RESEARCH ARTICLE OPEN ACCESS

Performance Evaluation of Coconut Fiber-Reinforced Concrete with Waste Marble Aggregate Replacement

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ABSTRACT
Fibrous concrete (FRC) is a type of concrete that contains fibrous material. The structure and weight of this fibrous material continues to grow. Contains discrete short fibers evenly distributed and randomly oriented. The concept of using fibers for reinforcement is not new. Fiber-reinforced concrete can provide a convenient, practical and cost-effective way to overcome micro-cracks and similar imperfections. Due to the weakness of the concrete, certain measures must be taken to compensate for this defect.In this study, volumetric variation of fibers used varied as 0%, 1.5% and 3% by weight of cement fine & coarse aggregate. And replace the coarse aggregates with waste marble pieces as 0%, 5%, 10% and 15%. Although fiber used in this hybrid-reinforced concrete is coconut fiber.For each combination of concrete components, we tested the mechanical properties of with 48 mix proportions M-25, M-30, M-35, M-40 concrete. We tested cubes found that adding coconut fiber as fiber reinforcement improves the different properties and strengths of the concrete. A slump test was carried out on each fresh mix to determine the workability of the mixed fiber-reinforced concrete.The expected result, i.e. the strength of mixed fibrous hybrid-concrete, is greater than that of ordinary concrete. Therefore, more research is needed through specific adjustments to methods and materials.
Keywords —Coconut Fiber, Waste Aggregates, Sustainable Concrete, Mechanical Properties, Recycled Materials, Eco-Friendly Construction.

I. INTRODUCTION

Concrete is the most widely used synthetic construction material in the world. It is produced by mixing cementitious materials, water, aggregates, and sometimes chemical or mineral admixtures in appropriate proportions. Fresh or plastic concrete is the workable mixture that can be molded into any desired shape and, upon hardening, transforms into a solid, stone-like material. This hardening is the result of a chemical reaction between cement and water known as hydration, which continues over time and contributes to increased strength as the concrete ages.

Traditionally, in the first half of the 20th century, concrete structures were built using Ordinary Portland Cement (OPC) and low-carbon round steel bars, emphasizing ease of use over performance. Over time, with advances in engineering knowledge and materials science, concrete design has evolved to prioritize both aesthetics and durability.

Fiber-reinforced concrete (FRC) is a modern advancement that incorporates fibrous materials into the cementitious matrix. These fibers are short, discrete, and randomly distributed throughout the mix, enhancing the structural integrity of the concrete. The concept of using fibers for reinforcement is not new historically; asbestos fibers were used in concrete in the early 20th century. However, due to significant health concerns, asbestos has been replaced by safer alternatives such as steel, glass, synthetic, and natural fibers.

Fibers are small, reinforcing elements with specific properties that influence the mechanical behavior of concrete. The type, length, aspect ratio, and volume fraction of fibers play a critical role in determining their effectiveness. Since concrete is inherently brittle and has low tensile strength, the addition of fibers improves its ductility, toughness, and resistance to cracking, making it more suitable for high-performance construction applications.

II. METHODOLOGY

3.1. Concrete and Its Testing

Concrete is a composite material made from cement, sand, water, and aggregates (fine and coarse). It may also contain admixtures and additives for enhanced performance. Types include reinforced, pre-tensioned, post-tensioned, precast, lightweight, ready-mix, pump, rapid-hardening, and glass concrete.

Water-Cement Ratio plays a critical role in determining strength, workability, durability, and heat resistance.

Common Concrete Tests

Slump Test: Measures workability. A cone-shaped mould (20 cm top dia, 10 cm bottom dia, 30 cm height) is filled in layers, tamped, and the slump measured in mm.

Compressive Strength Test: Involves casting concrete cubes (70.6 mm), curing them, and applying load until failure to determine strength in N/mm².

Ultrasonic Pulse Velocity (UPV) Test: Evaluates internal concrete quality by measuring the velocity of an ultrasonic pulse through the specimen.

Rebound Hammer Test: Assesses surface hardness and relative compressive strength by measuring the rebound number from a spring-driven hammer impact on the surface.

These tests help in evaluating concrete consistency, strength, durability, and quality before and after placement.

3.2 Cement and Its Testing

Cement is a fine powder used as a binding material in construction. When mixed with water, it undergoes hydration, forming a hard, durable matrix that binds aggregates. The most commonly used type is Ordinary Portland Cement (OPC). For this study, JK Laxmi OPC 43 grade cement was used.

Types of Cement:

- **Hydraulic Cement:** Sets under water (e.g., OPC)
- **Masonry Cement:** Used in mortars
- **Oil-Well Cement:** Specialized for oil well linings
- **Rapid Hardening Cement:** Quick setting and high early strength
- **Slag Cement:** Made from granulated blast furnace slag

Common Tests Conducted on Cement:

Fineness Test: Measures particle size using a 90-micron sieve. The percentage retained indicates fineness.

Consistency and Setting Time Test (Vicat Apparatus): Determines Initial Setting Time (start of stiffening) and Final Setting Time (end of setting).

Compressive Strength Test (Mortar Cubes, 70.6 mm): Determines cement strength after curing (typically 7 and 28 days).

3.3 Aggregate

Aggregates are key constituents in concrete, providing volume, stability, and resistance to wear and impact. Coarse aggregates are typically retained on a 4.75 mm IS sieve and evaluated as per IS: 2386-1963 for properties like crushing strength, impact resistance, water absorption, specific gravity, and durability. Several standard tests assess aggregate quality. The Aggregate Crushing Value Test measures resistance to compressive loads, while the Impact Value Test evaluates aggregate toughness under sudden shocks. The Los Angeles Abrasion Test determines wear resistance through rotational impact with steel balls. The Specific Gravity and Water Absorption Test helps assess density and porosity, influencing concrete mix design. Finally, the Soundness Test evaluates aggregate durability against weathering cycles using sodium or magnesium sulfate solutions. These tests ensure aggregates used in construction meet required strength, durability, and performance standards.

III. RESULTS AND DISCUSSION

In this section of research the results of experimental work. The results are displayed in graph and tabular format. Results will vary for cement, coarse aggregate and concrete.

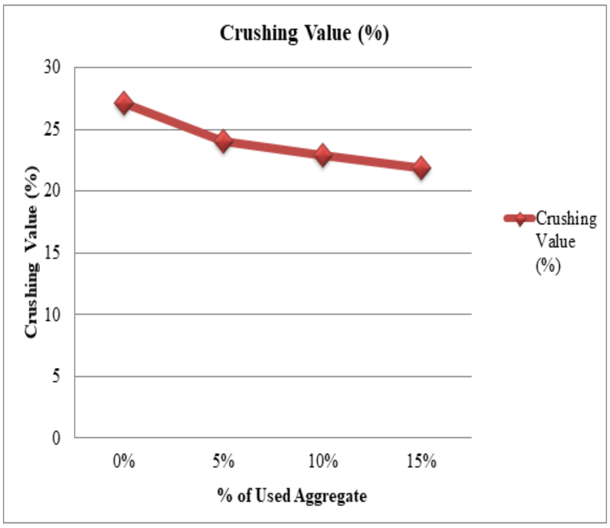

Figure 1: Crushing Test of Aggregate Due to Replacement of Marble Aggregates

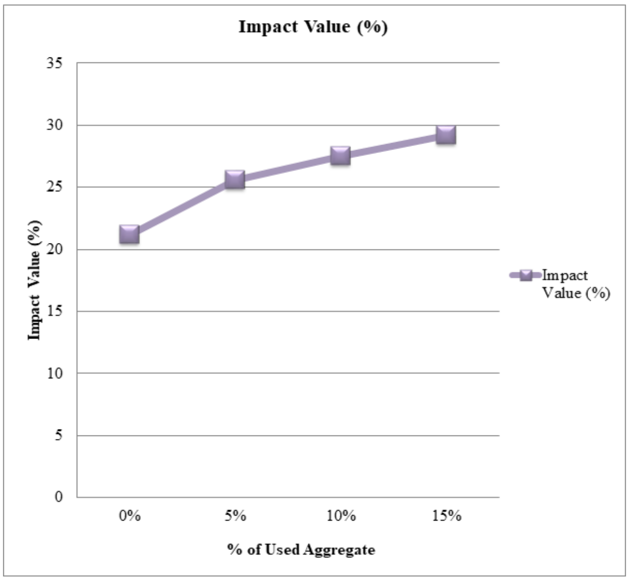

Figure 2: Impact Test of Aggregate Due to Replacement of Marble Aggregates

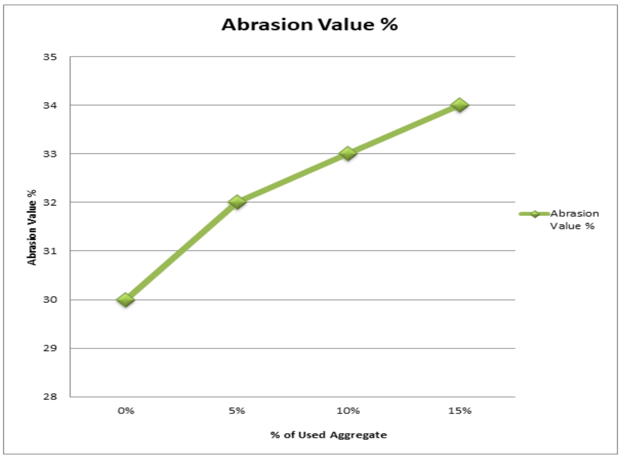

Figure 3: Abrasion Test of Aggregate Due to Replacement of Marble Aggregates

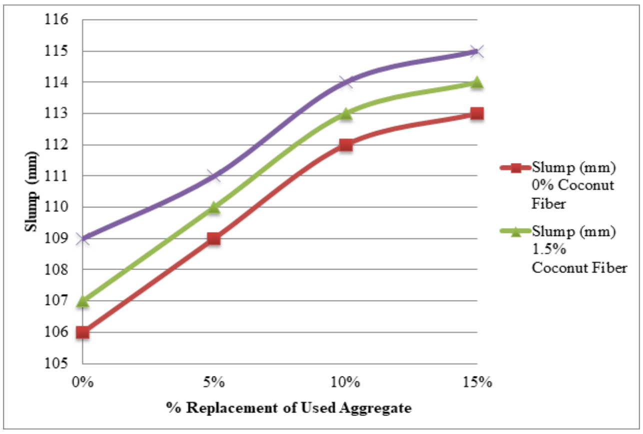

Figure 4: Slump Test for 0%, 1.5% and 3% Replacement of Cement with Coconut Fiber and Varying % of Aggregate replacement with Marble Aggregate

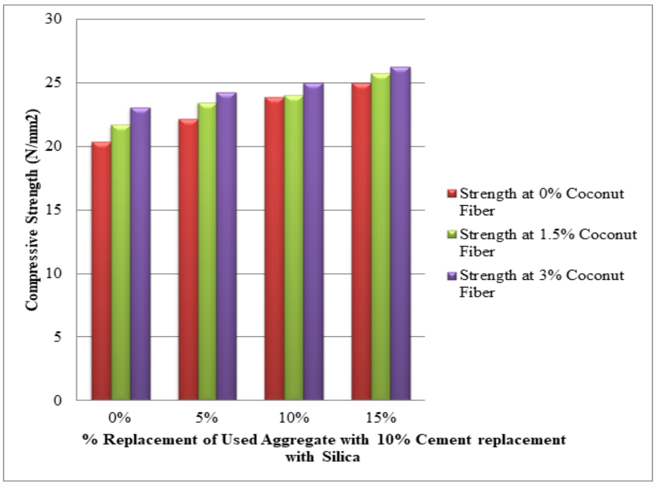

Figure 5: Compressive Strength for Varying % Addition of Coconut Fiber and Varying % of Aggregate replacement with Marble Aggregate At 7Days

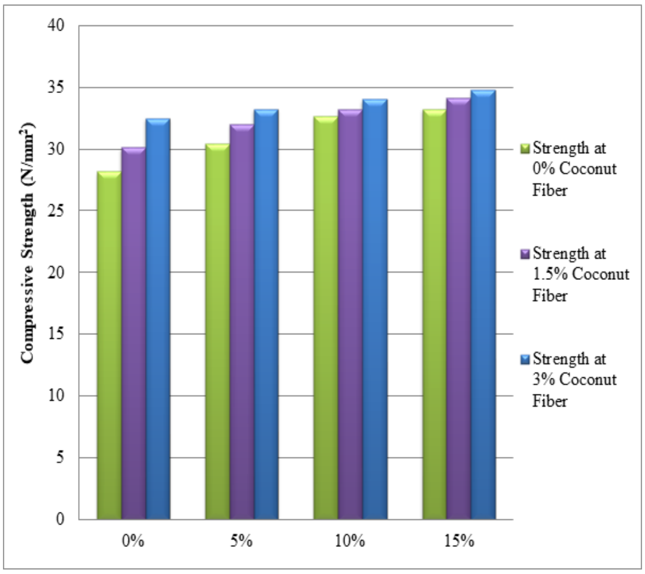

Figure 6: Compressive Strength for Varying % Addition of Coconut Fiber and Varying % of Aggregate replacement with Marble Aggregate At 28Days

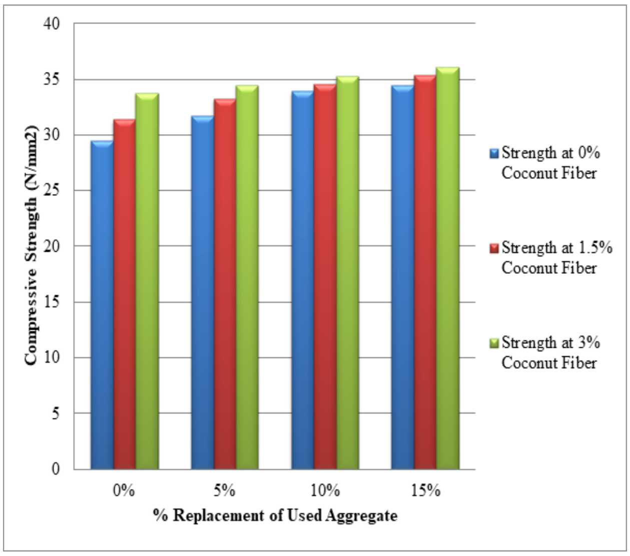

Figure 8: Rebound Hammer Test for 0%, 1.5% and 3% Replacement of Cement with Coconut Fiber and Varying % of Aggregate replacement with Marble Aggregate

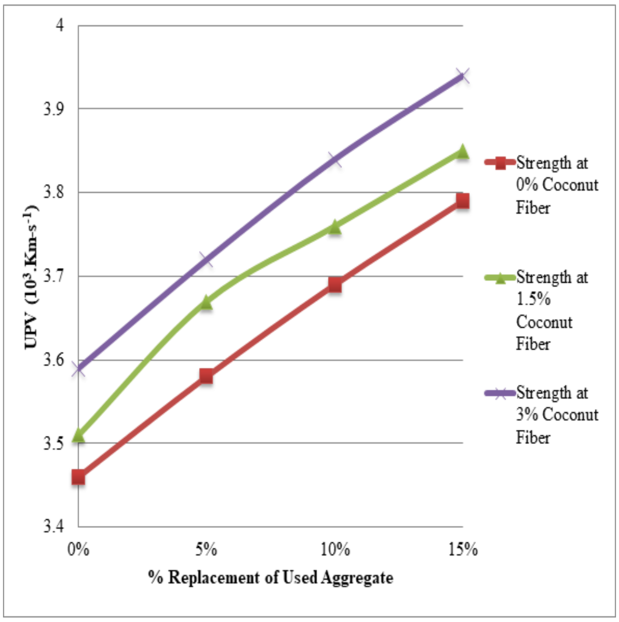

Figure 7: Ultra Sonic Pulse Test for 0%, 1.5% and 3% Replacement of Cement with Coconut Fiber and Varying % of Aggregate replacement with Marble Aggregate

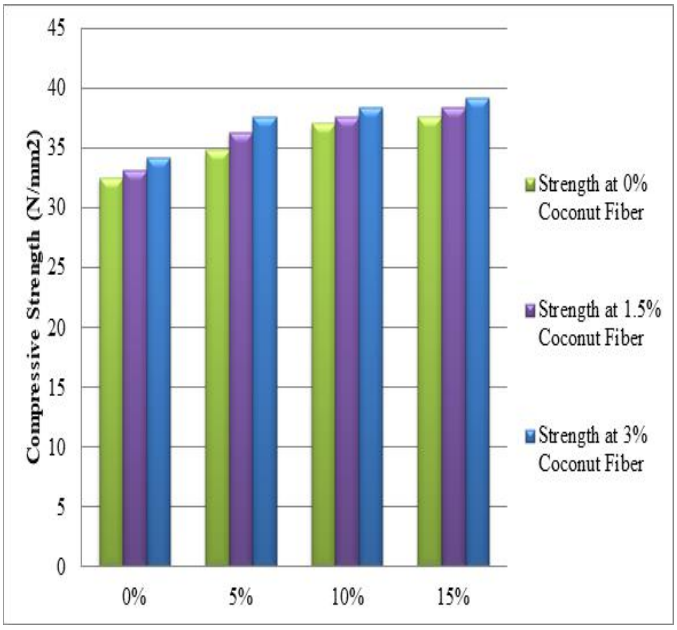

Figure 9: Compressive Strength for Varying % Addition of Coconut Fiber and Varying % of Aggregate replacement with Marble Aggregate At 28 Days

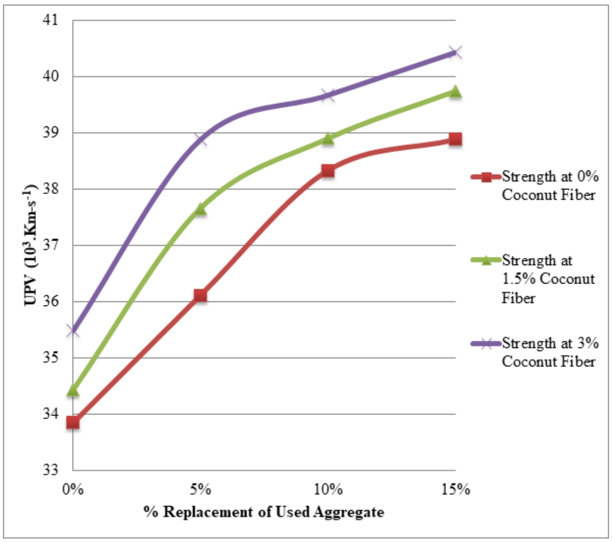

Figure 10: Ultra Sonic Pulse Test for 0%, 1.5% and 3% Replacement of Cement with Coconut Fiber and Varying % of Aggregate replacement with Marble Aggregate

IV. CONCLUSIONS

This experimental study investigated the combined effect of coconut fiber reinforcement and partial replacement of coarse aggregates with waste marble pieces on the mechanical properties of concrete. The results indicate that incorporating coconut fiber at 1.5% and 3% (by weight of cement) significantly improved the compressive strength, workability, and durability of the concrete when compared to conventional mixes. Additionally, the partial replacement of coarse aggregates with marble waste (up to 15%) further enhanced concrete performance, making it more sustainable and eco-friendly.

The slump test showed a decrease in workability with higher fiber content, as expected, but remained within acceptable limits for structural applications. The compressive strength tests at both 7 and 28 days demonstrated considerable improvement with fiber addition, especially at 1.5% fiber and 10% marble replacement levels. The ultrasonic pulse velocity (UPV) and rebound hammer tests confirmed better internal quality and surface hardness for fiber-reinforced mixes. Aggregate tests, including crushing, impact, and abrasion, also showed acceptable performance with marble aggregate replacement.

Overall, the hybrid use of coconut fiber and waste marble aggregates presents an effective, sustainable solution to enhance concrete properties while promoting the reuse of industrial waste materials. Further research can focus on optimizing fiber length, aspect ratio, and marble replacement percentages to achieve even better performance for specific structural applications..

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