# HYBRID FIBRE REINFORCED CONCRETE

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***Abstract*- Mixing closely spaced and evenly distributed fibers into concrete enhances crack resistance, impact and tensile strength, fatigue resistance, and durability, leading to Fiber Reinforced Concrete (FRC). Bamboo, known for its strength-to-weight ratio and ease of use, presents a sustainable alternative. Steel, traditionally used for tensile strength, has issues like corrosion and cost. Research explores Bamboo as reinforcement in concrete. Various fibers, including Aluminum, Coir, Jute, Carbon, and Steel, contribute to Fiber Reinforced Concrete (FRC) properties. This study investigates the mechanical properties of Bamboo Fiber Reinforced Concrete (BFRC) and introduces Jute fibers to enhance concrete's mechanical attributes, focusing on hybrid fiber reinforced concrete with Bamboo and Jute.**

## I. INTRODUCTION

Portland cement-based concrete has notable characteristics, excelling in compression but suffering from tension weakness and brittleness. Early crack formation, especially in large-scale applications, compromises durability. Conventional rod reinforcement and specific fibers partly address these issues. Recent concrete technology advancements focus on fiber reinforcement, especially polymeric, steel, and glass fibers, primarily for crack control, not structural enhancement. Research into randomly distributed fibers for cement-based materials began in the 1960s, with global research and development efforts. Polypropylene fibers counter plastic cracking, while steel fibers enhance fracture toughness, ductility, and impact resistance. Mixing fibers conventionally introduced "polypropylene fiber concrete," but no single fiber type comprehensively enhances concrete. Combining two or more fiber types in "hybrid fiber reinforced concrete" controls cracks and enhances properties. Historically, substantial effort enhanced concrete behavior, covering flexural, compressive, shear strength, and ductility. The ancient practice of reinforcing brittle materials with fibers, like Mesopotamians using straw, endures. Modern fibers derive from steel, glass, carbon, synthetics, and more, with steel being common. Early trials to enhance concrete with discontinuous steel reinforcing elements, like nail segments, date back to 1910. Fiber-reinforced concrete, containing uniformly distributed, randomly oriented, short fibers, bolsters structural integrity, and reduces permeability. Fiber content is typically expressed as a percentage of the total composite volume, typically ranging from 0.1% to 3%. Fibers with non-circular cross-sections use an equivalent diameter for aspect ratio calculations. When a fiber's modulus of elasticity exceeds the matrix's, it enhances tensile strength. Increasing fiber aspect ratio generally strengthens flexural strength and matrix toughness. Research continues into bamboo and jute fibers in concrete and their mechanical properties.

## II. AIM & OBJECTIVE

The objectives of the study are:

- To determine the compressive strength and flexural strength of bamboo fibre reinforced concrete.
- To determine the compressive strength and flexural strength of jute fibre reinforced concrete.
- To determine the compressive strength and flexural strength of hybrid fiber reinforced concrete.
- To compare the strength of concrete cube containing hybrid fibers with the concrete with normal concrete beams.

## III. MATERIAL USED AND METHODOLODY

a. Cement

Locally available Portland pozzolana cement of ACC brand have been procured

b. Coarse aggregate

Coarse aggregate shall consist of naturally occurring materials such as gravel, or resulting from the crushing of parent rock, to include natural rock, slags, expanded clays and shales (light weight aggregates) and other approved inert materials with similar characteristics, having hard, strong, durable particles, conforming to the specific requirements of this materials substantially passing through 20mm sieve and retained in 10mm, shall be classified as coarse aggregate

c. Jute fibres

Jute fibers of silky texture was used,These fibres are biodegradable and eco-friendly. The common structural properties o jute fibres are very high tensile strength and low extensibility. In the present study, raw jute fibres cut to a length of 10mm are used. The content of jute fibre is determined by volume fraction. The percentage of jute fibre used to cast the specimen is 0.1%, which is the optimum. Jute fibres of 10mm cut length and aspect ratio 400 were adopted.

| | |
|---|---|
| Diameter | 0.8mm |
| Tensile strength | 230MPa |
| Modulus of elasticity | 26.5GPa |
| Aspect ratio | 12.5 |

d. Fine aggregate

River sand, rich in silica, is a key concrete fine aggregate. Tested for gradation, fineness, and specific gravity, well-graded sand enhances workability and economy by reducing cement needs and acting as a void filler in coarse aggregates

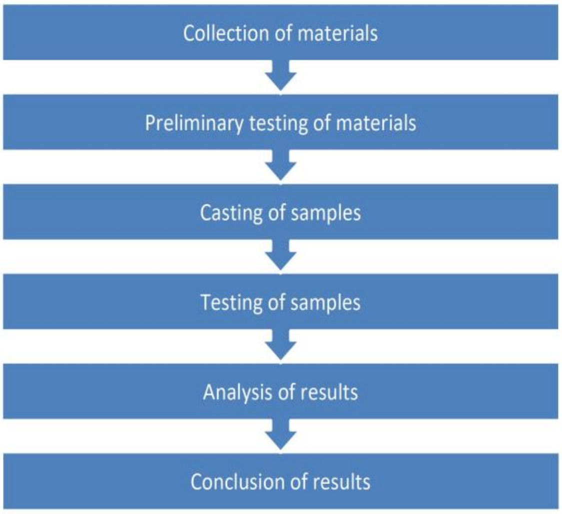
e. Bamboo fibre

Bamboo is a multipurpose reserve catogarized by large ratio of strength to weight and its ease of work with simple tools. It is one of the rapidly growing natural reserves, also it is easily and locally available. Bamboo fibres have better modulus of elasticity than any other natural material. The longer is the fibre, the higher it gives the tensile strength. As the bamboo fibres are susceptible to the biological attacks, it was given treatment of wood guard's anti-termite solution. Aspect ratio of 40 were adopted

| | |
|---|---|
| Diameter | 1.5mm |
| Tensile strength | 262MPa |
| Modulus of elasticity | 9.8GPa |
| Aspect ratio | 40 |

f. Water

Water is essential in concrete, with around 3/10 of its weight needed for proper hydration. A minimum water-cement ratio of 0.35 is crucial to prevent segregation and bleeding. Excess water weakens concrete, but fibers can absorb some, preventing bleeding. Insufficient water affects workability. Potable water with pH 6 to 9 is required.




## IV. PRILIMINARY TESTING OF MATERIALS

a. **Cement**

The test conducted on cement for our project work is:

 Normal consistency

The Vicat apparatus is used to determine the normal consistency of cement. A paste is prepared from 300g of cement and water, then placed in the Vicat mold. After gauging for 3-5 minutes, the Vicat plunger is released to penetrate the paste. The correct water content results in a penetration of 5-7 mm from the bottom. In this case, the standard consistency is found to be 33%, falling within the typical range of 25-35% for cement.

| Trial no | Weight of cement (g) | Amount of water added (ml) | Penetration from bottom of mould (mm) | Percentage of water for standard consistency (W2/W1)×100 |
|---|---|---|---|---|
| 1 | 400 | 112 | 38 | 28 |
| 2 | 400 | 120 | 21 | 30 |
| 3 | 400 | 124 | 12 | 31 |
| 4 | 400 | 128 | 9 | 32 |
| 5 | 400 | 132 | 6 | 33 |

 Initial and final setting time

To determine the initial setting time of cement, a needle is gently lowered onto test blocks until it fails to pierce the block beyond 5-7 mm from the bottom of the mold. The final setting time is found using a needle with an annular attachment, considering cement as finally set when the needle makes an impression on the block's surface while the attachment does not. In this case, the initial setting time is 35 minutes, and the final setting time is 10 hours.

 Specific gravity

The specific gravity is normally determined as the ratio between the weight of a given volume of material and weight of equal volume of water. The Portland cement have a specific gravity of around 3.15 and for Portland pozzolana cement, the value come near to 2.90. the specific gravity test for cement is carried out using Le-chatelier flask apparatus.

b. **Fine aggregate**

i. Sieve analysis

The grain size distribution and specific gravity of fine aggregates were examined for experimental purposes. Sieve analysis, also known as gradation test, was conducted using various sieves. The air-dry sample, weighing 1 kg, was sequentially sieved through IS sieves of different sizes. Each sieve was shaken in varied directions for at least 2 minutes until minimal material passed through. The results showed a fineness modulus of 3.858, indicating the particle size distribution of the fine aggregates.

| Sl. No | IS sieve size (mm) | Weight retained (kg) | Percentage weight retained | Cumulative percentage weight retained | Percentage finer |
|---|---|---|---|---|---|
| 1 | 4.75 | 0.030 | 3 | 3 | 97 |
| 2 | 2.36 | 0.056 | 5.6 | 8.6 | 91.4 |
| 3 | 1.18 | 0.150 | 15 | 23.6 | 76.4 |
| 4 | 600 µ | 0.340 | 34 | 57.6 | 42.4 |
| 5 | 300 µ | 0.364 | 36.4 | 94 | 6 |
| 6 | 150 µ | 0.050 | 5 | 99 | 1 |
| 7 | 75µ | 0.010 | 1 | 100 | 0 |

ii. Specific gravity

The specific gravity of fine aggregate is the ratio of weight of a given volume of aggregate to weight of equal volume of water. The specific gravity of sand is considered to be around 2.65. specific gravity sand is determined by pycnometer apparatus.

c. **Coarse aggregate**

i. Sieve analysis:

Grain size analysis is done to determine the particle size distribution of coarse aggregate by sieving. Grain size analysis expresses quantitatively the percentage by weight of various sizes of particles in the sample.

Weight of coarse aggregate = 2kg

| Sl. No | IS Sieve size (mm) | Weight retained (kg) | Percentage weight retained | Cumulative percentage weight retained | Percentage of weight passing |
|---|---|---|---|---|---|
| 1 | 80 | 0 | 0 | 0 | 100 |
| 2 | 40 | 0 | 0 | 0 | 100 |
| 3 | 20 | 1.696 | 56.533 | 56.533 | 43.467 |
| 4 | 10 | 1.270 | 42.33 | 98.866 | 1.134 |
| 5 | 4.75 | 0.022 | 0.733 | 99.399 | 0.401 |
| 6 | 2.36 | 0.012 | 0.400 | 99.999 | 0.001 |

Fineness modulus = 354.797 / 100 = 3.547

## V. EXPERIMENTAL PROGRAMME

### i. Mix designation

Six mixes were adopted in this study. One control mix, two mixes each with optimum percentage of bamboo fibre and jute fibre respectively and three mixes of hybrid fibre containing both bamboo and jute fibre. Mix designation is presented in table 3.5.

M0 – Control mix
M1 – 1% bamboo fibre
M2 – 0.1% jute fibre
M3 – 0.25% jute fibre + 0.75% bamboo fibre
M4 – 0.5% jute fibre + 0.5% bamboo fibre
M5 – 0.1% jute fibre + 0.9% bamboo fibre

The quantity of material required for different mixes for one cube are given in table

| Mix | Cement (kg) | Bamboo fibre (g) | Jute fibre (g) | Fine aggregate (kg) | Coarse aggregate (kg) | Water (ml) |
|---|---|---|---|---|---|---|
| M0 | 1.532 | - | - | 2.298 | 4.396 | 689.4 |
| M1 | 1.498 | 15.32 | - | 2.247 | 4.494 | 674.1 |
| M2 | 1.499 | - | 8.257 | 2.249 | 4.497 | 674.5 |
| M3 | 1.495 | 11.49 | 20.64 | 2.243 | 4.485 | 672.7 |

| | | | | | | |
|---|---|---|---|---|---|---|
| M4 | 1.492 | 7.66 | 41.284 | 2.238 | 4.476 | 671.4 |
| M5 | 1.497 | 13.788 | 8.257 | 2.246 | 4.491 | 673.6 |

The quantity of material required for different mixes for one beam are given in table

| Mix | Cement (kg) | Bamboo fibre (g) | Jute fibre(g) | Fine aggregate (kg) | Coarse aggregate (kg) | Water (ml) |
|---|---|---|---|---|---|---|
| M0 | 2.312 | - | - | 3.476 | 6.932 | 1040.4 |
| M1 | 2.313 | 23.17 | - | 3.47 | 6.939 | 1048.5 |
| M2 | 2.314 | - | 12.74 | 3.471 | 6.942 | 1041.3 |
| M3 | 2.308 | 17.38 | 31.855 | 3.462 | 6.924 | 1038.6 |
| M4 | 2.303 | 11.59 | 63.71 | 3.455 | 6.909 | 1036.4 |
| M5 | 2.311 | 20.853 | 12.74 | 3.467 | 6.933 | 1039.9 |

**ii. Casting of concrete cubes and beams with specified proportions**

Procedure:

1. Choose nominal mix M20 (1:1.5:3)
2. Weigh accurately the ingredients and mix them thoroughly.
3. Pour the concrete in the mould, after applying oil in the mould
4. Fill the concrete in the mould in three layers and compact it thoroughly.
5. Trowel off surplus concrete from the top of the mould
6. Specimens are removed from the mould after 24 hours
7. Cure in water 7, 14 and 28 days.

**iii. Preparation of test specimens**

a) Casting of cube specimens for the compression strength test

The steel cube moulds were coated with oil on their inner surfaces. The amount of cement, fine aggregate, coarse aggregate, jute fibre and bamboo fibre required for required numbers of cubes were weighed. The materials were first dry mixed, then mixed with water. The water/cement ratio of 0.45 were cautiously maintained.

Concrete was poured in to the moulds in three layers and each layer is compacted by 25 blows using tamping rod, surface was finished using trowel. After 24 hours, concrete cubes were demoulded and the specimens were kept for curing in water.

b) Casting of beam specimens for flexural strength test

The steel beam moulds were coated with oil on their inner surfaces. The amount of cement, fine aggregate, coarse aggregate, jute fibre and bamboo fibre required for required numbers of beams were weighed. The fibres are randomly distributed in the mix and the materials were first dry mixed, then mixed with water.

Concrete was poured in to the moulds in three layers and each layer is compacted by 25 blows using tamping rod, surface was finished using trowel. After 24 hours, concrete cubes were demoulded and the specimens were kept for curing in water.

**iv. curing of the test specimens**

Moulds were safely demoulded without causing any damage to the specimen and immediately concrete cube and beam specimens were kept in curing tank completely immersed in water for curing.

**v. Compression test**

The compressive strength of concrete is defined as the load that causes specimen failure divided by its cross-sectional area under uniaxial compression at a specified loading rate. To ensure consistent results, great care is taken during specimen casting and loading in compression tests. Although concrete in actual structures experiences complex stress conditions, the test is conventionally conducted in uniaxial compression. The use of 150mm cubes follows IS code IS456. A compression testing machine is employed, and the compressive strength is calculated using the formula: COMPRESSIVE STRENGTH = (LOAD/AREA) N/mm². Specimens are removed from water, surface-dried, and then tested at various curing periods.

Procedure

a. Remove the specimen from water after specified curing time and wipe out excess water from the surface
b. Take the dimension of the specimen to the nearest point to meter.
c. Clean the bearing surface of the testing machine.
d. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides o the cube cas

**vi. Flexural strength test**

Flexural strength, a measure of a material's ability to resist deformation under load, is often determined through a three-point flexural test using beam specimens. This test provides dependable results and the modulus of rupture, or flexural strength, varies based on beam dimensions and loading method. Typically, it's about 10 to 20 percent of compressive strength, influenced by factors like time, size, and volume of coarse aggregate used.

## VI. RESULT

### i. COMPRESSIVE STRENGTH

For each mix three cube specimens of size 150mm×150mm×150mm were tested for compressive strength test. Cubes were tested after 7, 14 and 28 days of curing. The average cube compressive strength for the various mixers were shown in table and Figure 1 & 2 shows the graphical representation.

| Mix Designation | 7 Days(N/mm²) | 14 Days(N/mm²) | 28 Days(N/mm²) |
|---|---|---|---|
| M0 | 16.12 | 22.32 | 24.80 |
| M1 | 20.35 | 25.58 | 32.34 |
| M2 | 18.17 | 24.40 | 27.91 |
| M3 | 14.93 | 19.51 | 22.89 |
| M4 | 13.95 | 18.21 | 20.50 |
| M5 | 23.83 | 31.46 | 36.52 |

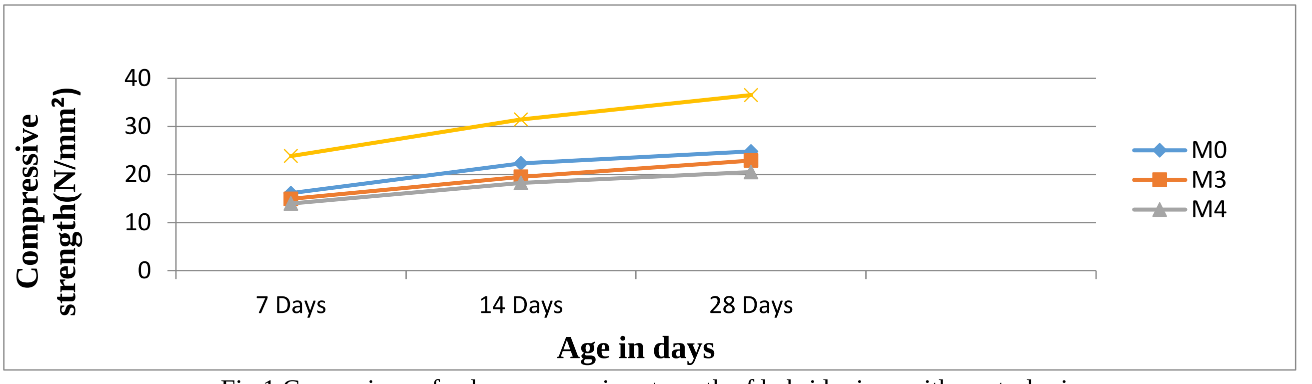



Fig.1 Comparison of cube compressive strength of hybrid mixes with control mix

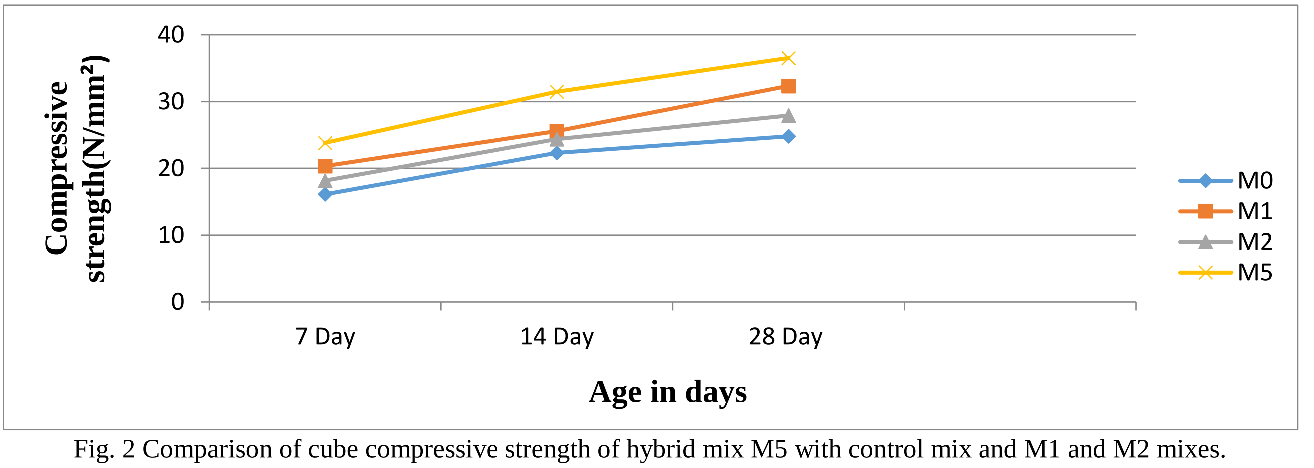



Fig. 2 Comparison of cube compressive strength of hybrid mix M5 with control mix and M1 and M2 mixes.

### ii. FLEXURAL STRENGTH

The modulus of rupture is determined by testing standard test specimens of sixe 100mm×100mm×500mm. Average values of flexural strength of various mixes at 7,14, and 28 days are given in table

| Mix designation | 7 Days(N/mm²) | 14 Days(N/mm²) | 28 Days(N/mm²) |
|---|---|---|---|
| M0 | 2.71 | 3.20 | 3.35 |
| M1 | 2.95 | 3.29 | 3.56 |
| M2 | 2.98 | 3.46 | 3.69 |
| M3 | 2.65 | 3.09 | 3.32 |
| M4 | 2.58 | 2.98 | 3.17 |
| M5 | 3.28 | 3.71 | 4.16 |

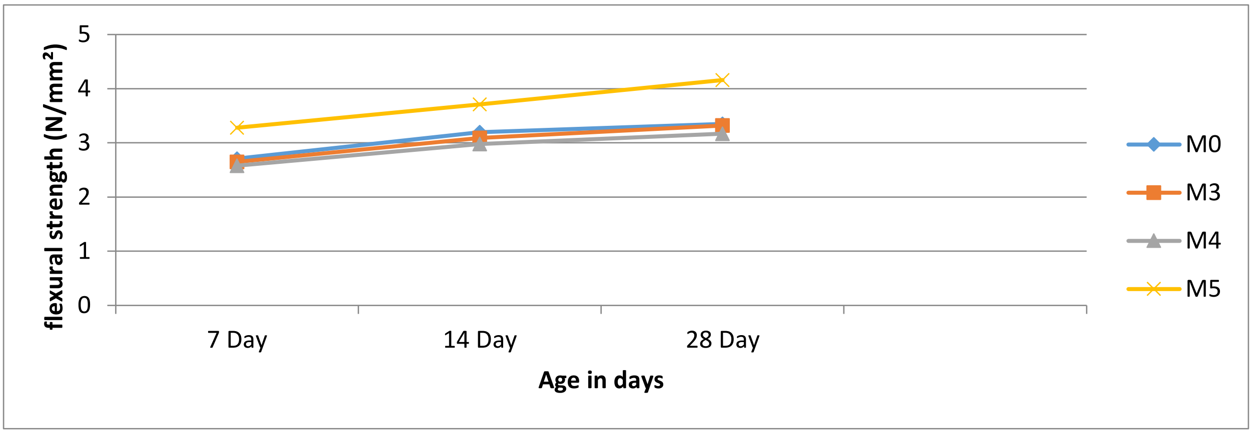



Fig 3. Comparison of flexural strength of hybrid mixes with that of control mix

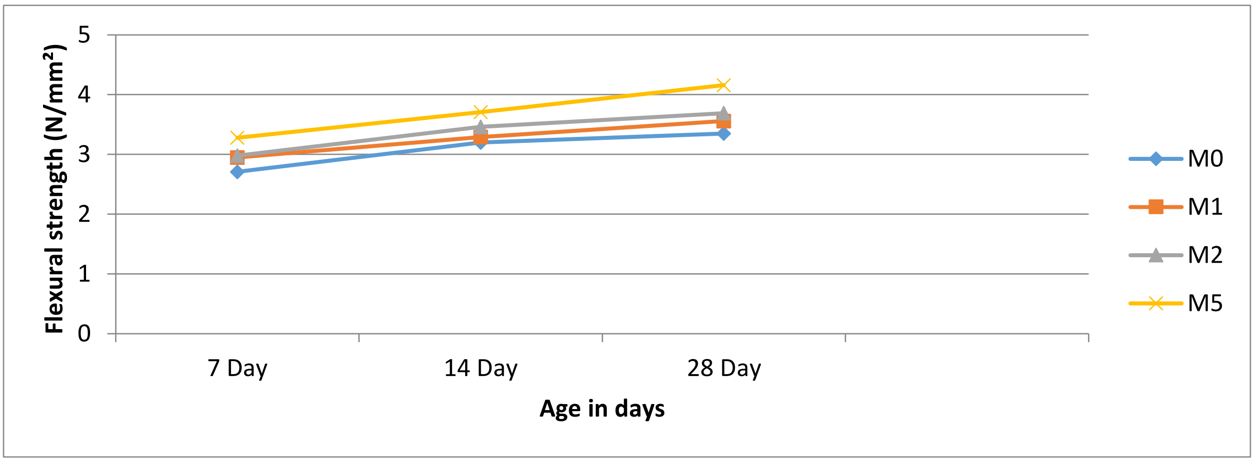



Fig. 4 Comparison of flexural strength of hybrid mix M5 with control mix and M1 and M2 mixes.

## VII. CONCLUSION

In the quest to enhance concrete's performance, the addition of fibers has emerged as a promising solution. Concrete, prone to cracking upon placement, benefits from fiber reinforcement. Hybrid fibers, a combination of different types, offer precise control over cracking at various levels and zones within concrete, improving its mechanical properties. In experiments, it was observed that adding fibers increased compressive and flexural strength, with bamboo fibers boosting compressive strength by 26.2% and flexural strength by 6.3%, while jute fibers showed increases of 12.8% and 10.1%, respectively. Among the tested mixes, M5 demonstrated substantial improvements, with a 47% increase in compressive strength compared to the control mix.

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