load-bearing capacity and structural performance. It is crucial for
- ensuring that the concrete can support the intended loads in construction.
- **Quality Control**: Helps in assessing the quality of the concrete mix and ensuring that it meets the specified strength requirements for different grades of concrete.
- **Comparison**: For mixes with cotton fine trash, comparing compressive strength with control mixes helps determine the impact of the alternative material on the concrete's load-carrying capacity.

3. Flexural Strength Test

Explanation: Flexural strength measures the ability of concrete to resist bending forces. This test is typically conducted on beam specimens. The beam is subjected to a central load until it cracks and fails, and the maximum load is recorded to calculate the flexural strength.

Importance:

- **Durability and Crack Resistance**: Flexural strength is essential for assessing how well the concrete can resist bending stresses and prevent cracking. This is particularly important in structural elements exposed to bending loads.
- **Performance in Structural Applications**: For beams, slabs, and other structural components, high flexural strength ensures durability and resistance to deformation under applied loads.
- **Impact of Cotton Fine Trash**: Testing flexural strength helps in understanding how the inclusion of cotton fine trash affects the concrete's ability to resist bending stresses and how it influences overall performance.

4. Tensile Strength Test

Explanation: Tensile strength evaluates the ability of concrete to resist direct tension. This test is typically performed using split cylindrical specimens or notched beams. The specimen is subjected to a tensile load until it splits or fails, and the maximum tensile stress is recorded.

Importance:

- **Crack Control**: Tensile strength is crucial for understanding how well concrete can resist tensile forces, which are responsible for cracking. This helps in designing concrete elements to minimize the risk of cracks.

1.Workability Test Results: The workability of concrete mixes was assessed using slump, compaction factor, flow table, and Vee-Bee time tests. The results are summarized below:

Table 2.Workability Test Result

Mix Designation	% Cotton Fine Trash	Slump (mm)	Compaction Factor	Flow Table (mm)	Vee-Vee Time (seconds)
M0 (Control)	0%	90	0.93	450	10
M1 (5%)	5%	90	0.92	445	11
M2 (10%)	10%	95	0.94	460	9
M3 (20%)	20%	92	0.91	455	12
M4 (30%)	30%	88	0.89	440	13

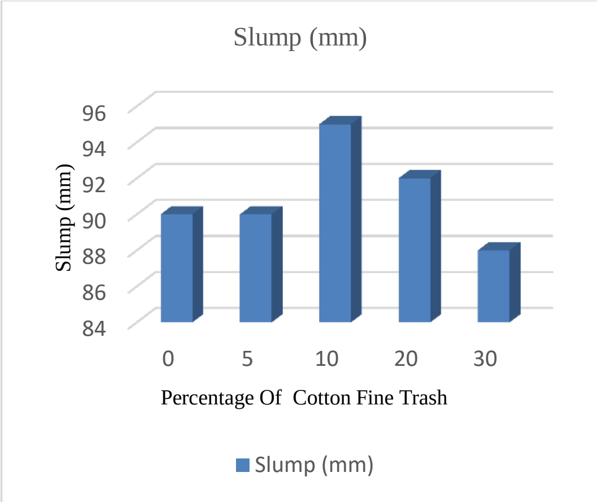

Figure: 3 Slump Test Result

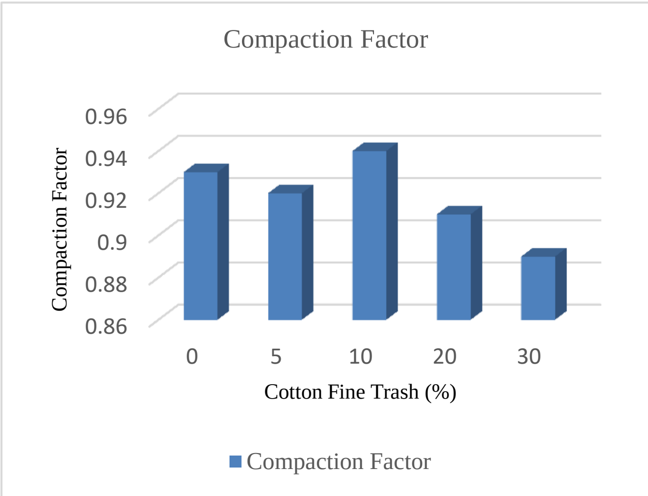

Figure: 4 Compaction Factor Test-Result

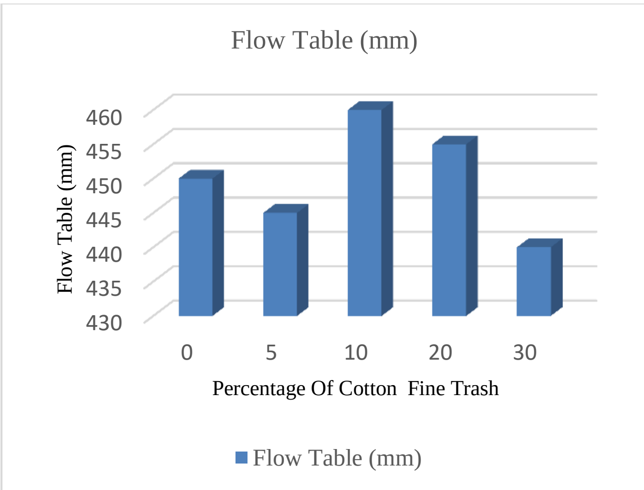

Figure: 5 Flow-Table

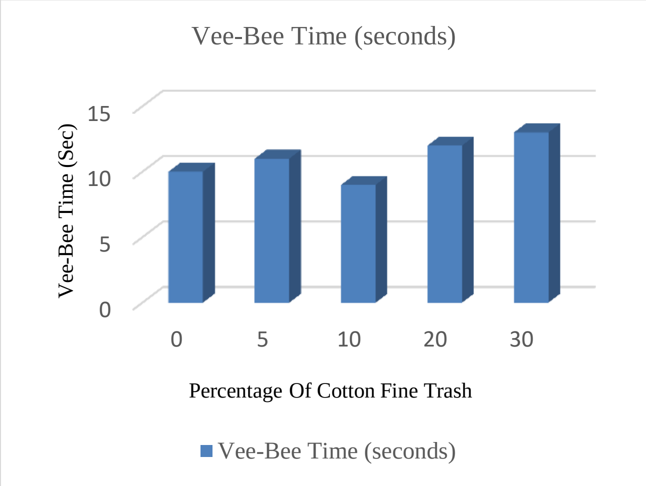

Figure: 6 Vee-Bee Time

The results indicate that the mix with 10% cotton fine trash (M2) exhibited the highest workability. This is evident from the highest slump value of 95 mm, the highest compaction factor of 0.94, the highest flow table value of 460 mm, and the lowest Vee-Bee time of 9 seconds.

2.Compressive Strength:

Table 3.Compressive Strength Result

Mix Designation	% Cotton Fine Trash	7Days (MPa)	14 Days (MPa)	28Days (MPa)
M0 (Control)	0%	21.5	30.2	37.0
M1 (5%)	5%	23.0	31.0	39.0
M2 (10%)	10%	24.5	32.0	40.0
M3 (20%)	20%	22.0	29.0	35.0
M4 (30%)	30%	20.5	25.0	32.0

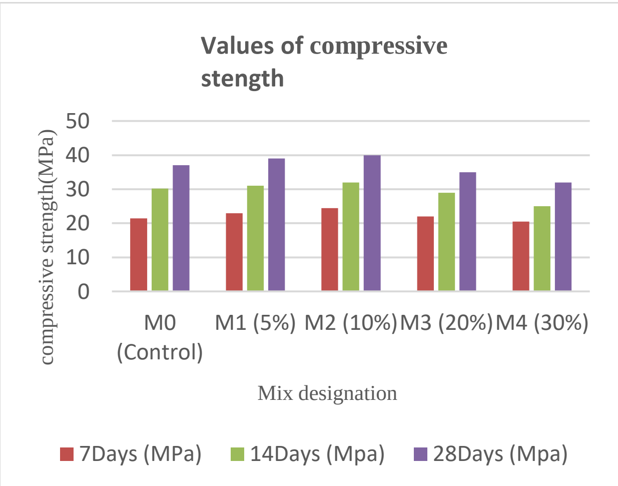

Figure: 7 Compressive Strength For Various Proportions At 7,14,28 Days

The M2 mix with 10% cotton fine trash achieved the highest compressive strength at all ages, with 24.5 MPa at 7 days, 32.0 MPa at 14 days, and 40.0 MPa at 28 days. The increase in compressive strength at 10% replacement can be attributed to several factors:

- Improved Particle Packing: The fine and fibrous nature of the cotton trash helps in filling the voids between cement particles, leading to a denser and more compact mix.
- Pozzolanic Reaction: Cotton trash contains some organic materials that can react pozzolanically with calcium hydroxide released during cement hydration, contributing to additional strength gain.
- Improved Bonding: The fibrous content of the cotton trash can enhance the bonding between the cement matrix and the aggregate, leading to better stress distribution and higher compressive strength
- At higher replacement levels (20% and 30%), a decrease in compressive strength is observed, likely due to the reduction in the effective cement content and the potential negative effects of excessive organic content on the hydration process

3.Flexural Strength:

Table 4.Flexural Strength Result

Mix Designation	% Cotton Fine Trash	7Days (MPa)	14 Days (MPa)	28Days (MPa)
M0 (Control)	0%	3.5	4.7	6.0
M1 (5%)	5%	3.7	4.9	6.3
M2 (10%)	10%	3.6	4.9	6.5
M3 (20%)	20%	3.2	4.6	6.0
M4 (30%)	30%	3.1	4.2	5.0

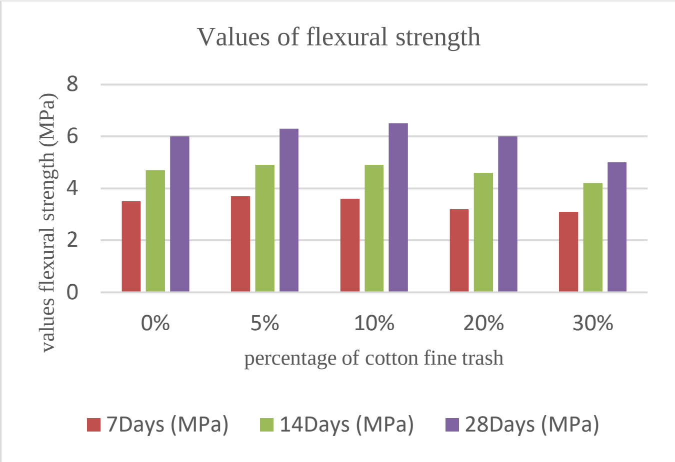

Figure: 8 Flexural-Strength For Various Proportions At 7,14,28 Days

The M2 mix with 10% cotton fine trash also showed the highest flexural strength, with 3.6 MPa at 7 days, 4.9 MPa at 14 days, and 6.5 MPa at 28 days. The increased flexural strength can be attributed to the improved bonding and stress distribution provided by the fibrous cotton trash, which helps in resisting bending stresses more effectively.

4.Tensile Strength:

The M2 mix with 10% cotton fine trash showed the highest tensile strength, with 2.4 MPa at 7 days, 2.9 MPa at 14 days, and 3.9 MPa at 28 days. The improvement in tensile strength is due to the enhanced bonding and crack-bridging properties of the fibrous cotton trash, which helps in resisting tensile stresses more effectively.

Table 5.Tensile Strength Result

Mix Designation	% Cotton Fine Trash	7Days (MPa)	14 Days (MPa)	28Days (MPa)
M0 (Control)	0%	2.0	2.7	3.5
M1 (5%)	5%	2.2	2.9	3.7
M2 (10%)	10%	2.4	2.9	3.9
M3 (20%)	20%	2.1	2.7	3.4
M4 (30%)	30%	2.0	2.5	3.0

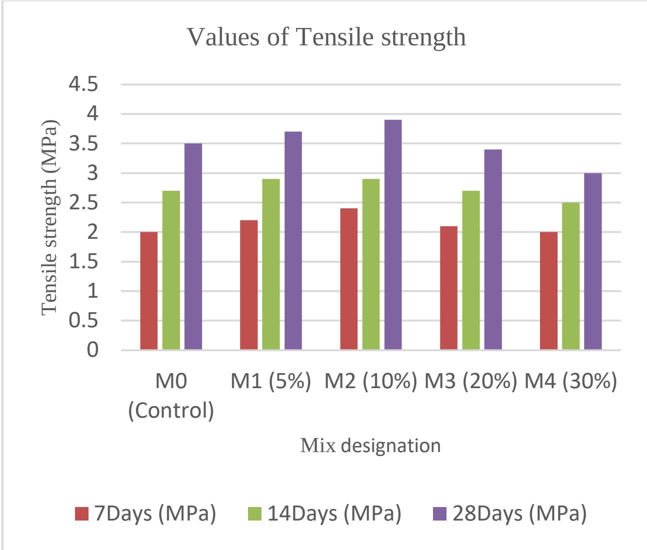

Figure: 9 Tensile-Strength For Various Proportions At 7,14,28 Days

5.CONCLUSION

1. Optimal Replacement Level:10% Cotton Fine Trash (M2) demonstrated the most favorable balance of workability and mechanical properties, making it the optimal replacement level among the tested percentages.

2.Enhanced Workability:The 10% replacement level achieved the highest workability with increased slump, compaction factor, and flow table values, and reduced Vee-Bee time. This is attributed to the improved particle packing and reduced friction due to the fibrous nature of the cotton fine trash.

3.Improved Mechanical Properties:

Compressive Strength: M2 exhibited the highest compressive strength at 7, 14, and 28 days, due to better particle packing, potential pozzolanic reactions, and improved bonding.

Flexural Strength: The 10% mix also showed superior flexural strength, indicating better resistance to bending stresses.

Tensile Strength: The highest tensile strength was observed in the 10% replacement mix, reflecting enhanced crack-bridging and bonding properties.

4.Density Reduction:

The density of the concrete decreased with the increase in cotton fine trash content, with the 10% mix achieving a lower density, beneficial for lightweight concrete applications.

5.Higher Replacement Levels:

Replacement levels beyond 10% (20% and 30%) resulted in decreased mechanical properties, likely due to reduced cement content and the negative effects of excess organic material on the concrete matrix.

6.Sustainability Benefits:

Utilizing 10% cotton fine trash contributes to sustainable construction practices by recycling waste material and reducing dependency on conventional cement, while maintaining acceptable mechanical properties.

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