CocoCrete: Enhancing M60 Grade Concrete with Coconut Fibre Reinforcement

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ABSTRACT

The integration of natural fibers in concrete has gained attention for its ability to enhance mechanical properties while promoting sustainable construction. Among various fibers, coconut fiber stands out due to its abundance, cost-effectiveness, and environmental benefits. This study investigates the impact of coconut fiber reinforcement on the strength characteristics of M60 grade concrete, focusing on compressive and tensile strength variations at different fiber percentages (1% to 5% by weight of cement). Experimental results indicate that the incorporation of coconut fiber improves the toughness and ductility of concrete, with optimal performance observed at specific fiber content levels. By reducing dependency on synthetic reinforcements and utilizing renewable resources, this research highlights the potential of CocoCrete as a sustainable, durable, and eco-friendly alternative in modern construction.

Key words: M60 Grade Concrete, CFRC (coconut fiber reinforced concrete), tensile strength, compressive strength, Renewable Reinforcement, Structural Durability

1. INTRODUCTION

One of the undesirable characteristics of concrete as a brittle material is its low lastingness and strain capability. Therefore, it needs reinforcement so as to be used because of the most general construction material. Conventionally, this reinforcement is within the kind of continuous steel bars placed within the concrete structure within the acceptable positions to face up to the obligatory tensile and shear stresses. Fibers, on the opposite hand, are usually short, discontinuous, and every which way distributed throughout the concrete member to provide a composite construction material called fiber ferroconcrete (FRC). Fibers utilized in cement-based composites are primarily made from steel, glass, and chemical compound or derived from natural materials. Fibers can control cracking more effectively due to their tendency to be more closely spaced than conventional reinforcing steel bars. It ought to be highlighted that fiber is used because the concrete reinforcement isn't a substitute for standard steel bars. Fibers and steel bars have totally different roles to play in advanced concrete technology, and there are several applications during which each fiber and continuous reinforcing steel bar ought to be used. Coconut fibers (Coir fibers) are one of the most popular types of fibers used as concrete reinforcement. Coconut fiber is the most ductile among all-natural fibers and has the potential to be used as a reinforcement material in concrete. It is biodegradable so the impact on the environment will be minimal. This is also a way to dispose of the fibers which are derived as waste materials from coir-based manufacturing units to produce high-strength materials. They are also nonabrasive in nature, cheap and easily available. Initially, Coir fibers are used to prevent or control plastic and drying shrinkage in concrete. Further research and development revealed that the addition of Coir fibers in concrete significantly increases its compressive strength, energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability. This study reviews the effects of the addition of Coir fibers in concrete and investigates the mechanical properties, and applications of coconut fiber reinforced concrete (CFRC). Concrete containing cement, water, fine aggregate, coarse aggregate and discontinuous coconut fibers is called fiber reinforced concrete. Coconut fiber reinforced concrete is a composite material having fibers as the additional ingredients, dispersed uniformly at random in small percentages between 0.3% and 5% volume in plain concrete. CFRC products are manufactured by adding coconut fibers to the ingredients of concrete in the mixture and by transferring the green concrete into the mould the product is then compacted and cured by the conventional method. Segregation or boiling is one of the problems encountered during mixing and compacting CFRC. This should be avoided for uniform distribution of fibers. The energy required for mixing, conveying, placing and finishing CFRC is slightly higher.

2. LITERATURE REVIEW

Coconut fiber is out there in abundance at the test site, which makes it quite viable as a reinforcement material in concrete. Further, it acts as a replacement source of income for the coconut producer who gets the advantages of the new demand generated by the development industry. In addition to the present, it's an efficient method for the disposal of coir mattress waste which can reduce the demand for extra waste disposal infrastructure and reduce the load on existing landfills and incinerators. The problem of a high rate of water absorption of the fiber might be reduced by coating the fibers with oil. This has led to enhancing the strength of concrete by the adoption of a natural fiber like Coconut. Moreover, the fibers have been natural in origin. The construction industry is revolutionizing in two major ways. One way is the development of construction techniques, like using automated tools in construction. The other is the advancement in high-performance construction materials, such as the introduction of high-strength concrete. In recent years, research and development of fibers and matrix materials and fabrication processes related to the construction industry have grown rapidly. Their advantages over other construction materials are their high lastingness to weight ratio, ability to be mould into various shapes and potential resistance to environmental conditions, leading to potentially low maintenance cost. These properties make FRCB composite a good alternative for innovative construction. Their application in construction includes both upgrading existing structures and building new ones, which may apply to varied sorts of structures, for instance offshore platforms, buildings and bridges **(Thou, 2005).**

(Majid Ali et al.,2012) A major roadblock towards the development of high-performance concrete using steel fibers is the high costs involved, availability and also the problem of corrosion. Coconut fiber is the foremost ductile among all the natural fibers and has the potential to be used as a reinforcement material in concrete. It is biodegradable so the impact on the environment will be minimal. This is also how to dispose off the fibers which are derived as waste materials from coir-based manufacturing units to supply high-strength materials. They are also non-abrasive in nature, cheap and easily available. Research work is being carried out to find the possibility of coconut-fiber ropes as a vertical reinforcement in mortar-free interlocking structures. This is believed to be an economical solution to earthquake-resistant housing.

The coconut fiber is added to concrete and Plain Cement Concrete (PCC) is employed to study its effect on flexural, compressive and lastingness properties and also drying shrinkage. Fiber is coated with oil so on decreases water absorption. Some of the benefits being observed are low cost, rarity, reasonable specific strength, good thermal insulation, reduced wear and skill to be recycled with minimal impact on the environment **(Majid Ali et al.,2011).** Thus, additionally to the enhancement within the physical properties of concrete, it seems to be a sustainable waste management technique. Coconut fiber with a lastingness of 21.5 MPa is the toughest among all the natural fibers **(Munawar et al., 2003)**. They are capable of taking strains4–6 times higher than other fibers **(Munawar et al., 2003** The advantages of coconut fibers are low cost, reasonable specific strength, low density, ease of availability, enhanced energy recovery, biodegradability, ability to be recycled in nature during a carbon-neutral manner, resistance to fungi moth and decay, excellent insulation to sound, flame, moisture and dampness, toughness, durability, resilience.

Waweru nancy mugure was investigated on sugarcane fiber (1%, 2%, 3%) in concrete. He compared oven-dried bagasse with sunlight-dried bagasse and that sunlight bagasse is stronger than oven-dried bagasse. Studied the fresh concrete properties like workability tests (slump cone test, compaction factor test) and harden concrete properties like (compressive strength, split tension test, flexural strength), slump values are 37,15,15,10 and compaction factors are 0.95,0.95,0.90,0.85 for 0%,1%,2%,3% respectively. Harden properties like Compressive strength, split tension test and flexural strengths are obtained at the age of 7,28 days. Compressive strengths at age of 28 days for 0%-15.6, 1% - 17.25, 2%-16,3%-7. For 1%-1.65MPa,2%-0.4MPa increased and for 3% it is deceased. Split tension strength for 0%-1.41, 1%-1.48,2%-1.27,3%-0.42MPa. Flexural strength are for 0%- 0.747,1%-1.676,2%-0.747,3%-0.687MPa. Plain concrete (control) compared with bagasse fiber reinforced concrete at 7 days of curing; addition of bagasse fiber is seen to reduce the compressive strength consistently. Tests after 28days of curing show that the compressive strength increases as fibers are increased to an optimum of 1% where the strength starts to drop with more increase of the fiber. The compressive strength is increased by up to 10.6% compared to that of the control. The tensile strength was highest at 1.48N/mm2 for the fiber content of 1% at 28days of age. **M. Sivaraja (march 2010):** was investigated on natural fibers he was used 0.5%,1%,1.5% in concrete with aspect ratios of 30,60,90. He gives relation compressive strength, flexural strength and split tension for bagasse reinforced concrete. **Reis, Ferreira (2006):** were reported that the chopped sugarcane fibers increase the fracture properties-both fracture toughness and fracture energy of concrete**. S**ugarcane fibers slightly increases flexural strength (3.5 %). David Stephen was used 1%, 2% and 3% of sugarcane fibers in cement mortar. He said that the dry bagasse fibers float on water indicating a bulk density of less than one. An approximate value of 0.5 (considered adequate for preliminary purposes) was eventually found by using a density bottle. and he studied that the standard slump cone test gave slumps ranging from 80mm for the unreinforced mix down to 35mm for the mix with 3 percent fibers. He tested compressive strength, tensile strength and impact resistance for 14,42,56,84 days for air-cured as well as water-cured cubes. Compressive strengths are 1.34, 1.37, 1.32, 1.27 for 0%, 1%, 2%, 3% respectively. Impact resistance values are 5.67, 10.3, 12.0, 16.0 and the percentage for plain concrete is 81,211,282 for 1%,2% and3% respectively. (a) Water cured 14 day strength 0.23, 0.25, 0.17, 0.17. 42 day strength 0.32 0.36, 0.15, 0.21. 56 day strength 0.32, 0.32, 0.19, 0.2. 84 day strength 0.40, 0.38, 0.24, 0.23 (b) Air cured 14 day strength 0.23, 0.34, 0.15, 0.19. 42 day strength 0.29, 0.41, 0.20, 0.18. 56 day strength 0.29, 0.39, 0.20, 0.17.84 day strength 0.32, 0.41, 0.23, 0.21 for 0,1,2,3% respectively. According to this thesis, air-cured cubes are stronger than water-cured cubes for bagasse fibers Control (1.41 N/mm2). The tensile strength also reduces as the fiber content is increased beyond the optimum. The flexural strength results indicate that the addition of bagasse fiber increased the flexural strength of the concrete mass by up to 56.2% 9 (i.e. from 0.747N/mm2 to 1.167N/mm2) at 2% bagasse fiber content (for 28days). This is the same as was for 2% coir fiber. It is seen that at 7 days of age the optimum fiber content is seen to be 2%. We use the optimum of 1% as concrete is assumed to attain its highest strength at 28 days of curing. Just as discussed above, additional fiber increases flexural strength up to the optimum.

Bhatia studied the usefulness of fiber reinforced concrete in various civil engineering applications. Fibers include steel fiber, natural fibers and synthetic fiber search which lend varying properties to the concrete. The study revealed that the fibrous material increases the structural integrity. **Chouw et al.** studied the viability of using coconut-fiber ropes as vertical reinforcement in mortar-free low-cost housing in earthquake prone regions. The rope anchorage is achieved by embedding it within the foundation and top tie beams. The bond between the rope and the concrete plays a crucial role in the stability of the structure and the rope's lastingness is additionally found to be fairly high. The rope tension generated due to earthquake loading should be less than both the pull-out force and the rope tensile load to avoid structure collapse. The study concluded that the pull-out energy increases with an increase in embedment length, rope diameter, cement and fiber content in the matrix. **Li et al**, studied fiber volume fraction by surface treatment with a wetting agent for coir mesh reinforced mortar using non-woven coir mesh matting. They performed a four-point bending test and concluded that cementitious composites, reinforced by three layers of coir mesh with a low fiber content of 1.8%, resulted in a 40% improvement in flexural strength compared to conventional concrete. The composites were found to be 25 times stronger in flexural toughness and about 20 times higher in flexural ductility. (**Kelleret al., 2005)** investigated the shear behavior of ferroconcrete beams strengthened by the attachment of various configurations and quantities of carbon fibers. The study revealed that the strengthening by using carbon fibers increased the resistance to shear and also spalling of concrete.

Shreeshail. B.H, (2014) conducted a study on concrete reinforced with coir fiber. The coir fibers of different proportions and lengths are studied. The proportions of 1, 2, 3 and 4 % weight of cement and length of 1.7 and 2.8 cm were used and considered the mix design of M30. From the study, it was concluded that 1% and 3% coconut fiber has given lesser compressive strength when compared to 2%. The higher fiber content in CFRC might have caused voids resulting in decreased compressive strength. **Thandavamoorthy (2013)** conducted a study on concrete reinforced with steel fiber (4%), polypropylene fiber (4%) and hybrid fiber that enclose (2% steel fiber and 2% polypropylene fiber). The results of those fibers were compared with standard concrete. The test results showed that the addition of steel and polypropylene fibers to concrete reveals better concert. Results of the water absorption test for SFRC and hybrid specimens were the same as that of normal concrete. But in the case of polypropylene fiber reinforced concrete, it was 4% booster than normal concrete. **Venkat Rao et al (2013)** carried out an investigational study on the durability of high-strength self-compacting concrete (HSSCC). The sulphate attack effect on concrete and confrontation of concrete to the attack had been experienced in the laboratory, by immersing specimens of concrete cubes in the solution which encloses 5% sodium sulphate. The chemical attack effect had been estimated by the taking adjustment of mass into consideration. The sulphate attack effect on the performance and properties of concrete were acknowledged. Even from the optical surveillance, the intensity of sulphate attack on cracking and the impact of breakdown was noticed. **Srinivasa Rao (2012)** investigated the durability studies on glass fiber reinforced concrete (GFRC). The results showed that there was an increase in the durability of the concrete by adding together these glass fibers in concrete. The addition of glass fibers in concrete gave a reduction in bleeding, and also enhanced the resistance of concrete to the assault of acids. Maximum improvement in durability of concrete with different percentages of glass fibers was observed at 28 days and 90 days at 0.1% for all grades of concrete. **Vijaya Sekhar Reddy et al (2012)** conducted studies on the test specimens of 15 cm x 15 cm x15 cm cubes were immersed in 5% of sodium hydroxide solution over a period of 90 days. The effect of alkali attack on performance and properties of concrete were found out. The percentage decrease in weight after 28 days was found to be 10.32%. **Desai et al (2012)** conducted a study on the durability properties of fiber reinforced concrete on marine structures. In this study, the properties of fiber reinforced concrete were compared with those of conventional concrete and also its environmental effects on the durability of concrete. Results showed that the addition of polypropylene triangular fibers improved the durability of concrete. The compressive strength of concrete increases with an increase in fiber dosage up to 0.3%, then it starts diminishing. So the best possible percentage of fiber found from the experiment was 0.3%. **Kokseng Chia et al (2002)** accomplished an investigational study on the water permeability and chloride permeability of high strength lightweight concrete (LWC) in comparison to that of normal strength concrete with or without silica. Results were compared with LWC and NWC (Normal Weight Concrete) at a normal strength of about 30- 40MPa. The water penetrability of the LWC with a w/c of 0.55 was lower than that of the equivalent NWC, when the concrete was subject to a pressure of 4 MPa when the strength level reached 30-40 MPa. The water penetrability of the high-strength LWC and NWC with a w/c of 0.35 was of the same order regardless of whether silica fume was incorporated. The results point out that the resistance to the chloride dissemination does not seem to be concurrent to the water permeability of the concrete. **Dr. M. Sivaraja et al (2009)** accomplished an investigation and concluded that the fibers recovered from the various waste stream are suitable to use as secondary reinforcement in concrete. The advantage of using such rural fibers provides generally a low cost construction than using virgin fibers and the elimination of the need for waste disposal in landfills. **Izad Amir Bin Abdul Karim et al (2012):** made a study on coconut fibers. They stated that coconut fibers have in chemical composition although lignin content is higher and cellulose content is lower. The use of coconut waste from the disposal of coconut fibers could be a useful material in the formation of an admixture for housing construction. Therefore, an in-depth study will be made to ensure the appropriate use of coconut waste such as coconut fibers by conducting some experiments so as to obtain good results. **Yalley, P. P. and Kwan et al (2008)** The Addition of coconut fibers improve the properties of concrete, notable torsion, toughness and tensile strength. The ability to resist cracking and spalling were also enhanced. However, they concluded that the addition of fibers adversely affects the compressive strength due to difficulties in compaction which consequently led to increasing in voids.

3. PROPOSED SYSTEM

The CocoCrete system focuses on enhancing the mechanical properties of M60 grade concrete using coconut fiber reinforcement as a sustainable alternative to conventional reinforcement methods. This system aims to improve tensile strength, ductility, and impact resistance while promoting eco-friendly construction by utilizing natural fibers.

1. Materials and Mix Design

- **Cement:** Ordinary Portland Cement (OPC) is used as the primary binder.
- Fine and Coarse Aggregates: Conventional aggregates are used to maintain structural integrity.
- **Coconut Fiber Reinforcement:** Coconut fibers are added at varying percentages (1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, and 5% by weight of cement) to evaluate their effect on strength properties.
- **Water-Cement Ratio:** Optimized to maintain workability while ensuring proper bonding between fibers and cement matrix.
- **Admixtures:** Superplasticizers are incorporated to enhance workability and fiber dispersion.

2. Workability Assessment (Slump Test)

The slump test is performed to assess the workability of CocoCrete at different fiber content levels. As fiber percentage increases, workability decreases due to fiber absorption and entanglement, requiring adjustments in the mix design to balance flow ability and strength.

3. Hardened Properties Evaluation

Compressive Strength Test:

Concrete cubes (15 cm × 15 cm × 15 cm) are cast and tested at 7, 14, and 28 days to analyze compressive strength development.

Results indicate a slight reduction in compressive strength with increasing fiber content due to the lower density of coconut fibers. However, optimized fiber percentages provide adequate strength for structural applications.

Tensile Strength Test:

Cylindrical specimens are tested to evaluate the enhancement in tensile strength due to fiber reinforcement.

Results show a significant improvement in tensile strength, especially at 3% to 4% fiber content, demonstrating the fibers' effectiveness in crack resistance and load distribution.

Flexural Strength Test:

Beam specimens are tested for bending strength to determine the impact of fiber reinforcement on flexural performance.

Improved flexural capacity is observed, with optimal reinforcement enhancing ductility and crack resistance.

4. Key Findings

- **Optimal Performance:** 3% to 4% coconut fiber provides the best balance of compressive, tensile, and flexural strength.
- **Workability Reduction:** Higher fiber content reduces workability, necessitating superplasticizer adjustments for better mix performance.
- **Enhanced Tensile Strength:** Coconut fiber reinforcement significantly improves tensile and flexural properties, making CocoCrete suitable for load-bearing applications.
- **Sustainability Impact:** Utilizing natural coconut fibers reduces reliance on synthetic reinforcements, promotes waste utilization, and lowers CO_2 emissions, making CocoCrete an eco-friendly alternative for modern construction.

4. RESULTS AND DISCUSSIONS

Slump Test is conducted for a various concrete mixes containing coconut fiber. The study on slump test helps us to know the amount of water required to obtain a concrete mix with good workability. The slump value for concrete with 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5% and 5% coconut fiber. The test results given in below table 5.1.

Table 4.1: Slump cone test

Cocounut fiber(%)	**Slump (mm)**
Control mix	120
1	110
1.5	105
2	98

2.5	93
3	85
3.5	82
4	78
4.5	72
5	70

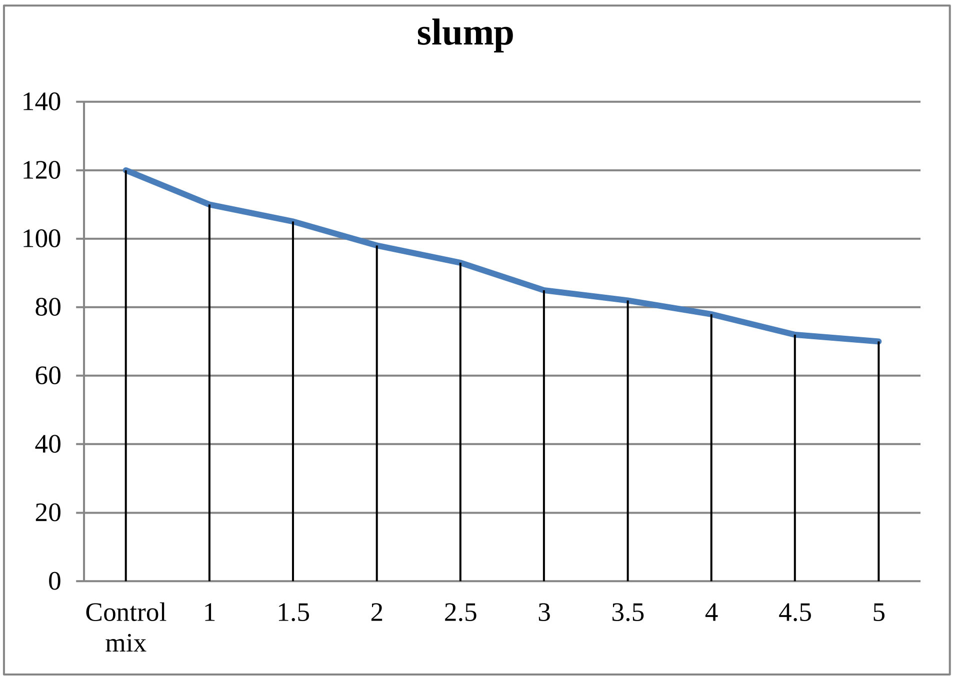

Fig 4.1: Slump test

The control mix has a slump value of 120 mm. It is observed that concrete with increasing percentages of coconut fiber has decreasing slump value. Thus, lesser the amount of coconut fiber better will the workability.

4.2 Harden properties of concrete

4.2.1 Cubes Compressive strength

Compressive strength tests were conducted on standard cubes of dimension 15cm x 15cm x 15cm specimens each for plain concrete and coconut fiber reinforced concrete were cast at varying percentages of fiber (1%, 1.5%, 2% 2.5%, 3%, 3.5%, 4%, 4.5% 5%). For each combination of coconut fiber addition in concrete, nine specimens were tested.

Table 4.2: Cubes Compressive strength (N/mm^2)

Coconut fiber (%)	**7days**	**14days**	**28days**
Control mix	41	56.1	62.1
1	43	58.2	64.8
1.5	46	59.5	65.8

2	44	57	63.5
2.5	40	52	61.72
3	35	49.2	58.2
3.5	31	45.64	54
4	28	42.34	51.8
4.5	25.3	36.2	48.45
5	20	32.84	45

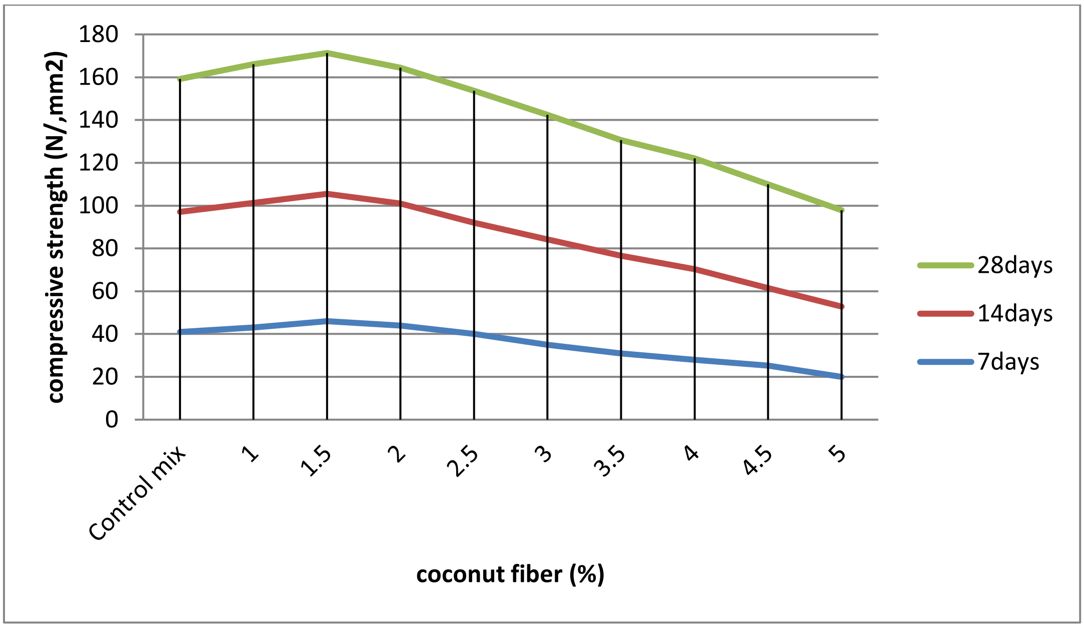

Fig 4.2: Cubes Compressive strength

5. CONCLUSIONS

The CocoCrete system successfully demonstrates that coconut fiber reinforcement enhances the mechanical properties of M60 grade concrete, particularly in terms of tensile and flexural strength, while maintaining adequate compressive strength. Experimental results show that an optimal fiber content of 3% to 4% provides the best balance between strength, durability, and workability, improving crack resistance and ductility. Although increased fiber content reduces workability, proper mix adjustments can mitigate this effect. By integrating natural and sustainable materials, CocoCrete not only reduces reliance on synthetic reinforcements but also promotes eco-friendly construction, making it a viable and sustainable alternative for modern infrastructure.

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