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EXPERIMENTAL STUDY ON ENHANCING THE MECHANICAL CHARACTERISTICS AND DURABILITY OF CONCRETE USING JUTE FIBER

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Abstract - *The commonly utilized general-purpose cement, despite its cost and energy intensity, is a key ingredient in concrete production. Concrete, though brittle, possesses strength, durability, and adaptability, making it moldable into various shapes and sizes. However, it is prone to developing structural cracks even before loading, primarily due to drying shrinkage. To mitigate this, natural fibers such as jute can enhance material properties. A research study explored the mechanical characteristics of jute fiber concrete, demonstrating its sustainability and innovative construction material, combining concrete's strength and durability with the eco-friendliness of jute fibers. Jute fiber was chopped and blended into concrete at varying percentages (0.3%, 0.6%, & 0.9% in M30 concrete mixes), and the resulting specimens showed reduced workability with increased jute fiber content. Nevertheless, the inclusion of jute fiber notably enhanced the compressive, tensile and flexural strength of each concrete mix. This study highlights the potential of jute as an additive to improve concrete's durability and strength.*

Key Words: Portland cement, Jute fiber, Durability Compressive strength, Flexural strength and Tensile strength.

1.INTRODUCTION

Concrete, an essential construction material, has been widely utilized in buildings since ancient times. Its association with Portland cement and rapid increase in production due to urbanization and industrialization have led to environmental concerns. The significant CO2 emissions from the production of concrete and its environmental impact are urgent concerns that must be addressed to mitigate harm to the environment.

Natural fibers, such as jute, offer a cost-effective, renewable, and biodegradable alternative. With unique characteristics and widespread availability, natural fibers have been employed for diverse applications for thousands of years. Jute is recognized for its robustness, resilience, and eco-friendliness, finding applications in textiles, packaging, home furnishings, and more. Its versatility and sustainability make it an attractive option for diverse industries.

Research efforts focusing on incorporating jute fiber into concrete have shown promising results. By adding jute fibers in varying percentages, the toughness and mechanical characteristics of concrete can be notably enhanced, leading to enhanced compressive, flexural and tensile strength. The advancement of composite construction materials using jute fiber holds the potential to increase structural strength and extend the lifespan of structures, offering a sustainable solution with a positive environmental impact.

2. LITERATURE REVIEW

- Saulo Rocha Ferreira and Marco Pepe Sing et al., This research conducted experiments on natural fibers such as sisal, coconut, and jute to identify their adhesion properties in cement. The study analyzed the different characteristics of these fibers and their impact on bonding with cement. This inquiry offers valuable findings on the potential of these natural fibers to enhance the resilience of concrete and offers guidance for forthcoming research in this field. The results indicated that variables like the roughness of the fiber's surface, its aspect ratio, and its composition significantly influence its adhesion to cement. Specifically, fibers with rough surfaces and longer lengths exhibited stronger adhesion, thereby improving the collective strength of the blend. The study recommends considering these inherent qualities of fibers to optimize cement mixtures.

- Arpitha M, Yashaswini et al., This research conducted experiments on mechanical characteristics of concrete using coconut coir fibers. Fiber Reinforced Concrete is a materials mix including cement, sand, stones, and fibers like natural, steel, or glass. These fibers make concrete stronger and can be eco-friendly and affordable. This study aimed to enhance concrete strength by utilizing cost-effective, sustainable coconut coir fibers, known for their heat resistance and renewability. They added coconut coir to M30 concrete in different amounts and found that 2% coir gave the best strength, making it stronger than plain concrete. From the experiments conducted in the lab, the study concludes that using 2% incorporation of coconut coir fibers based on the weight of cement yielded the most favorable outcomes. The concrete's compressive strength increased by 22.4% at 7 days, 30.37% at 14 days, and 27.18% for 28 days compared to no coir fibers. Similarly, the split tensile strength improved by 33.47% at 7 days, 34.70% at 14 days, and 30.03% at 28 days. Coir fibers enhanced the concrete's mechanical properties by acting as bridges for cracks, although using more than 2% fibers caused a decrease in strength due to reduced cohesiveness.

- Gukendran Rangasamy and Sambathkumar Mani et al., This research tested different angles of jute fibers (0°, 15°, 30°, 45°, 60°, and 75°) in epoxy materials to see how it affects strength and heat behavior. The most favorable outcomes were achieved when utilizing fibers at 30° angle. They also used special methods to study how the materials react to heat, showing changes in their structure and composition. They made strong jute fiber and epoxy composite sheets by arranging the fibers differently. The sheets with fibers at 30° held the most weight and bent without breaking because the fibers shared the load well. These fibers also handled impact the best, with 0.814 Joule of energy absorbed. When they looked at how the materials handle heat, they discovered that they behaved similarly, with slight differences.

- D. P. Archana, H. N. Jagannatha Reddy et al., The study focused on bio composites prepared from natural fibers, which are gaining more popularity for being environmentally friendly. The researchers used sisal and jute fibers to create these biocomposites using a hand layup technique and studied their strength and water absorption properties. They also investigated the impacts of a 4% NaOH treatment on these properties. The results shows that treating the fibers improved the strength and reduced water absorption in the biocomposites, making them adapted for strengthening civil structures. By using the hand layup method, the researchers successfully made natural fiber-reinforced polymer composites (SNFRC and JNFRC) and tested their tensile, flexural, impact, and water consumption properties. They discovered that composites with 4% NaOH-treated sisal and jute fibers displayed better mechanical characteristics due to improved fiber-matrix adhesion. These treated composites also showed reduced water consumption and are promising for reinforcing epoxy-based matrix composites suitable for both domestic and industrial use under light to moderate loads.

- Genbao Zhang and Jiaqing Wang et al., This study aimed to improve self-compacting concrete (SCC), which typically relies heavily on cement, harming the environment. Researchers sought alternatives and discovered that incorporating special jute fibers and mineral powders in place of some cement can enhance the concrete's strength and workability. This innovation holds their potentiality to advance both quality and eco-friendliness of future buildings. By experimenting with plant fibers and specific minerals, scientists developed a more robust and environmentally sustainable self-compacting concrete. This new concrete mixture is eco-friendly as it reduces pollution and is more cost-effective than conventional concrete. Their observations indicated that using a lesser amount of treated plant fibers and a specific mineral powder provides positive results, advising that this eco-friendly concrete could replace traditional types, thereby reducing pollution and waste.

3. MATERIALS AND METHODOLOGY

3.1 MATERIALS USED

a. *Cement*

The capacity of concrete determined by the grade of cement utilized. There are 33 grade, 43 grade, and 53 grade cements available. We used general-purpose cement of 53 grade, this means that under standard conditions, as per Indian Standards, Portland cement has a 28-day compressive strength of 53 megapascals (MPa).

Table -1: Characteristics of Cement

Sl No	Properties	Obtained values
1	Color	Gray
2	Specific gravity	3
3	Standard consistency	27%
4	Initial setting	25Mins
5	Final setting	400Mins

b. *Fine aggregates*

Manufactured sand(M-Sand) is artificial sand made by crushing hard stones, offering consistent quality and reducing voids in concrete. It's free of impurities, has denser particles, and a specific gravity of 2.61. The sieve analysis confirms that it meets Zone II specifications according to IS: 383-1970.

Fig -1: Fine aggregates

c. Coarse aggregates

The coarse aggregates are particles greater than 4.75mm in diameter, such as gravel or crushed stone, used in construction. They contribute to the durability and firmness of the concrete mixture. The size and quality of coarse aggregates significantly impact the characteristics of concrete, and a specific gravity of 2.7. The combined aggregates meet IS: 383-1970 specifications for graded aggregates after sieve analysis.

Fig -2: Coarse aggregates

d. Water

The specimens in this experimental study are cast using clean and fresh water that meets Indian standards by devoid of organic matter, oil, or silt, chloride, sugar, and acidic materials.

e. Admixture

Superplasticizer (Conplast sp 430) by FOSROC chemicals has been utilized in this particular experiment work to create high-quality concrete and achieve a significant water reduction of up to 25% without compromising workability. Typically, the usage range is between 0.5 to 2.0 liters per 100 kg of cement. The characteristics of Conplast sp 430 include a specific gravity ranging from 1.200 to 1.225 at 30°C, approximately 1% additional air entrainment, and no chloride content as per IS:456 and BS:5075 standards.

Fig -3: Super Plasticizer Conplast sp 430

f. Jute Fiber

The jute fiber is making waves in construction for its eco-friendly properties. With its biodegradability and high cellulose content, it's great for strengthening concrete and reducing cracking. Jute-reinforced concrete is especially useful in earthquake-prone areas, absorbing energy and resisting seismic stress. Besides concrete, jute is utilized in geotextiles for erosion control, stabilizing soil and promoting vegetation growth. Its biodegradability eliminates the need for removal, reducing environmental impact. Overall, jute fiber offers versatility, sustainability, and a positive impact on both construction and the environment.

Fig -4: Jute Fiber

This research aims to do the experimental investigation carried out on cubes, cylinders and Prism for 28 days respectively to understand the strength characteristics of varying percentages of Jute fiber by 0%, 0.3%, 0.6% and 0.9%.

This research aims to assess the characteristics such as

1. The compressive strength of Jute fiber concrete.
2. The tensile strength of Jute fiber concrete.
3. The flexural strength of Jute fiber concrete.

A. Concrete Mix proportion Design

A Concrete mix proportion guidelines (IS10262:2019) & Balanced concrete mix design process were used to create Concrete. The proportion of fine aggregate to total aggregate by volume is about 52-58% & remaining 42-48% is the volume ratio of coarse aggregate to total aggregate.

Table -2: Mix Proportion Ratio

Cement	Coarse Aggregate	Fine Aggregate	Water	Super Plasticizer
1	3.12	1.69	0.4	0.7

B. Casting

The coarse aggregates was added in to concrete mixer, and fine aggregates was added along with cement for mixing. During the dry mix, various percentages of Jute fiber was added. 0.7% Super plasticizer was mixed with water. At first, a portion of water was added during the mixing process, and the rest was incorporated to ensure proper blending of the materials.

Then 4 Cubes of size 150mm x 150mm x 150mm were casted by adding Jute fibre of 0%, 0.3%, 0.6% and 0.9% and 0.7% of super plasticizer Conplast- SP430 based on the weight of cement and demoulded 24 hours later, then the specimens underwent a 28-days curing period.

Then 4 Prism of 500mm x 100mm x 100mm sizes were casted by adding Jute fibre of 0%, 0.3%, 0.6% and 0.9% and 0.7% of super plasticizer Conplast- SP430 by the weight of cement and demoulded 24 hours later, then the specimens underwent a 28-days curing period.

Then 4 Cylinder of 150mm ϕ & 300mm height sizes were casted by adding Jute fibre of 0%, 0.3%, 0.6% and 0.9% and 0.7% of super plasticizer Conplast- SP430 by the weight of cement and demoulded 24 hours later, then the specimens underwent a 28-days curing period.

4. RESULT AND DISCUSSION

1. Compressive Strength

Results presented in Figure 5 indicate that the incorporation of varying proportions of jute fiber into M30-grade concrete led to an enhancement in its flexural strength following 28 days of standard curing. The research showed that the most substantial increase in strength, amounting to 13.03%, was attained with a 0.9% jute fiber content, attributed to the uniform dispersion of the fiber within the concrete. Conversely, the fewest compressive strength was observed with a 0.3% jute fiber content. Specifically, the utilization of 0.3%, 0.6%, and 0.9% jute fiber resulted in strength enhancements of 4.7%, 7.97%, and 13.03%, respectively.

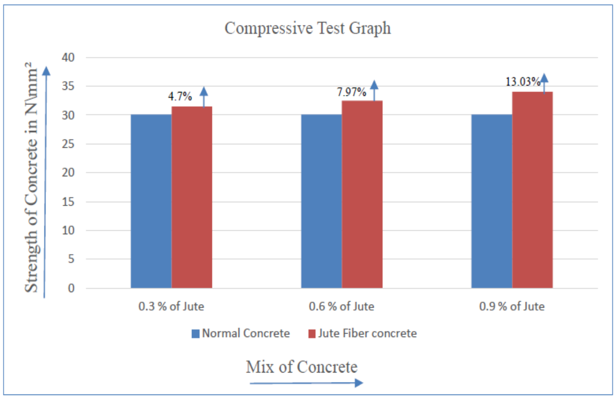

Fig -5: Compressive Test Graph

2. Split Tensile Strength

Figure 6 illustrates the split tensile strength outcomes of cylindrical specimens when different percentages of jute fiber were mixed to M30-grade concrete after 28 days of regular curing. The inclusion of jute fiber resulted in an increased split tensile strength, showing that the inherent brittleness of M30-grade concrete can be addressed through this addition. The study uncovered that the highest split tensile strength, experiencing an 18.64% increase, was accomplished by incorporating 0.9% of jute fiber into the concrete mix after the prescribed 28 days curing period, attributed to the proper and even dispersion of fiber throughout the concrete mixture. Conversely, the minimum split tensile strength was noted at a 0.3% addition of jute fiber.

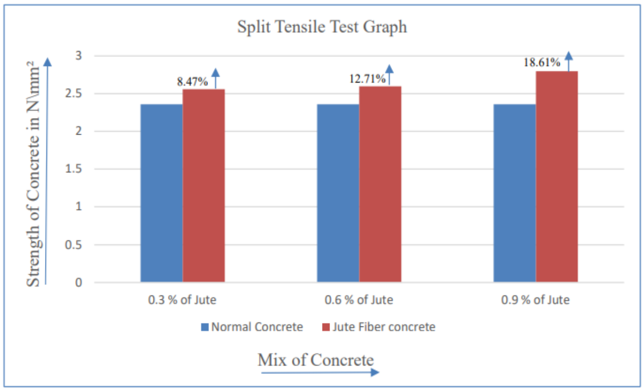

Fig -6: Split Tensile Test Graph

3. Flexural Strength

The flexural strength outcomes of prism specimens, incorporating varying percentages of jute fiber in M30-grade concrete after 28 days of standard curing, are depicted in Figure 7. The study demonstrates an enhancement in flexural strength, reaching a maximum increase of 20.04% with the incorporation of 0.9% jute fiber into the concrete matrix for M30 grade after the 28-day curing period.

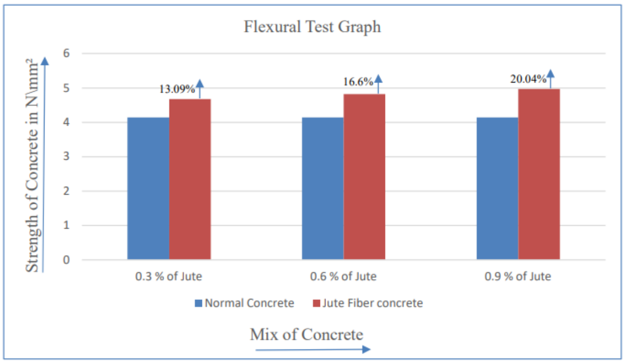

Fig -7: Flexural Test Graph

5. CONCLUSIONS

Jute fiber was incorporated into M30 grade concrete at three different percentages: 0.3%, 0.6%, and 0.9%, Striving to improve the mechanical characteristics of the concrete. Additionally, the study delved into the durability of the concrete, examining the influence of Jute fiber on strength. Throughout the investigation, each aspect was thoroughly examined, resulting to the following conclusions.

- The introduction of jute fiber to the concrete mix resulted in a reduction in the workability of Jute fiber concrete. The highest workability was attained when no jute fiber was added, across all concrete grades. Conversely, the lowest workability was attained with the addition of 0.9% jute fiber. This decline in workability is attributed to the hydrophilic nature of jute fiber, as it takes in water from the concrete mixture crucial for strength, workability and heat of hydration. Consequently, the Jute fiber concrete mix had reduced water content, leading to diminished workability.

- Incorporating jute fiber into the concrete resulted in a rise in compressive strength. The peak compressive strength was achieved with the addition of 0.9% of jute fiber, while the minimum compressive strength was observed with the addition of 0.3% jute fiber. The improvements in compressive strength were measured as 4.7%, 7.97%, and 13.03% when integrating 0.3%, 0.6%, and 0.9% of jute fiber, respectively.

- The flexural and split tensile strength outcomes mirrored the compressive strength of the concrete specimens. The highest strength was attained with the addition of 0.9% jute fiber, while the lowest strength was observed at a 0.3% jute fiber addition. Increased split tensile strength was noted as 8.47%, 12.70%, and 18.64% with the help of 0.3%, 0.6%, and 0.9% of jute fiber, respectively. Additionally, there was an enhancement in flexural strength, with improvements of 13.09%, 16.6%, and 20.04% observed with the addition of 0.3%, 0.6%, and 0.9% of jute fiber, respectively.

- The inclusion of jute fiber into the concrete matrix leads to the attachment of materials, thereby improving the compressive, flexural, and split tensile strength of the concrete.

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