FIBER REINFORCED CONCRETE (FRC) AN EFFECTIVE WAY TO IMPROVE THE PERFORMANCE OF CONCRETE (STUDY BASED ON UTILITY IN INDIA)

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Abstract:
Hybrid Fiber Strengthened Cement (HFSC) is tested for mobility, crushing, cleavage tensile, and bending with varying fiber ratios. The research seeks the best steel-to-PVA filament ratio for HFRC robustness. Slump cone and compaction factor experiments tested HFRC feasibility. High-range water reducers evaluated new concrete compositions' agility and homogeneity. Slump ratings were satisfactory, showing movement. Densification coefficient decreased controllability with amalgamated filaments. To measure compressive strength, cubes were wet and surface-dried at different curing phases. Amalgamated filaments improved compression. High-performance fiber-reinforced concrete (HFRC) mixes with 0.75% steel and 0.25% PVA filament had the maximum compressive strength. At varied solidifying intervals, cylindrical samples were compressive tested. Cement was weaker than HFRC mixtures. Amalgamated filaments had the maximum compressive effectiveness. Amalgamated filaments strengthened cylindrical samples. High-performance fiber-reinforced concrete with 0.75% steel filament and 0.25% polyvinyl alcohol filament achieved the greatest split tensile strength. Amalgamated filaments strengthened rectangular parallelepiped samples. High-performance fiber-reinforced concrete with 0.75% steel filament and 0.25% polyvinyl alcohol filament exhibited the maximum bending resistance. Studies show Al amalgamated filaments boost cement potency. 0.75% metal filament and 0.25% polyvinyl alcohol filament in high-performance fiber-reinforced concrete improve crushing, cleavage, and bending. HFRC combinations' compressive, cleavage, and bending potencies are related in the research's observational formulations.

Keywords: Hybrid Fiber Reinforced Concrete, steel fiber, polyvinyl alcohol fiber, workability, compressive strength, split tensile strength, flexural strength.

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1. INTRODUCTION

By means of exploration and innovation, the civil engineering building sector endeavours to discover means to enhance the tensile potency and after-cracking resilience, and diminish the fragility of the concrete. Novel advancements are being implemented in the creation of resilient and adaptable composite fiber reinforced concrete. HFRC, also referred to as Composite Fiber Reinforced Concrete (CFRC), is a type of concrete matrix that is fortified with a haphazardly dispersed blend of diverse hybrid fibers. The efficacy of HFRC is impacted by diverse aspects like fiber material characteristics, fibers' geometry, fibers' volume fraction in the concrete, matrix characteristics, and the interfacial characteristics. It is perpetually advantageous to conduct evaluations on fundamental mechanical characteristics of HFRC, thereby acquiring knowledge on the importance of incorporating specific varieties of amalgamated fibers, and subsequently, enhancing the material's quality.

In the ongoing investigation of hybrid fiber reinforced concrete, a concoction of two varieties of fibers, specifically, steel fiber and polyvinyl alcohol (PVA) fiber, each incorporated in diverse ratios, was employed as hybrid fibers. In order to examine the impact of the aforementioned amalgamated fiber, an all-encompassing experimental regimen was formulated and executed to ascertain the pliability, crushing potency, cleavage tensile potency, and bending potency of the HFRC substrate.

2. OBJECTIVES

1. This research study investigates the strength characteristics of Hybrid Fiber Reinforced Concrete (HFRC) by combining steel fiber and polyvinyl alcohol (PVA) fiber.
2. The study aims to assess the workability, compressive strength, split tensile strength, and flexural strength of HFRC with varying proportions of hybrid fibers.
3. The research aims to determine the optimum dosage of steel fiber and PVA fiber in the HFRC mix to achieve the highest strength performance .

3.WORKABILITY TEST ON HYBRID FIBER REINFORCED CONCRETE

Workability Tests

Slump cone and compaction factor experiments were performed on hybrid fiber enhanced concrete mixtures. Sulphonated naphthalene formaldehyde-derived super plasticizer was added to concrete mixtures to improve fresh concrete's consistency and maneuverability. Ultra plasticizer at 2% sticky weight was accepted. Table 3.1 shows the decline and densification coefficients for each amalgamated fiber-strengthened cement mix and the regular cement blend, showing cement's manoeuvrability.

Slump Test

Newly mixed concrete compositions were slump-tested according to IS: 1199 – 1959. The droop evaluation equipment is a 300-mm-tall truncated cone with a 200-mm base and 100-mm top. However, the concrete combination was tested for viability. The slump examination cone had a smooth base. Three layers of unique cement amalgamation filled the pyramidal receptacle. The same approach was used to condense each layer 25 times using a 16-mm metal pole. After filling and tamping, the concrete amalgamation was smoothed at the apex and lifted perpendicularly, causing it to sag. The cement's height drop was measured but notated. Table 3.1 shows how each concrete mix declines.

Compaction Factor Test

The IS: 1199-1959-compliant compacting factor evaluation equipment yielded inconclusive findings. The doorway of the tallest truncated cone was unlatched to enable freshly mixed concrete to fall onto the next cone. To pour concrete onto the cylinder, the second truncated cone was unsealed. The incompletely crushed cement-filled cylindrical container was weighed. The vibrator crushed concrete into the cylinder again, but this time it was weighed. The density ratio of incompletely compacted concrete to fully compacted concrete determined densification. Table 3.1 shows the calculated examination data, although.

Table 3.1 Assessment of the Performance of Standard Concrete and Hybrid Fiber Strengthened Concrete Using Workability Test Outcomes

Sl. No.	Mix Identification	Fiber (%)		Slump (mm)	Compaction factor
		Steel Fiber	PVA Fiber		
1	HFRC 0	0.00	0.00	73	0.83
2	HFRC 1	0.00	1.00	71	0.82
3	HFRC 2	0.25	0.75	69	0.77
4	HFRC 3	0.50	0.50	68	0.76
5	HFRC 4	0.75	0.25	66	0.75
6	HFRC 5	1.00	0.00	65	0.72

According to Table 3.1, slump ranges from 65 to 73 millimeters. The droop measurement is within the IS: 456 – 2000 limits for moderate manoeuvrability. Compaction coefficient is 0.72–0.83. Compaction factor is 0.8–0.9. As amalgamated filaments increase in percentage, the cement mixture's droop and densification coefficient decrease.

4. PREPARATION AND TESTING OF SPECIMENS

Cube Compressive Strength Test

Composite fiber-reinforced concrete mixture block samples 150 mm x 150 mm x 150 mm were tested for strength. After drying, each item was examined in completely saturated surface aridity. Twelve cube samples were made, and a 2000 kN Compression Testing Device was used to examine three identical samples for each combination composition at the 7th, 14th, 28th, and 56th days. IS: 516 – 1959 was strictly followed for the compressive strength test. The material was orientated in the inspection device. The stress rate was 149 kg/cm2/min. The dial gauge pointer precisely reversed the loading. The specimen failed when the dial gauge indicator's direction of motion regressed. The dial indicator needle's opposite motion created the final load. Dividing the greatest load by the specimen's transverse measurements gave compressive resilience.

Cylinder Compressive Strength Test

Three identical cylindrical specimens of 150 mm diameter and 300 mm altitude for each composite fiber reinforced cement amalgamation were tested for compressive potency at 7, 14, 28, and 56 solar days. 2000-kilonewtons Compression Evaluation Device was used. IS: 516 – 1959 guided scrutiny, with minor modifications.

Split Tensile Strength Test

Another way to measure circular specimen tensile strength is divide tensile capability. For each reinforced concrete mixture containing composite fibers, three identical tubular specimens of 150 mm diameter and 300 mm length were tested. After 28 days, a 2000-kilonewton Compression Testing Apparatus accomplished this achievement. IS: 5816–1970 provided the division tensile strength assessment method. Gradually applying stress until the specimen burst, readings were obtained."
The association calculated 28-day tensile strength.

$$f_{ct} = \frac{2P}{\pi d l}$$

where,

fct = Splitting Tensile Strength of the Specimen (MPa)

P = Maximum Load Applied to Specimen(N)

l = Length of the Specimen(mm)

d = Cross Sectional dimension of the Specimen (mm)

Flexural Strength Test

In accordance with IS: 516 – 1959, three identical prism specimens measuring 100 mm x 100 mm x 500 mm were tested for flexural strength at 28 days for each fiber-reinforced cement mixture. A 1000-kilonewton Universal Testing Apparatus held the specimen. Loading was two-pronged. Formula for flexural strength:

$$f_b = \frac{Pl}{bd^2}$$

Where,

fb = Flexural Strength of the Specimen(MPa)

P = Maximum Load (N)applied to the Specimen

L = Length of the Span (mm)

B = Measured Width of the Specimen (mm)

D = Measured Depth of the Specimen (mm) at the point of failure

5. TEST RESULTS AND DISCUSSION

Cube Compressive Strength

Analytical methods analyzed compressive strength testing findings. The results are examined. Figure 5.1 depicts the compressive strength test results for cubic specimens of the conventional concrete mix and composite fiber reinforced concrete blend at 7, 14, 28, and 56 days. After 28 days, amalgamated filaments in amalgamated material blends HFRC 1, 2, 3, 4, and 5 increase cube compressive potency. In particular, amalgamated filaments at 0% iron fiber + 1% polyvinyl alcohol (PVA) fiber, 0.25% iron fiber + 0.75% PVA fiber, 0.5% iron fiber + 0.5% PVA fiber, 0.75% iron fiber + 0.25% PVA fiber, and 1% iron fiber + 0% PVA fiber increased compressive potency by 3.56%, 9.89%, 11.42%, 21.08%, and 14.83%, respectively, compared to the control concrete mix HFRC 0.

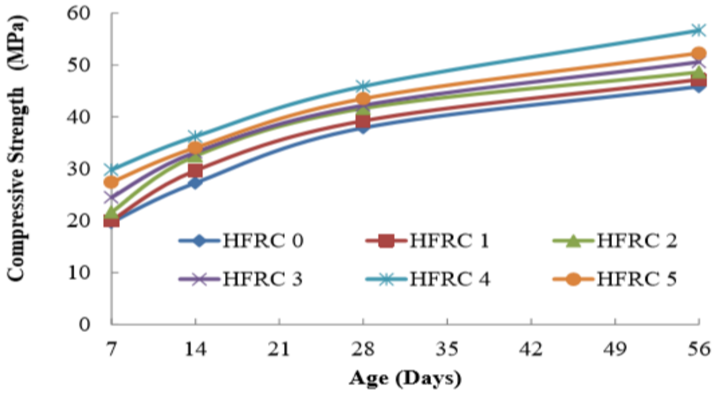

Figure 5.1 Advancement of Cubic Compressibility Resilience of Standard Concrete and Compound Fiber Enhanced Concrete during the Timeframe of 7, 14, 28 and 56 Solar Cycles.

HFRC 4, with 0.75% steel fiber and 0.25% PVA fiber, has the greatest cube compressive strength of 45.89 MPa among the several mix ratios from HFRC 0 to HFRC 5. Compared to the typical concrete mix HFRC 0.

Table 5.2 shows HFRC mixture compressive strength effectiveness. The compressive strength activity marker shows the ratio of HFRC mixture compressive strength to ordinary concrete mixture compressive strength for each curing interval.

Table 5.1 Action Indicator of Composite Fiber Strengthened Cement with Improved Cube Crushing Resistance.

Sl. No.	Mix Identification	Volume of Fiber (%)		Activity Index			
		Steel Fiber	PVA Fiber	7 days	14 days	28 days	56 days
1	HFRC 0	0.00	0.00	1.00	1.00	1.00	1.00
2	HFRC 1	0 .00	1.00	1.02	1.09	1.04	1.03
3	HFRC 2	0.25	0.75	1.10	1.19	1.10	1.06
4	HFRC 3	0.50	0.50	1.24	1.22	1.11	1.10
5	HFRC 4	0.75	0.25	1.51	1.33	1.21	1.24
6	HFRC 5	1.00	0.00	1.39	1.25	1.15	1.14

Table 5.1 shows how HFRC amalgams outperform authoritative cement mixtures in block squashing power. HFRC 4 with 0.75% steel strand and 0.25% polyvinyl alcohol strand increases block compressive strength more proportionally.

Table 5.2 The proportion escalation in the compactness potency of the block. The durability of Hybrid Fiber Reinforced Cementitious Composite as opposed to Conventional Cement

Sl.No.	Mix Identification	Volume of Fiber (%)		Increase in Compressive Strength with Compared to Control Concrete (%)			
		Steel Fiber	PVA Fiber	7 days	14 days	28 days	56 days
1	HFRC 0	0.00	0.00	0.00	0.00	0.00	0.00
2	HFRC 1	0.00	1.00	1.57	8.72	3.56	2.94
3	HFRC 2	0.25	0.75	9.89	19.05	9.89	6.04
4	HFRC 3	0.50	0.50	24.25	21.62	11.42	10.29
5	HFRC 4	0.75	0.25	51.34	32.83	21.08	23.57
6	HFRC 5	1.00	0.00	39.12	24.88	14.83	14.04

Cylinder Compressive Strength

Figure 5.2 shows composite fiber reinforced cement mixture compressive strengths at 7, 14, 28, and 56 days. HFRC 1, HFRC 2, HFRC 3, HFRC 4, and HFRC 5 increase their cylinder compressive potency by 2.68%, 7.16%, 9.56%, 19.05%, and 13.85% after 28 days of age. Assimilation of amalgamated filaments in different proportions, such as 0% iron filament + 1% polyvinyl alcohol filament, 0.25% iron filament + 0.75%, 0.5%, 0.75%, and 1%, is responsible for the increase in numbers. This rise opposes the cylinder compressive durability of the command concrete mixture HFRC 0.

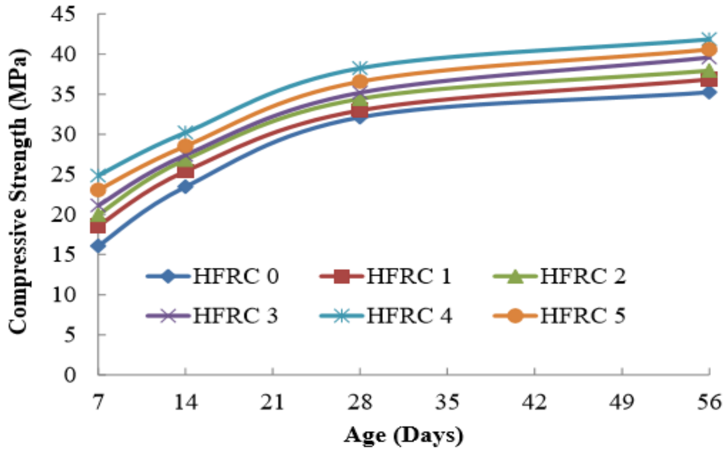

Figure 5.2 Advancement of Cylinder Compressive Resilience of Standard Cement and Hybrid Fiber Enhanced Cement over the Course of 7, 14, 28, and 56 Days

However, HFRC 4, reinforced with 0.75% steel filament and 0.25% PVA filament, has the highest cylinder robustness of 38.24 MPa. The cylinder compressive potency increased 19.05% compared to the HFRC 0 command amalgamation.

Based on cylinder compressive potency test findings, the ideal ratio of blended fibers to concrete mixture is 0.75% steel fiber and 0.25% PVA fiber. HFRC 4 cement mixture efficiency illustrates this. Table 5.3 shows HFRC mixture cylinder compressive strength performance metrics.

Table 5.3 Round Compression Capability Activity Gauge of Compound Fiber Enhanced Cement

Sl. No	Mix Identification	Volume of Fiber (%)		Activity Index			
		Steel Fiber	PVA Fiber	7 days	14 days	28 days	56 days
1	HFRC 0	0.00	0.00	1.00	1.00	1.00	1.00
2	HFRC 1	0 .00	1.00	1.16	1.08	1.03	1.05
3	HFRC 2	0.25	0.75	1.24	1.14	1.07	1.08
4	HFRC 3	0.50	0.50	1.32	1.17	1.10	1.12
5	HFRC 4	0.75	0.25	1.55	1.29	1.19	1.19
6	HFRC 5	1.00	0.00	1.43	1.22	1.14	1.15

Table 5.3 shows the tube compressive strength of HFRC amalgams compared to conventional cement mix. However, HFRC 4 with 0.75% steel filament and 0.25% polyvinyl alcohol filament increases cylinder compressive strength more.

Table 5.4 The proportion escalation in the canister. The compressive strength of the composite fiber-reinforced cement in contrast to that of the standard cement.

Sl.No.	Mix Identification	Volume of Fiber (%)		Increase in Cylinder Compressive Strength with Compared to Control Concrete (%)			
		Steel Fiber	PVA Fiber	7 days	14 days	28 days	56 days
1	HFRC 1	0.00	1.00	15.63	8.32	2.68	4.54
2	HFRC 2	0.25	0.75	24.28	14.50	7.16	7.66
3	HFRC 3	0.50	0.50	31.51	16.89	9.56	12.29
4	HFRC 4	0.75	0.25	54.79	28.83	19.05	18.73
5	HFRC 5	1.00	0.00	43.46	21.66	13.85	15.12

Split Tensile Strength

Figure 5.3 shows a histogram of the diverging tensile strength estimations of the normal cement mixture and consolidated fiber reinforced cement mixture at 28 days. The divergent tensile strength of cylindrical specimens made of HFRC cement mixes after 28 days ranges from 3.17 N/mm2 (HFRC 0 - concrete mix under supervision) to 4.25 N/mm2 (HFRC 5). HFRC blends 1, 2, 3, 4, and 5 increase overall tensile resilience by 8.20%, 14.20%, 19.24%, 24.07%, and 27.13%. Unlike normal concrete's dichotomous tensile strength (HFRC 0).

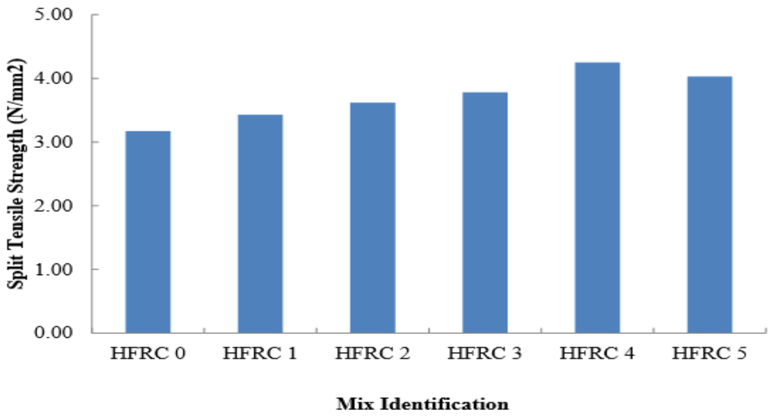

Figure 5.3 The tensile durability of the typical cement and the blended fiber enhanced cement at the 28-day point was evaluated.

The HFRC 4 amalgamation has the greatest bifurcated tensile strength. HFRC 5 has a lower divided stretching strength than HFRC 4, yet it still outperforms cement. Figure 5.4 shows 28-day HFRC mixture branching tensile strength.

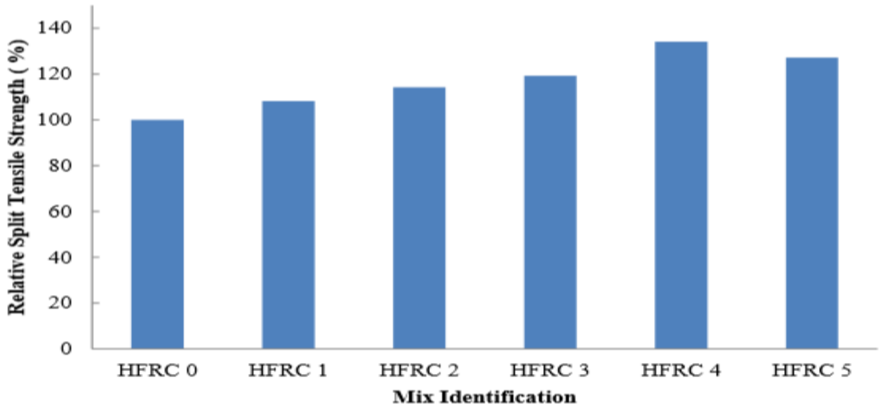

Figure 5.4 Contrasting Isolation Tensile Capacity of Composite Fiber Enhanced Concrete at the Duration of 4 Weeks.

The increase in the ratio of split tensile strength of HFRC mixtures and standard concrete is demonstrated in Table 5.5.

Table 5.5 Proportion Increase in Split Tensile Durability of Composite Fiber Reinforced Concrete Compared to Conventional Concrete

Sl.No.	Mix Identification	Volume of Fiber (%)		Increase in Split Tensile Strength with Compared to Control Concrete at the Age of 28 days (%)
		Steel Fiber	PVA Fiber	
1	HFRC 0	0.00	0.00	0.00
2	HFRC 1	0.00	1.00	8.20
3	HFRC 2	0.25	0.75	14.20
4	HFRC 3	0.50	0.50	19.24
5	HFRC 4	0.75	0.25	34.07
6	HFRC 5	1.00	0.00	27.13

The performance marker for the divided stretching strength of the typical cement and high-strength fiber-reinforced concrete blends is displayed in Chart 5.6.

Table 5.6 Segregate Tensile Endurance Metric of Composite Fiber Enhanced Concrete

Sl.No.	Mix Identification	Volume of Fiber (%)		Activity index
		Steel Fiber	PVA Fiber	
1	HFRC 0	0.00	0.00	1.00
2	HFRC 1	0.00	1.00	1.08
3	HFRC 2	0.25	0.75	1.14
4	HFRC 3	0.50	0.50	1.19
5	HFRC 4	0.75	0.25	1.34
6	HFRC 5	1.00	0.00	1.27

Flexural Strength

Figure 5.5 shows prism sample bending strength assessments for the conventional cement mix and the combination fiber reinforced cement blends after 28 days. Compared to ordinary concrete (HFRC 0), HFRC blends "HFRC 1, HFRC 2, HFRC 3, HFRC 4, and HFRC 5" have flexural strengths of 10.31%, 15.71%, 19.07%, 30.54%, and 25.88%. However, HFRC 4 (0.75% steel filament + 0.25% PVA filament) has the highest flexural aptitude.

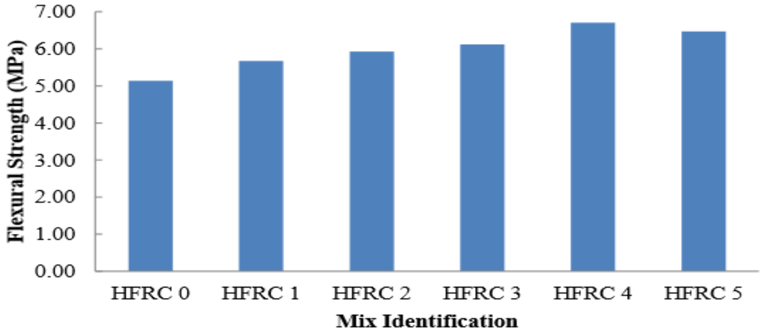

Figure 5.5 Bending Toughness of Unmodified Concrete and Blended Fiber Reinforced Concrete at the Twenty-Eighth Day of Curing

The Relationship between the Mechanical Properties of HFRC

An effort has been made to create empirical formulas to show the relationship between block compressive strength, split tensile strength, and bending strength of composite fiber reinforced cement mixtures. Figure 5.6 shows that HFRC's compressive cube and tensile cleave are connected. The power properties are linked:

$$f_{th} = 0.45\sqrt{f_{ch}}$$

$$R^2 = 0.9615$$

where,

fth = Split Tensile Strength of HFRC (MPa),

fch = Cube Compressive Strength of HFRC (MPa)

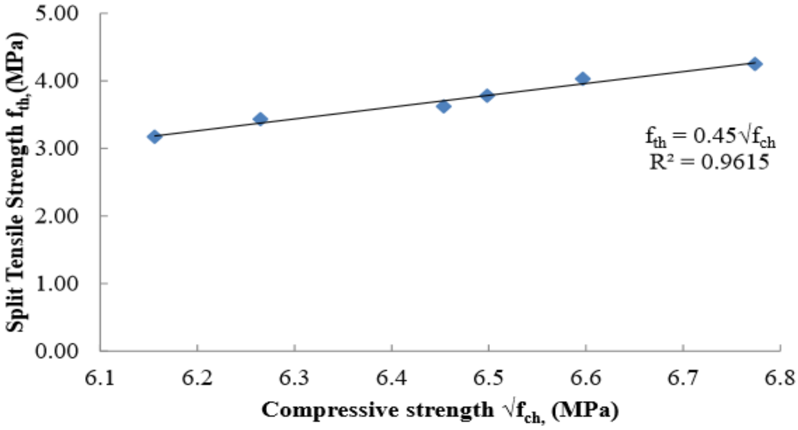

Figure 5.6 Association Between Compressional Resilience and Fragmented Tensile Resilience of High-Performance Fiber-Enhanced Cementitious Material (HPFECM)

Nonetheless, Figure 5.7 depicts the association between the compressive potency of cubes and the bending potency of HFRC. The association between the two power characteristics can be expressed as follows:

$$f_{fh} = 0.9\sqrt{f_{ch}}$$

$$R^2 = 0.9445$$

Where
Ffh = Flexural Strength of HFRC (MPa)
Fch = Cube Compressive Strength of HFRC (MPa)

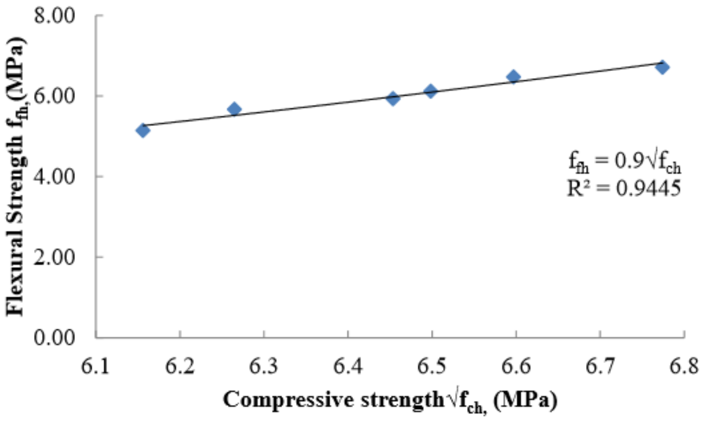

Figure 5.7 Correlations between Compressive Strength and Flexural Strength of High-Performance Fiber-Reinforced Cement

6. CONCLUSION

Practical experiments on mixed fiber reinforced cement mixture efficacy yielded these findings:

- Hybrid Composite Reinforced Cement with 1% volume proportion of various fibers and amalgamation ratio of 0.75% Metal fiber and 0.25% Polyvinyl alcohol fiber by cement volume gives remarkable strength in every phase.
- The combined fiber combination at "0.75% steel fiber and 0.25% PVA fiber per unit volume of concrete, regardless of standard concrete" increases the cube's strength by 21.08% and the cylinder's by 19.05%.
- HFRC mixes expand fissures significantly. HFRC 4 with 0.75% steel filament and 0.25% PVA filament has a 34.07% higher split tensile strength than HFRC 0 after 28 days.
- HFRC blends improve flexural robustness. After 28 days, HFRC 4 amalgamation (0.75% metal strand and 0.25% PVA strand) has 1.31 times the flexural durability of HFRC 0.
- Based on the trial assessment of compressive strength, split tensile strength, and flexural strength of HFRC mixtures, HFRC 4 blend with 1% amalgamated fiber (0.75% iron fiber and 0.25% polyvinyl alcohol fiber) proportional to concrete has the optimal composite fiber to concrete mixture ratio.
- However, the compressive strength-split tensile strength relationship of Hybrid Fiber Reinforced Concrete was fth = 0.45fch. In standard concrete, compressive strength and splitting tensile strength are 0.35 times the square root of fck.
- Hybrid Fiber Strengthened Concrete's compressive and flexural resilience are correlated as ffh = 0.9 fch, however this connection is crucial to the concrete's overall durability. In normal cement, compressive strength and bending strength are 0.7 multiplied by the square root of fck.

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