Experimental Investigation on Application of Coconut Fibre and Glass Fibre in Reinforced Concrete

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Abstract - This research presents an experimental investigation on the mechanical and durability properties of fibre-reinforced concrete using coconut fibre (CF) and glass fibre (GF) in M15, M20, and M25 grade concrete. The study aims to evaluate the effectiveness of natural and synthetic fibres in enhancing the performance of conventional concrete. Coconut fibre, being eco-friendly and sustainable, and glass fibre, known for its high tensile strength and durability, are incorporated in varying proportions of 5%, 10%, and 15% by weight (or volume, as applicable). A series of tests were conducted, including compressive strength, split tensile strength, flexural strength, and water absorption, at curing periods of 7, 14, and 28 days. Standard cube, cylinder, and beam specimens were prepared and tested as per relevant IS codes. The experimental results were compared with control concrete to assess the improvement in strength and durability characteristics. The findings indicate that the addition of fibres significantly influences the mechanical behavior of concrete. An optimum fibre content was observed at intermediate percentages (typically around 5–10%), beyond which workability decreased and strength gains were not proportionally significant. Coconut fibre improved crack resistance and ductility, while glass fibre enhanced tensile and flexural strength. However, excessive fibre content (15%) led to reduced workability and possible fibre clustering. Overall, the study demonstrates that both coconut fibre and glass fibre can be effectively used as reinforcing materials in concrete, contributing to improved performance and sustainability. The results provide valuable insights for the development of cost-effective, durable, and eco-friendly construction materials.

Key Words: Coconut Fibre and Glass Fibre

1.INTRODUCTION

Concrete is the most extensively used engineered construction material worldwide, with global production exceeding 10 billion tonnes annually. Its dominance stems from its unrivalled combination of compressive strength, mouldability, fire resistance, availability of raw materials, and relatively low cost. However, as the construction industry confronts mounting pressures related to resource depletion, energy consumption, and carbon emissions, there is an imperative to develop concrete technologies that are not only structurally effective but also environmentally responsible and economically accessible, particularly in the context of developing nations like India.

Two significant limitations of conventional plain concrete are its low tensile strength — typically only 8–12% of its compressive strength — and its brittle failure mode. These drawbacks necessitate heavy steel reinforcement in most structural applications. The concept of fiber reinforced concrete (FRC) addresses these limitations by incorporating short discrete fibers into the concrete matrix. Randomly distributed fibers act as crack arresters, bridging cracks as they form and propagating, thereby transforming brittle failure into a more progressive, ductile mode. The result is improved tensile strength, flexural strength, toughness, impact resistance, and fatigue performance.

While synthetic fibers such as steel, polypropylene, and glass are widely used in FRC, they carry significant cost and environmental burdens. Natural plant-derived fibers — particularly those derived from agricultural by-products — present a compelling sustainable alternative. Among these, coconut (coir) fiber stands out for its exceptional availability in India, its remarkable natural toughness, and its resistance to biodegradation owing to its high lignin content

2. METHODOLOGY

2.1.Material Used

2.1.1.Cement

- **Composition**
  - Clinker (Main binding material)
  - Gypsum (For setting time control)
  - Pozzolanic materials (Fly ash, silica fumes, or volcanic ash)
- **Properties**
  - Higher durability due to reduced permeability.
  - Lower heat of hydration, reducing the risk of cracks in large structures.
  - Improved workability, making it easier to use in plastering and masonry work.
  - Increased resistance to chemical attacks, making it ideal for marine and sulfate-prone areas.

- **Grades Available**
  - PPC does not have specific grades like OPC (33, 43, 53), but its strength is generally comparable to OPC 33 or 43 grade.
- **Advantages**
  - **Eco-friendly :** Reduces carbon footprint due to the use of industrial byproducts like fly ash.
  - More economical than OPC.
  - Better long-term strength development compared to OPC.
- **Uses**
  - **Residential & Commercial Construction :** Houses, offices, and other buildings
  - **Dams & Bridges :** Due to its resistance to chemical attacks
  - Roads & Pavements
  - **Marine & Sewage Systems :** Due to its sulfate resistance

2.1.2.Coarse Aggregate

- **Physical Properties**
  - **Size & Shape**
    a. **Size :** Commonly used sizes are 10 mm, 20 mm, and 40 mm.
    b. **Shape :** Rounded, angular, flaky, or elongated. Angular aggregates provide better interlocking in concrete.
  - **Specific Gravity**
    Typically ranges between 2.5 - 2.9, depending on the type of rock.
  - **Bulk Density**
    Varies between 1200 - 1750 kg/m³.
  - **Water Absorption**
    Should be less than 2%; excessive absorption can impact concrete mix design.
  - **Porosity & Permeability**
    High porosity leads to water retention, affecting the strength of concrete.
- **Mechanical Properties**
  - **Strength**
    a. Must be strong enough to withstand crushing loads.
    b. **Common test :** Aggregate Crushing Value (ACV) should be ≤30% for concrete works.
  - **Hardness**
    Measured by the Los Angeles Abrasion Test. Should be ≤30% for road construction.
  - **Toughness**
    Determined by the Impact Value Test. Should be ≤45% for concrete work.
  - **Flakiness & Elongation**
    High flakiness or elongation affects workability and compaction. Flakiness & Elongation Index should be ≤15% for concrete.
- **Types of Coarse Aggregates**
  - **Crushed Stone Aggregate**
    a. Obtained by crushing hard rocks like granite, basalt, limestone.
    b. Commonly used in concrete, road construction, and railway ballast.
  - **Gravel**
    a. Naturally occurring rounded aggregate from river beds.
    b. Suitable for moderate-strength concrete.
  - **Recycled Concrete Aggregate (RCA)**
    a. Made from crushed old concrete.
    b. Environmentally friendly but requires quality control.
  - **Lightweight Aggregate**
    Pumice, expanded clay, or shale used for lightweight concrete applications.
- **Uses of Coarse Aggregates**
  - **Concrete Production :** Provides volume and strength in concrete.
  - **Road Construction :** Used as a base material for roads and highways.
  - **Railway Ballast :** Provides stability to railway tracks.
  - **Drainage & Filter Media :** Used in drainage systems to prevent water accumulation.

2.1.3.Fine Aggregate

- **Properties of Fine Aggregates**
  - Grain Size – Typically less than 4.75 mm and greater than 0.075 mm.
  - Shape & Texture – Can be rounded, angular, or flaky, affecting workability.
  - Specific Gravity – Ranges between 2.5 to 2.9, depending on the type.
  - Water Absorption – Generally between 0.1% to 2%, influencing mix design.
  - Bulk Density – Typically around 1400–1600 kg/m³.
  - Fineness Modulus – Indicates particle size distribution; generally between 2.2 and 3.2.
  - Silt & Clay Content – Should not exceed 3% (as per IS 383:2016).
- **Types of Fine Aggregates**
  - Natural Fine Aggregates
    a. River Sand – Naturally occurring, found in riverbeds; well-graded and commonly used in concrete and masonry.

b. Sea Sand – Found on seashores, not suitable for construction due to high salt content.
c. Pit Sand – Coarse sand collected from deep pits; angular and sharp, suitable for mortar.

- Manufactured Fine Aggregates
  a. Crushed Stone Sand (M-Sand) – Produced by crushing hard stones; an alternative to river sand in construction.
  b. Granulated Blast Furnace Slag Sand (GBFS Sand) – By-product of steel manufacturing, used in specialized construction applications.

➢ **Uses of Fine Aggregates**

- Concrete Production – Provides cohesion and improves workability.
- Plastering & Masonry – Used in wall plaster and brick/block construction.
- Road Construction – Used in asphalt and subgrade layers.
- Filling Material – Used for levelling and filling low-lying areas.

2.2.Mix Design

A series of mix designs were prepared with varying proportions of RHA and coconut charcoal to evaluate their effects. The mix was designed to maintain an optimal balance between strength and permeability.

Material	Conventional Concrete	Modified with Coconut Fiber	Modified with Glass Fiber
Cement	1	1	1
Coarse Aggregate	2 – 4	2 – 4	2 – 4
Fine Aggregate	1 – 2	1 – 2	1 – 2
Water-Cement Ratio	0.30 – 0.40	0.30 – 0.40	0.30 – 0.40
Coconut Fiber (% of Cement)	0	5% - 15%	0
Glass Fiber (% of Cement)	0	0	5% -15%

Table 1 : Mix Proportion

2.3.Water-Cement Ratio

A lower water-cement ratio (0.30 - 0.40) is used to maintain adequate workability while ensuring sufficient strength.

2.4.Mix Design Calculation

0.016 m^3 of pervious concrete with a target compressive strength of 15-25 MPa, the approximate quantities of materials are :

- **Cement :** 7 kg
- **Coarse Aggregate (10 mm) :** 21 kg
- **Fine Aggregate :** 10.5 kg
- **Coconut Fiber :** 0.7 kg
- **Glass Fiber :** 0.7 kg
- **Water :** 2.8 kg

4.5 Mixing Procedure

➢ **Dry Mixing :** Combine cement, Coconut Fiber, and aggregates uniformly.
➢ **Water Addition :** Gradually add water while mixing.
➢ **Mixing Duration :** 3-5 minutes until a uniform mix is achieved.
➢ **Casting :** Place the mix into moulds without excessive compaction.
➢ **Curing :** Water cure for at least 7-28 days for strength development.

3.RESULTS AND APPLICATIONS

Concrete

❖ Water Absorption test results for concrete M15 after curing for 7, 14 and 28 days :

Duration	Control Mix	CF (0.5 %)	CF (1 %)	CF (1.5 %)	GF (1 %)	GF (1 %)	GF (1.5 %)
7 Days	5.8	5.3	5.1	5.4	4.9	4.6	4.8
14 Days	5.5	5.0	4.8	5.1	4.6	4.3	4.5
28 Days	5.2	4.8	4.6	4.9	4.3	4.0	4.2

Table 2 : Water Absorption (%) after curing for 7, 14 and 28 days on Concrete (M15)

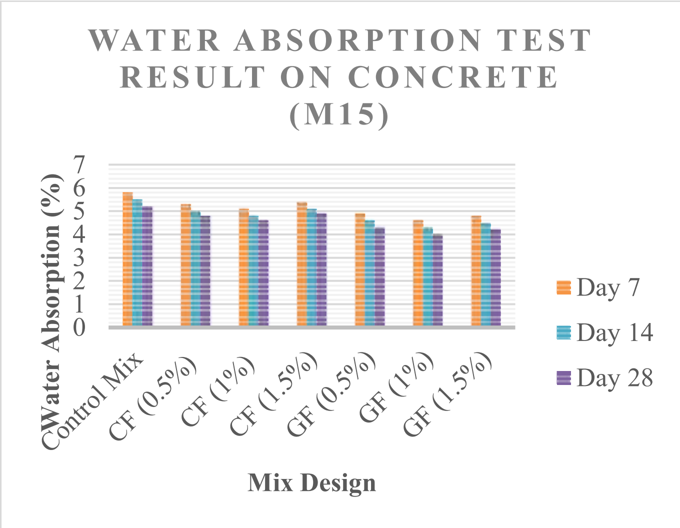

Figure 1 : Water Absorption (%) after curing for 7, 14 and 28 days on Concrete (M15)

❖ Water Absorption test results for concrete M20 after curing for 7, 14 and 28 days :

Duration	**Control Mix**	**CF (0.5 %)**	**CF (1 %)**	**CF (1.5 %)**	**GF (0.5 %)**	**GF (1 %)**	**GF (1.5 %)**
7 Days	5.1	4.7	4.5	4.8	4.3	4.0	4.2
14 Days	4.8	4.4	4.2	4.5	4.0	3.7	3.9
28 Days	4.6	4.2	4.0	4.3	3.8	3.5	3.7

Table 3 : Water Absorption (%) after curing for 7, 14 and 28 days on Concrete (M20)

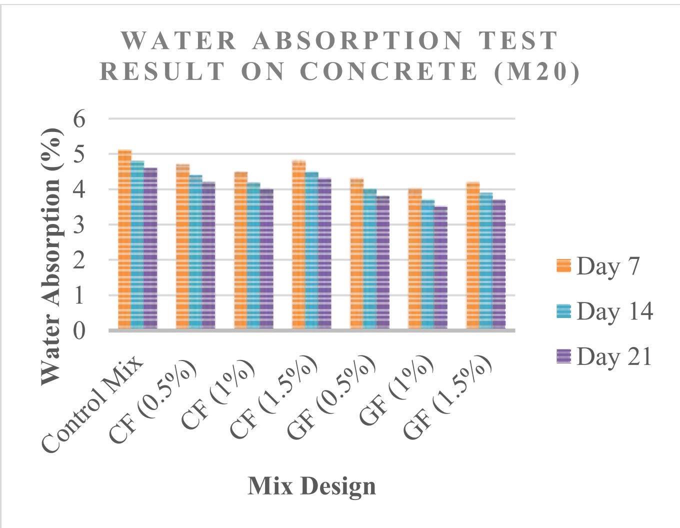

Figure 2 : Water Absorption (%) after curing for 7, 14 and 28 days on Concrete (M20)

❖ Water Absorption test results for concrete M25 after curing for 7, 14 and 28 days :

Duration	**Control Mix**	**CF (0.5 %)**	**CF (1 %)**	**CF (1.5 %)**	**GF (0.5 %)**	**GF (1 %)**	**GF (1.5 %)**
7 Days	4.6	4.2	4.0	4.3	3.8	4.2	3.7
14 Days	4.3	3.9	3.7	4.0	3.5	3.9	3.4
28 Days	4.1	3.7	3.5	3.8	3.3	3.7	3.2

Table 4 : Water Absorption (%) after curing for 7, 14 and 28 days on Concrete (M20)

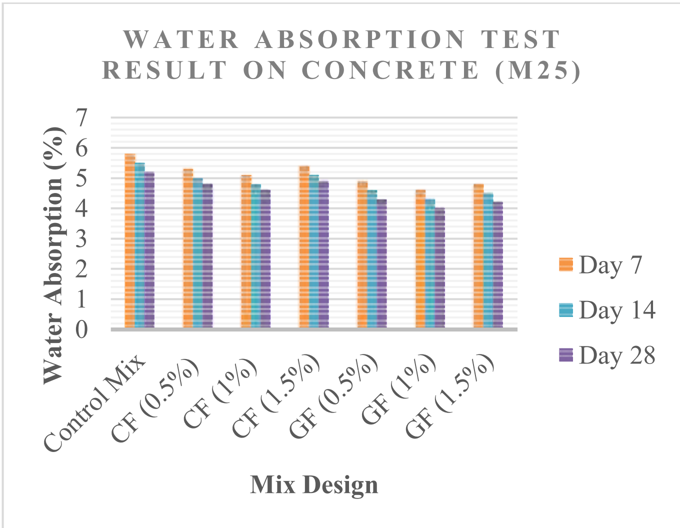

Figure 3 : Water Absorption Test Result on Concrete (M25) grade

5.2 Compressive Strength Test

- Compressive Strength test results for concrete M15 after curing for 7, 14 and 28 days :

Duration	**Control Mix**	**CF (0.5 %)**	**CF (1 %)**	**CF (1.5 %)**	**GF (0.5 %)**	**GF (1 %)**	**GF (1.5 %)**
7 Days	10.5	11.2	11.	11.0	11.5	14.	17.0

			8			5	
14 Days	13.2	14.0	14.8	13.8	12.2	15.5	18.5
28 Days	15.8	16.5	17.2	16.2	11.6	14.6	17.3

Table 5 : Compressive Strength (MPa) after curing for 7, 14 and 28 days on Concrete (M15)

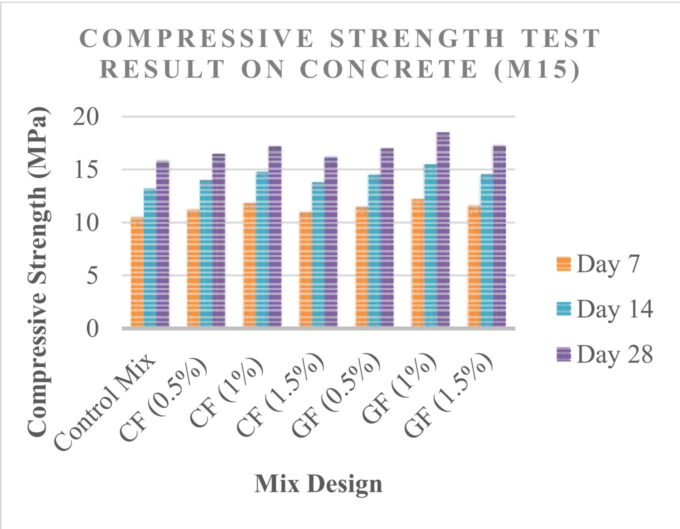

Figure 4 : Compressive Strength Test Result on Concrete (M15)

- Compressive Strength test results for concrete M20 after curing for 7, 14 and 28 days :

Duration	Control Mix	CF (0.5 %)	CF (1 %)	CF (1.5 %)	GF (0.5 %)	GF (1 %)	GF (1.5 %)
7 Days	14.0	15.0	15.8	14.8	15.5	16.5	15.6
14 Days	18.5	19.5	20.8	19.0	20.2	21.8	20.5
28 Days	21.5	23.0	24.5	22.8	24.0	26.5	24.8

Table 6 : Compressive Strength (MPa) after curing for 7, 14 and 28 days on Concrete (M20)

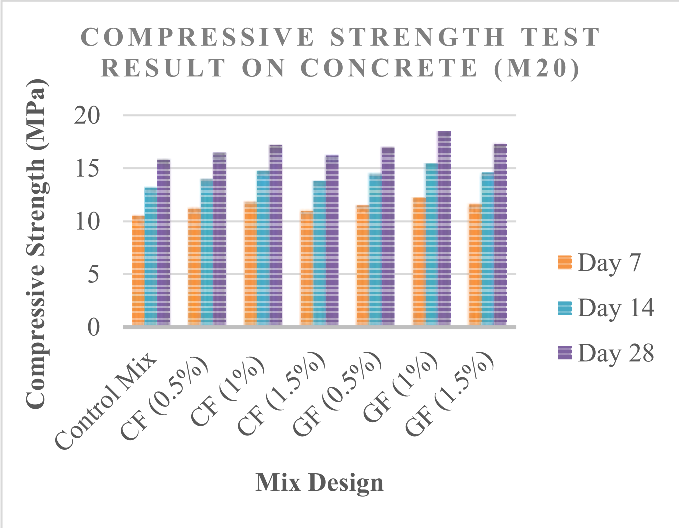

Figure 5 : Compressive Strength Test Result on Concrete (M20)

- Compressive Strength test results for concrete M25 after curing for 7, 14 and 28 days :

Duration	Control Mix	CF (0.5 %)	CF (1 %)	CF (1.5 %)	GF (0.5 %)	GF (1 %)	GF (1.5 %)
7 Days	17.5	18.8	19.8	18.5	19.5	21.0	20.0
14 Days	22.5	24.0	25.5	23.8	25.0	27.2	26.0
28 Days	26.8	28.5	30.2	28.0	29.8	32.5	30.5

Table 7 : Compressive Strength (MPa) after curing for 7, 14 and 28 days on Concrete (M20)

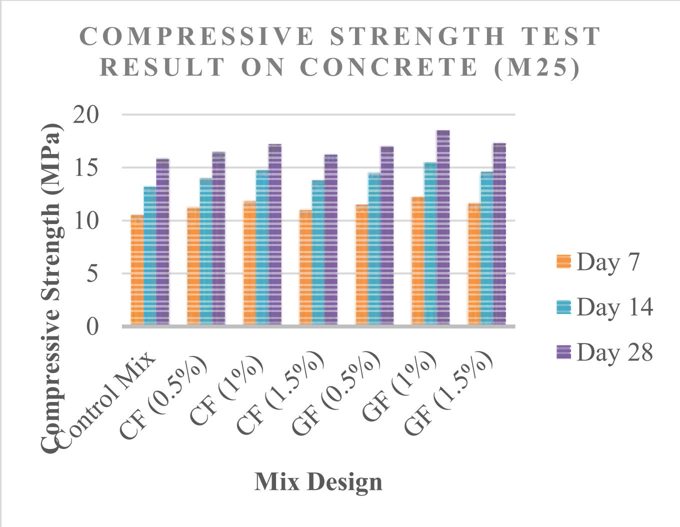

Figure 6 : Compressive Strength Test Result on Concrete (M25)

CONCLUSIONS

The study demonstrates that both Coconut Fibre and Glass Fibre can be effectively used as reinforcement materials in concrete. Glass Fibre is more suitable for strength and durability enhancement, while Coconut Fibre offers a sustainable and cost-effective alternative with improved ductility. For practical applications, a fibre content of around 10% is recommended to achieve an optimal balance between strength, durability, and workability.

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