

Performance Evaluation of Self Compacting Concrete with Hybrid Fibres at Varying Fibre Percentages

MD Sohail Pasha¹, Sharankumar S. Gobbur², Shivakumar Kalgi³,

Dr. Brijbhushan S.⁴, Dr. Maneeth P. D. ⁵, Samrudh Kamalapurkar⁶

¹ Postgraduate Student, Department of Civil Engineering, M.Tech. in Construction Technology
Visvesvaraya Technological University, Centre for Postgraduate Studies, Kalaburagi - 585105,
Karnataka, India.

^{2,3,4,5} Assistant Professor, Department of Civil Engineering, Visvesvaraya Technological University,
Centre for Postgraduate Studies, Kalaburagi - 585105, Karnataka, India.

⁶Research Scholar, Department of Civil Engineering, Visvesvaraya Technological University,
Centre for Postgraduate Studies, Kalaburagi - 585105, Karnataka, India

ABSTRACT

This study investigates the mechanical properties of fibres and evaluates the compressive strength of Hybrid Fiber Reinforced Concrete (HFRC) developed using Self-Compacting Concrete (SCC). The research focuses on the synergistic effect of combining glass and polypropylene fibres, aiming to enhance strength, durability, and crack resistance. A detailed review of composite materials, fibre properties, and hybridization concepts establishes the basis for experimental work. Standard tests, including slump flow, L-box, and compressive strength, were conducted on concrete specimens prepared with varying fibre dosages and curing periods. The results revealed that the incorporation of hybrid fibres improved workability, passing ability, and compressive strength, with optimum performance observed at 1.5% fibre addition. Glass fibres enhanced early strength and crack resistance, while polypropylene fibres contributed to toughness and reduced shrinkage cracks. The findings confirm that hybrid fibre reinforcement can significantly improve concrete performance, making it suitable for structural applications where strength, durability, and workability are critical. The study concludes by recommending further optimization of fibre content and curing methods to maximize efficiency and cost-effectiveness.

Keywords- Compressive strength, Hybrid fibre reinforced concrete, Self-Compacting concrete.

I.INTRODUCTION

1.1 Background on Composite Substances

One of the most common types of material is to compose important developments in modern engineering, offering a special set of characteristics that cannot be achieved by conventional metals or polymers alone [1]. They are created by fusing They differ in at least two ways. Materials, typically a matrix and a stage of reinforcement and form system with tailored mechanical and functional behavior [2]. The matrix, typically a ceramic, metal, or polymer serves to bind the reinforcement and transfer loads, and the reinforcing often as fibers provides stiffness, strength, and improved resistance to failure. Because of this synergy, composites are increasingly adopted in civil infrastructure, marine, automotive, and aerospace and defense applications [3].

Composites with a polymer matrix (PMCs) have experienced quick expansion Due of the excellent ratio of strength to weight, ease of fabrication and resistance to corrosion [4]. Their capacity to be customized for specific requirements makes them versatile in addressing structural, thermal, and environmental demands [5]. As industries strive for materials that combine strength with flexibility, polymers reinforced with fibers such as glass, carbon, aramid, and emerging alternatives like polyurethane (PU) fibers have become crucial [6].

1.2 Evolution of Fiber-Reinforced Composites

The development of fiber-reinforced composites (FRCs) has enabled engineers to achieve tailored material properties by selecting appropriate reinforcement [7]. For decades, glass fiber reinforced polymers (GFRPs) have dominated due to their cost-effectiveness, corrosion resistance, and reasonable strength. In contrast Carbon fibers

are stronger and stiffer but also far more costly, restricting their use to high-end aerospace or defense applications [8][9]. Aramid fibers like Kevlar provide outstanding impact resistance but suffer from poor UV resistance and moisture absorption[11].

The continuous search for fibers that provide a balance between strength, durability, toughness, and cost has led researchers to investigate new reinforcement materials. Among them, polypropylene fibers are gaining importance [12][13][14]. Polypropylene fibers exhibit excellent elasticity, toughness, and impact resistance, which are highly desirable in hybrid composites [15][16][17][18]. When combined with glass fibers, PU fibers can potentially overcome the brittleness of glass while retaining strength and reducing overall cost.

II. LITERATURE REVIEW

1. Suhad D. Salman, W.S. Wan Hassim, Z. Leman

This study used a static uniaxial compression test to experimentally examine two sets of hybrid composite materials. Kevlar and glass fiber made up the first group, while carbon and epoxy resin bonded with glass fiber made up the second. Four subsets of hybrid composite materials (A, B, C, and D) were included in each group. ASTM D695 was followed for performing the compression test, and. Every test was conducted five times. Glass fiber layers both at the top and bottom and carbon or Kevlar fiber layers in the middle of the specimens under compressive test were found to have more profound impacts than carbon or Kevlar fiber layers at the top and bottom of hybrid composites of the same kind. As opposed to the results of the group reinforced with Kevlar/glass fiber, The composite hybrid laminates with carbon/glass fiber for the same quantity of layers produced the maximum amount of compressive stress value, up to 40%.

2. P. Amuthakkannan, V. Manikandan and M. Uthayakumar

This study explains the mechanical characteristics of hybrid composites bonded with glass and basalt fibers developed by using compression moulding techniques. Woven Basalt fibers and Glass fibers were used for fabricating the hybrid composites, polyester resin as matrix with different fiber stacking sequences. The hybrid's mechanical characteristics composites like Flexural strength, Tensile strength and impact strength of the various specimens are calculated by using computer assisted Universal testing machine and Charpy Impact testing machine as per the ASTM standards. The result shows that it was discovered that the intermediate qualities between basalt glass fiber reinforced composites and the reinforcement of woven basalt and glass fiber hybrid composites significantly influenced the composites' mechanical properties.

3. Muhammad Md. Sanaul Rabbi, Sababa Erfan Moma, and Ed. Abdur Razzaq

To encourage the synergistic effect of both fibers' qualities on the composites' overall properties, hybrid composites use multiple types of strands within the same matrix. Artificial, natural, or a mix of the You can utilize two fibers. for hybridization. Numerous modifications to the constituent filaments can result in a range of composite qualities. a better mechanical performance than composites made entirely of natural fibers. Composites that are hybrid. The fibers used for hybridization can be natural, synthetic, or a combination of the two. A variety of composite properties can be produced by modifying the constituent filaments in a variety of ways. A higher mechanical performance than pure natural fiber composites is made possible by the partial replacement of natural fibers, which gives glass fiber composites an edge. Researchers have recently become interested in the development of hybrid composites with advantageous static properties. the most recent developments in composites reinforced with glass fiber and natural materials made by hand lay-up. It provides a summary of earlier research on hybrid composites that are currently accessible and discusses how various parameters affect the performance of composites that have been studied by various researchers

4. Muhammad Md. Sanaul Rabbi, Sababa Erfan Moma, and Ed. Abdur Razzaq

To encourage the synergistic effect of both fibers' qualities on the composites' overall properties, hybrid composites use multiple types of strands within the same matrix. Artificial, natural, or a mix of the two fibers can be used for hybridization. Numerous modifications to the constituent filaments can result in a range of composite qualities. When compared to glass fiber composites, partial replacement of natural fibers offers an advantage, allowing for a higher mechanical performance than that of pure natural fiber composites. The creation of hybrid composites with favorable static characteristics has recently drawn the attention of researchers. The latest advancements in natural/glass fiber-reinforced composites created using the hand lay-up process have been briefly reviewed in this context. It contains an overview of previous studies on hybrid composites and the impact of different parameters on the performance of composites that have been investigated by different researchers. It includes a survey of the past

research already available involving the hybrid composites and the effect of various parameters on composites' performance studied by various researchers.

5. Ishak, M. Sapuan, and M. Jawaid¹, SOTHMAN Y., M. Sapuan, and M. R. Ishak Alothman

The purpose of this study is to examine how glass fiber (GF) affects the thermal characteristics of hybrid composites made of sugar palm (SP) and thermoplastic polyurethane (TPU). Using melt-mixing compounding and a hot-pressing machine, sugar palm/glass fiber hybrid composites with various weight fractions of 0/40, 10/30, 20/20, and 30/10 were created. Hybrid composites' thermal characteristics were examined utilizing a dynamic mechanical analyzer (DMA) and thermo- a gravimetric analyzer (TGA), and the thermal properties of hybrid composites were examined. The modulus of storage (E'), loss modulus (End damping factor ($\tan \delta$)) was assessed in relation to various relative weight fractions of sugar palm and glass fiber. Additionally, the peak height for $\tan \delta$ curves was examined. The largest storage and loss modulus was found at larger loadings of glass fiber, whereas the lowest damping factor was found at higher loadings of sugar palm fiber. The amount of residue decreased as the glass fiber loading decreased, according to thermogravimetric analysis (TGA). In general, glass fiber hybridization with sugar palm/polypropylene composites improves the hybrid composites' thermal characteristics for use in automobiles.

III. PROBLEM STATEMENT AND OBJECTIVES

3.1 Problem Statement

Concrete, though widely used in construction, is inherently brittle and weak in tension, making it prone to cracking and reduced durability under varying load and environmental conditions. Traditional reinforcement methods often improve strength yet might not sufficiently address issues such as shrinkage cracks, impact resistance, and long-term serviceability. Single-fibre reinforcement provides only limited improvement, as every kind of fibre has its own advantages and drawbacks. Therefore, it is necessary to explore hybrid fibre reinforcement, where a mix of fibres such as glass and polypropylene can provide a balance of strength, toughness, and durability. However, limited experimental data and design guidelines are available on the mechanical performance and compressive strength of hybrid fibre reinforced self-compacting concrete (HFRC in SCC). This research aims to address these gaps by systematically evaluating the effect of hybrid fibres on fresh and hardened properties of concrete.

3.2 Objectives of the Research

- To investigate the impact of combining several kinds of fibers on the mechanical characteristics of HFRC in SCC
- To evaluate the compressive strength of the fabricated composites.
- To understand the way the SCC

IV. MATERIALS AND METHODOLOGY

4.1 Materials Used

4.1.1 Cement

Ordinary Portland Cement (OPC) of 53 grade is used as the primary binding material in this study.



Fig No. 4.1: OPC 53 Grade cement

4.1.2 Initial Setting Time

The period between the initial addition of water to cement and the point at which the paste starts to lose its fluidity and solidify is known as the initial setting time of cement. It is a crucial characteristic since it shows how long

cement concrete or mortar can be mixed, transported, placed, and compacted before hardening takes place. Ordinary Portland cement should take at least 30 minutes to set initially, according IS: 4031 norms

The test is performed using the Vicat apparatus, which consists of a frame, a movable rod, and a 1 mm² needle for initial setting. A paste of cement is prepared by mixing 300 g of cement with water equal to 0.85 times its standard consistency. The paste is then placed in the Vicat mould resting on a non-porous plate. The initial setting needle is gently lowered onto the paste surface and released to penetrate. This process is repeated at regular time intervals.

The point at which the needle penetrates only up to 5 ± 1 mm from the base of the mould is taken as the initial setting time of the cement. This value represents the practical limit up to which the cement paste can be worked before it starts stiffening. If the initial setting time is too short, it will not give enough time from the bottom of the placing and compaction of concrete. On the other hand, if it is too long, construction schedules get delayed and the quality of work may be affected.



Fig No. 4.2: Initial Setting Time of Cement

Physical properties

Fresh cement was devoid of lumps, and conforming to the requirements of IS codes.

Physical properties such as specific gravity, fineness, initial and final setting time, and compressive strength of cement are determined prior to use.

4.1.3 Fine Aggregate

Kalaburagi lies in the zone where river sand extraction from streams of orders IV, V, and VI is managed by Hatti Gold Mines Ltd., under the Karnataka Sand Policy 2020.



Figure No 4.3: Sand

Table No 4.1: Fine Aggregate Sieve Analysis

Size of the Sieve	Retained weight (in gm)	Cumulative weight retained (in gm)	% Retained	Cumulative % Retained	Percentage Passing
4.75	51.02	51.02	5.102	5.102	94.898
2.36	61.46	112.48	6.146	11.248	88.752
1.18	176.1	288.58	17.61	28.858	71.142
600	189.9	478.49	18.99	47.849	52.151
300	441.31	919.8	44.131	91.98	8.020
150	65.4	985.2	6.54	98.52	1.48
PAN	14.78	-	-	-	-
		TOTAL		283.557	

Fineness modules of Fine aggregate = sum of cumulative % retained / 100 The fine aggregate's fineness modulus = 283.557/100 = 2.83

Table No 4.2: The fine aggregate's fineness modulus Sand's physical characteristics

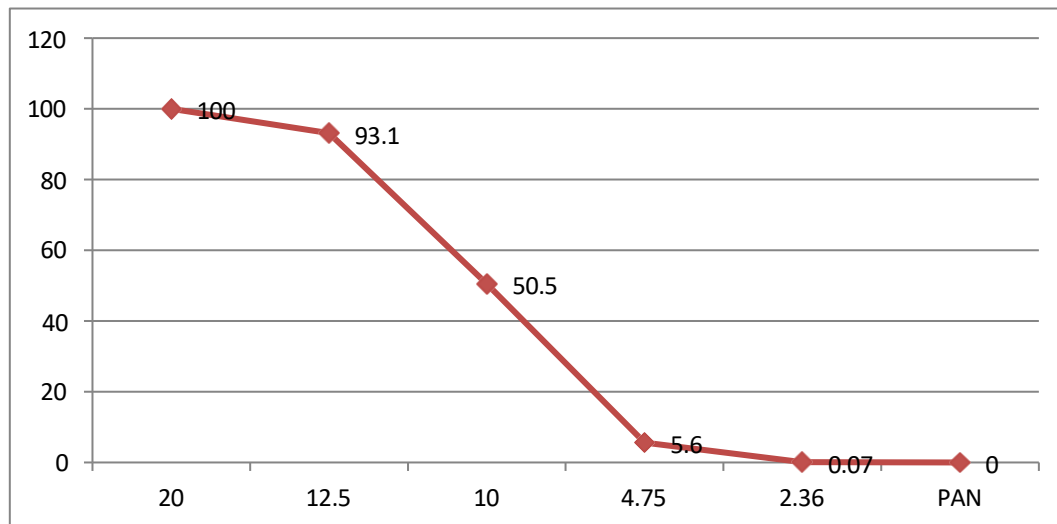
Sl. No.	Properties	Obtained Values
1	Fineness Modulus	2.83
2	Specific Gravity	2.69
3	Absorption of water	1%
4	Density in Bulk	1700 kg/cum



Fig No 4.4: Sieve Analysis

4.1.4 Coarse Aggregate

Any kind of aggregate can be used. The typical range of particle sizes is 16–20 mm. Nonetheless, SCC has employed particle sizes of 40 mm or more. Uniformity in grading is crucial. Rounder aggregates improve flow because of internal friction, whereas crushed aggregates tend to increase strength because of the angular particles' interweaving. Compared to regular concrete aggregates, SCC coarse aggregates were spherical in shape and had a smaller maximum size. Concrete was compacted using coarse aggregate that ranged in size from 10 to 12 mm. In terms of concrete, the smaller and rounder aggregate particles reduce segregation and increase passability and deformability. Ten millimeters is the aggregate size used. These aggregates are firm, angular, and devoid of dust or other contaminants. In accordance with IS: 2386-1963, the specific gravity, water absorption, and impact value are calculated.



Graph No 4.1: Sieve Analysis of 20 Mm Coarse Aggregate

Here's the grading curve for 20 mm nominal size coarse aggregate (as per IS:383–1970). The orange shaded zone shows the permissible grading limits.

The red dashed line = upper limit. The green dashed line = lower limit.

River sand, conforming to Zone II of IS: 383–1970 specifications, is used as fine aggregate. The sand is clean, well-graded, and free from silt, clay, organic impurities, or any deleterious materials. To guarantee appropriateness, physical characteristics such as specific gravity, water absorption, and sieve analysis are performed.



Fig No 4.5: Sieve Analysis of Coarse Material

Table No 4.3: The coarse aggregate's physical characteristics

Sl. No.	Characteristics	Obtained Values
F1	Specific gravity	2.69
F2	Value of Aggregate Impact	23.2%
F3	Water Absorption	0.6%



Fig No 4.6: Aggregate Impact Test Table No 4.4: Test of Water Absorption

Sl. No.	Weight of Oven-Dried Aggregate (W ₁) g	Weight of Saturated Surface-Dry Aggregate (W ₂) g	Water Absorption (%)
1	500	510	2.0
2	500	508	1.6
3	500	509	1.8
Average			1.8



Fig No 4.7: Water Absorption

The water absorption test's objective is to determine how much water an aggregate can absorb while submerged in water. It displays the aggregate's strength and porosity, two crucial characteristics influencing the durability and workability of concrete. High water absorption means the aggregate has more pores, making it weaker and less durable, while low absorption indicates a denser and stronger aggregate.

In this test, a sample of oven-dried aggregate is first weighed accurately and then immersed in water for about 24 hours. After immersion, the surface of the aggregate is dried using a cloth to eliminate extra water without permitting moisture to enter the pores, and the sample is weighed again in a saturated surface-dry condition. Finally, the aggregate is weighed in water to determine its buoyant weight.

4.1.5 Chemical Admixture

Superplasticizers (high-range water reducers), which are used with a water reduction of greater than 20%, are the most important admixtures. Using a Viscosity Modifying Agent (VMA) offers additional choices for regulating segregation when the amount of powder is limited. The mixing reduces the possibility of segregation and promotes great uniformity

i. SUPER PLASTICIZER The favored new generation of high-performance admixture designed to improve the properties of concrete is PCE (polycarboxylate ethers-based additive) [19][20]. It is a superplasticizer or high-range water-reducing ingredient. Its core is an aqueous copolymer of carboxylic acid. This mixture is easy to use to create a deformer and has high efficiency at low dosages. It has outstanding control over the cement's rheological parameters. Make it stronger. It reduces bleeding and material separation when added to concrete, enabling a 30% water content reduction. They also help to postpone the concrete setting period. At 0.6%, PCE is used.

Fig No 4.8: Polycarboxylate Ethers (PCE)



4.1.6 Water

The water used for mixing and curing must be free of harmful or detrimental elements. Portable water is often seen as adequate. In the current study, accessible water in the laboratory is used for both mixing and curing. The PH level must not be lower than 6. The solids present were within the acceptable limits specified in IS: 456 - 2000 clause 5.4.



Fig No 4.9: Water Used from laboratory

4.1.7 Glass Fibre

Alkali-resistant (AR) glass fibers are used due to their good tensile strength, stiffness, and resistance to cracking. They improve compressive strength, flexural performance, and reduce micro-cracks. Typical length ranges from 12 mm to 25 mm, with an aspect ratio suitable for dispersion in concrete.



Fig 4.10: Glass Fiber

Glass fibers are one of the essential accessories for concrete construction. The main purposes of this supplement are to increase the durability of the structure, improve resistance to surface abrasion, and drastically reduce microcracking.

Thanks to the significant increase in strength and durability that our glass fibers provide to concrete and mortar, the use of mesh and veils is replaced. It offers continuous and three-dimensional reinforcement throughout the coating.

Its multifilament structure ensures maximum compaction. Likewise, its excellent elasticity prevents deformation and allows it to withstand the tensions derived from thermal and hydraulic shrinkage.

Completely resistant to alkalis and most acids, our glass fibers for concrete impedes water loss. At the same time, they extend the lifespan of the mortar. The surface is completely ready for polishing, molding, and the addition of any desired additives [21][22].

Topciment®'s glass fibers for concrete have been modified to offer higher tensile and compressive strength than mesh and metallic fibers. They also provide increased impermeability, superior resistance to abrasion and impact, and a better final finish.

V. EXPERIMENTAL INVESTIGATION

5.1 General

The purpose of the experimental work was to assess the compressive strength of hybrid fiber reinforced concrete (HFRC) and investigate the mechanical characteristics of individual fibers. In the first phase, the chosen fibers were tested to ascertain their fundamental mechanical and physical characteristics. In the second phase concrete mixtures with different proportions of hybrid fibers were prepared, and After, their compressive strength was evaluated 7,21,28 days.

Steel and Polypropylene / Glass and Polypropylene – select your preferred combo] were the fibers used for this investigation. Their basic characteristics were assessed prior to their inclusion into the concrete matrix. These

experiments gave a baseline comprehension of the parameters, including diameter, that each fiber would contribute to the composite when embedded in concrete

A calibrated Compression Testing Machine (CTM) was accustomed to assessing compressive strength. After positioning the cubes midst of the loading platform, a constant Until the cubes failed, the loading rate was applied. Strength of compression was computed by dividing the highest load that the cube could withstand by its cross-sectional area. The cubes' failure patterns were also noted; in general, fiber-reinforced mixes showed more cohesive failure and less spalling because of the fiber bridging action.

5.2 EFNARC Guidelines

Currently, Indian Standards (IS) don't include detailed instructions for the mix design of Self- Compacting Concrete (SCC). However, mix design practices can be guided by European SCC standards, which offer general recommendations for the typical proportions of SCC ingredients, both by weight and by volume It's crucial to remember that these guidelines Don't give specific directions for specific mix formulations, but they serve as a useful reference for developing workable and stable SCC mixes.

Table No 5.1: Standard HFRC Concentration Range

Sl. No.	Components	Standard Deviation by Weight (kg/cum)	Typical Span (litres/cum)
1	Cement	±3.0	300
2	Fine Aggregate	±5.0	600
3	Coarse Aggregate	±7.0	900
4	Water	±2.0	150
5	Glass Fiber	±0.1	3
6	Polypropylene Fiber	±0.05	2
7	Admixture	±0.1	1
8	Others (if any)	±0.1	1

Table No 5.2: Mix Calculation of VCA Comparison

Item	Case A (VCA=0.35)	Case B (VCA=0.39)
Cement	312.9 kg	312.9 kg
Filler	203.1 kg	203.1 kg
Water	192.0 kg	192.0 kg
Fine agg (SSD)	421.54 kg	318.34 kg
Coarse agg (SSD, 12mm)	941.50 kg	1,049.10 kg
SP	2.68 kg	2.68 kg
Air	1.5% (vol)	1.5% (vol)

5.3 MIX RATIO

Cement	FA	CA	Chemical Admixture	Water
312.8	926.4	910.298	2.69	191
1	2.764	2.703	0.0084	0.612

Table No. 5.3: Materials required in kg / m³ of concrete

Materials (kg/m ³)	Conventional Concrete	Designed mix (M-30)
Cement	490	312.9
Slag	-	89.4
Fine Aggregate	932	926.5
Coarse Aggregate	880	910.299
Water	161	192

Superplasticizer (0.6%)	-	1.8774
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5.4 SPECIMEN CASTING AND CURING

The technique of producing concrete blocks with precise measurements for testing is known as specimen casting. During the casting process, concrete is combined and poured into a mold of a standard size. The technique of producing concrete blocks with precise measurements for testing is known as specimen casting. During the casting process, concrete is combined and poured into a mold of a standard size.

5.4.1 CUBES CASTING

- Using a watertight, non-absorbent surface, mix the cement and specific material until thoroughly combined and uniformly colored.
- Use cement and fine gravel to mix the coarse aggregate until it is equally distributed throughout the batch.
- Slowly dissolve the water solution until the concrete seems uniform and the right consistency.
- 4) Mould Should be cleaned and oiled.
- Fill the molds with layers of concrete that are 5 cm thick.
- Compact each layer with a minimum of 25 strokes using a tamping rod (a steel bar that is 60 cm long, 16 mm in diameter, and bullet-pointed at the lower end).
- Polish and level the upper surface using a trowel.



Fig No 5.1: Casting of Cubes

5.4.2 CURING

The specimens are kept in air-conditioned rooms for a maximum of 24 hours after casting in the facility. After these intervals, the specimens were taken out of the molds and put in a curing tank, where they had to stay cured for the specified amount of time while also being clean and fresh. This course of treatment is similar to 7, 21, and 28 days.



Fig No 5.2: Curing Yard

VI. RESULTS OF THE TEST AND DISCUSSIONS TEST ON FRESH

PROPERTIES

1) FLOW SLUMP AND TSO TEST: Without any external vibration, the slump flow test evaluates the horizontal free flow or filling capacity of hybrid fiber reinforced concrete (HFRC). This test involves filling a normal slump cone with the HFRC mix and then raising the cone vertically. Under its own weight, the concrete spreads out freely, as well as the diameter of the spread can be measured in two different ways. The HFRC's ease of flow and filling formwork is shown by the average of these measures.



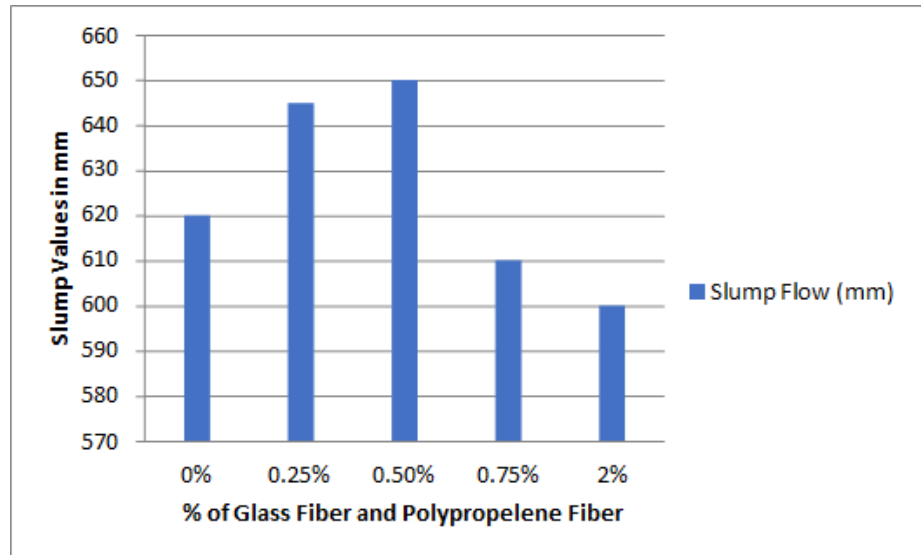
Fig No 6.1: Flow Table

Better flow and filling capacity of the HFRC mix are indicated by a wider spread diameter. Slump flow values usually fall between 600 and 750 mm, depending on the mix design and the fiber type and dosage. Less spreading of the concrete could be a sign of poor workability or that the flow of the mix is being impacted by the fiber content.

Table No 6.1: Slump Flow Test Results

Fiber Addition (%)	Slump Flow (mm)	T-500 Test (seconds)
0%	621	2.20
0.25%	646	2.52

0.5%	651	3.01
0.75%	609	3.22
2%	600	3.83

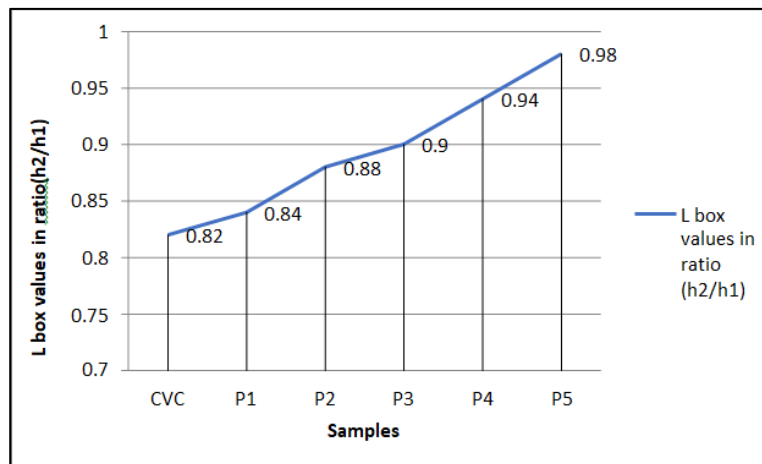


Graph No 6.1: Slump Flow V/S Different Percentages of Fibres

2) L-BOX TEST: To verify passing abilities, the L-box exam is used. After the vertical region of an L-Box. The gate is raised to let the concrete flow into the horizontal part after it has been filled. At the conclusion of the horizontal section, the height of the left vertical segment is displayed as a percentage of the height of the concrete. This demonstrates passing ability. EFNARC states that there is significant passing capacity when the h1 to h2 ratio is higher than 0.8.



Fig No 6.2: L Box



Graph No 6.2: L-Box values V/S Various % of Fibres TESTS ON HARDENED

SPECIFICATIONS OF HFRC

Tests on hardened HFRC (Hybrid Fiber Reinforced Concrete) are conducted to evaluate its mechanical and durability properties. The key tests include compressive strength to measure load-bearing capacity. Impact and fatigue tests assess toughness and resistance to repeated loading, while durability tests such as water absorption.

1) COMPRESSIVE STRENGTH: Compression force is the capacity of a material or structure to bear loads on its surface without cracking or deflecting. When a material is compressed, its size diminishes, and when it is tensioned, it increases. Standard cube specimens measuring 150 x 150 x 150 mm were used to assess compressive strength. Out of the thirty cubes that were cast, two cubes were analyzed for each distinct fiber %. The compressive strength was assessed using a 1000kN capacity compression testing machine in compliance with IS 516-1959. To ascertain the compressive strength, an average number of specimens were cast and examined strength.

In this investigation, conventional cube specimens measuring 150 × 150 × 150 mm were used to measure compressive strength. Two cubes were cast and tested for every fiber dosage, for a total of twelve cubes:

- 10 cubes cured for 7 days
- 10 cubes cured for 21 days
- 10 cubes cured for 28 days

After the respective curing periods, the cubes were tested using a compression testing machine with a capacity of 1000 kN, following IS 516–1959 guidelines. The compressive strength (f_{ck}) was calculated using the formula:

$F_{ck} = P/A$

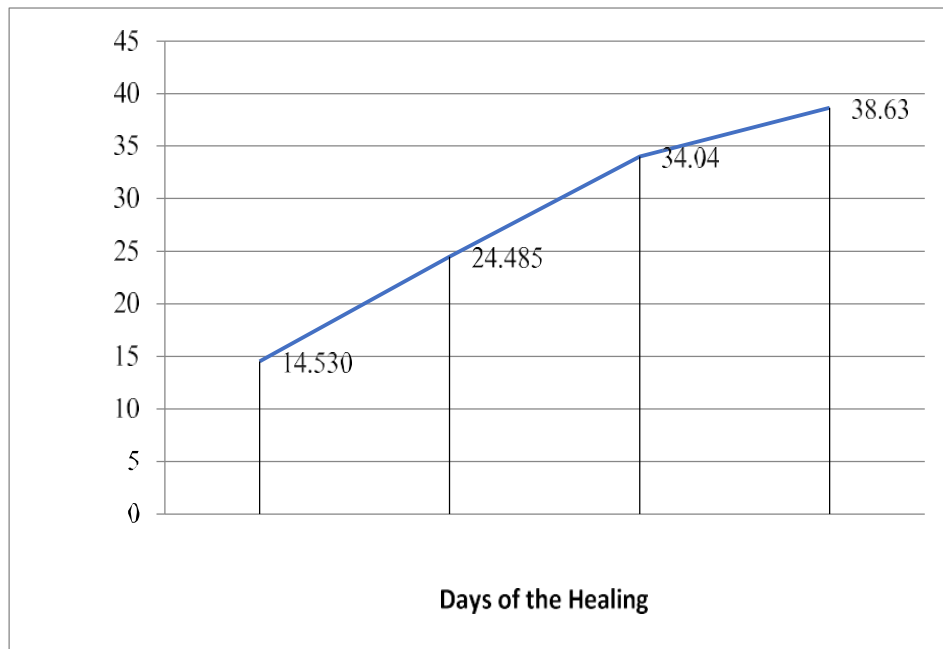
Where P= Ultimate load in Compression in kN A= Area of cross section in mm².

- P = Ultimate load in compression (kN)
- A = Cross-sectional area of the specimen (mm²)

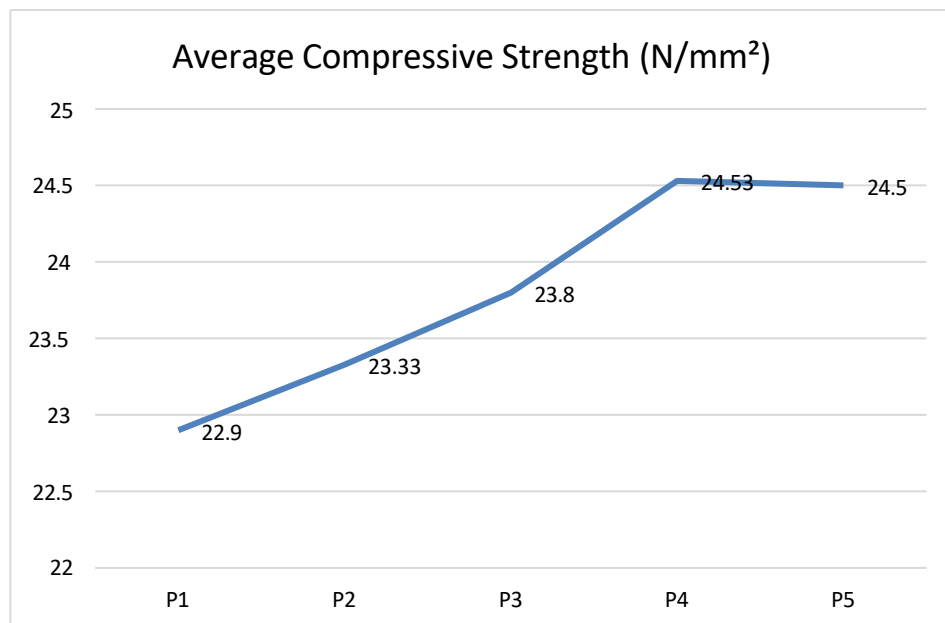


Fig 6.3: Compressive Strength Table No 6.2: CVC Comparison Values

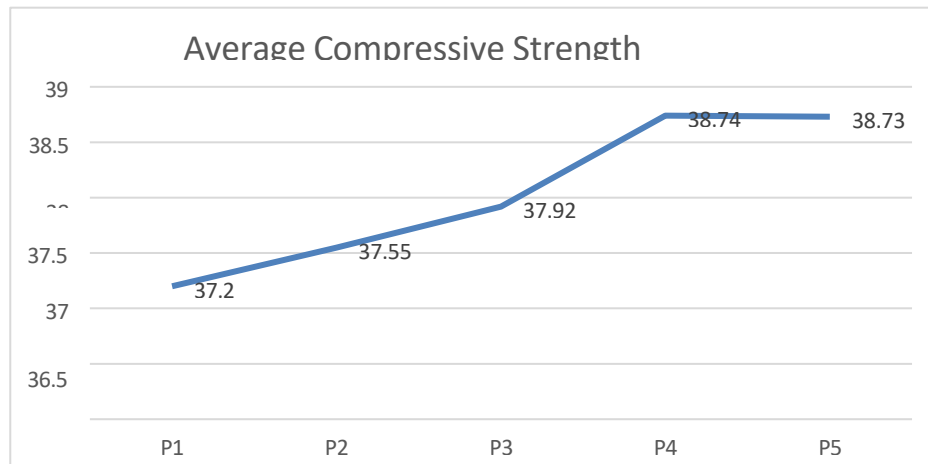
Sl. No	Identification	X-sectional area (m ²)	Average Compressive Strength (N/mm ²)
1	N3	22500	14.530
2	N7	22500	24.485
3	N21	22500	34.04
4	N28	22500	38.63



Graph No 6.3: CVC Compression Strength Output



Graph No 6.4: Average Compressive Strength at 7 days



Graph No 6.6 Average Compressive Strength at 28 days

VII. CONCLUSION

1. The slump flow test confirms that HFRC possesses good filling ability, allowing it to spread easily without external vibration.
2. The T50 test provides additional insight into flowability, with lower times indicating better performance in placing the concrete.
3. The L-box test demonstrates that HFRC has excellent passing ability, which is essential for filling formwork with reinforcements without segregation.
4. A h_1/h_2 ratio greater than 0.8, as recommended by EFNARC, confirms that the mix is capable of flowing through congested reinforcement areas effectively.
5. The addition of glass fibre and polypropylene to the concrete mix results in a steady increase in compressive strength across all samples.
6. Even though the values are slightly lower than steel fibre mixes, the improvement with increasing fibre content is clearly observed.
7. The mix with 1.5% glass fibre and polypropylene shows the highest average compressive strength, demonstrating the beneficial effect of fibre reinforcement.
8. Glass fibre improves the concrete's early strength, but at a lower rate compared to steel fibre, which is expected due to material properties.
9. The use of glass fibre still provides enhanced durability and crack resistance, making it a viable alternative in certain applications where weight and corrosion are concerned.
10. The results confirm that a combination of silica fume, slag, glass fibre, and polypropylene can effectively enhance the compressive strength of concrete in a controlled manner.
11. This study encourages further investigation into optimizing fibre content and curing methods to maximize performance while considering cost and environmental factors.

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