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A Study on Properties of Hybrid Fiber Reinforced Concrete's Strength

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Abstract: Improvements in concrete's tensile strength, post-cracking resistance, and brittleness are perennial goals in the field of civil engineering and construction. Strong and adaptable hybrid fiber reinforced concrete is being developed using new techniques. Hybrid fiber reinforced concrete (HFRC) is a concrete matrix containing hybrid fibers randomly scattered throughout. The hybrid fibers utilized in the current study of fiber-reinforced concrete were a mixture of steel fiber and polyvinyl alcohol (PVA) fiber. Workability, compressive, split tensile strength, and flexural strength of the HFRC matrix were all measured as part of an extensive experimental program aimed to examine the impacts of the aforementioned hybrid fiber.

Keywords: Split tensile strength, Polyvinyl Alcohol, HFRC, Hybrid Fiber.

1. Introduction

Concrete is widely used in civil engineering building projects. It is generally accepted that concrete has a high resistance to compression but a low resistance to tensile stress. The poor tensile strength of concrete is seen when, even under light loads, fractures appear in a concrete part. The ductility quality of the concrete structural component is compromised when fractures propagate and failure occurs under dynamic loads. Concrete's inherent weakness may be remedied by adding reinforcement, such as a single-type fiber incorporated into the material's matrix. [1-2]

Fiber Reinforced Concrete is the term for this material (FRC). The value of concrete will be diminished if just one kind of fiber is used as secondary reinforcement. To get over this limitation, hybrid fibers are used to enhance concrete's performance in a well-rounded way. Synergistic response and significant advantages may be achieved by combining two or more types of fibers to create a hybrid fiber. Hybrid fiber's synergy is the sum of the fibers' unique potential energies.[3-4]

The use of hybrid fibers into the concrete mixture is a step forward for fiber reinforced concrete. When incorporating two or more types of fibers into concrete, they must first be completely mixed together. The purpose of utilizing a combination of fibers is to maximize the concrete's resilience to tensile stress by capitalizing on the advantages of each fiber type. When two distinct fiber types are joined in the right proportions, a superior composite concrete is produced. Concrete with a hybrid fiber system added to it is more resistant to damage and cracking. The concrete may be made more durable by including hybrid fiber, which includes both metallic & non-metallic fiber, into the mix.[5-7]

While metallic fiber increases strength, it also decreases ductility and leads to postcracking events in concrete, neither of which are very appealing. In contrast, non-metallic fiber improves concrete by reducing plastic shrinkage and slowing the propagation of microcracks during in the plastic stage of concrete's growth. [8-9]

When added to concrete, metallic fibers increase the material's stiffness while also increasing its tensile strength, impact strength, flexural, or energy absorption capacity. The concrete's mechanical characteristics and structural performance may be greatly improved by including either low- or high-modulus fiber into the mix.[10]

2. Material and Methods

- **Concrete With Hybrid Fiber Reinforcement: A Testing Of Its Workability**

WorkabilityTests

The workability of the conventional concrete was evaluated using the slump cone test and the compaction factor test for many different hybrid fiber reinforced concrete mixes. Sulphonated naphthalene formaldehyde-based super plasticizer was added to the concrete mixes in recent studies to improve the material's workability and cohesion. It was decided to use a super plasticizer concentration of 2% by mass of binder. Concrete workability is shown by the slump or compaction factor in Table, which is included for both the hybrid effect in addition concrete mix types and the control concrete mix.

SlumpTest

The new concrete mixtures were subjected to a slump test according to the guidelines outlined in IS: 1199 - 1959. Slump testing apparatus includes a frustum of a cone with dimensions of 300 mm in height, 200 mm in base diameter, and 100 mm in upper diameter. This is how we found the concrete to be workable. For doing a slump test, a smooth foundation is required. Three layers of new concrete mix were poured into the conical container. Using a steel rod with a diameter of 16 mm, we tamped each layer 25 times. After being filled and tamped, the cone was elevated vertically, causing the concrete mixture to slump. It was noted how much the concrete had lowered in height. Table displays the slump values for all of the different concrete recipes.

CompactionFactorTest

We used compacting factor test equipment to conduct the test as specified by IS: 1199-1959. Fresh mix concrete was poured into the top cone frustum, and its gate opened so that the concrete poured down into the second frustum, and from there onto the cylinder. The amount of partly compacted concrete within the cylinder was weighed. Once again, the cylinder was loaded with concrete, vibrated to compress the mixture, and then weighed. The percentage of compaction was determined by comparing the density of uncompacted concrete to that of compacted concrete. Table displays the results of the computed tests.

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Table1: Comparison of Control & Hybrid Fiber Reinforced Concrete in Terms of Workability

Sl.No.	MixIdentification	Fiber(%)		Compactionfactor	Slump(mm)
		PVA Fiber	SteelFiber		
1	HFRC3	0.50	0.50	0.76	68
2	HFRC1	1.00	0.00	0.82	71
3	HFRC5	0.00	1.00	0.72	65
4	HFRC2	0.75	0.25	0.77	69
5	HFRC4	0.25	0.75	0.75	66
6	HFRC0	0.00	0.00	0.83	73

The slump value is shown to be in the range of 65 mm to 73 mm in the table data. Based on the IS: 456 - 2000 criteria, the resulting slump value is acceptable and classed as having a medium level of workability. Between 0.72 and 0.83, the compaction factor might take on different values. Allowable values for compaction factor are between 0.8 and 0.9. It has been shown that the slump value as well as the compaction factor value of a hybrid fiber reinforced concrete mix decrease as the percentage of hybrid fibers in the mix increases.

- **Specimen Preparation And Testing**

Cube Compressive Strength Test

Cube specimens of hybrid fiber reinforced concrete mix were subjected to a compressive strength test. After drying the surface of each specimen thoroughly, it was subjected to tests under the saturated surface dry conditions. Twelve cube specimens were cast, and even at 7, 14, 28, and 56 days of age, the compressive strength of each mix combination was tested using a Compression Testing Machine with a 2000 kN capacity. The testing apparatus had the specimen centered in it. A constant stress rate of 149 kg/cm2/min was used throughout the testing. The force was kept up until the dial gauge needle stopped moving in its previous direction. The failure of the specimen was indicated by the direction change of the dial gauge needle. The maximum load was recorded as the one that caused the dial gauge needle to move in the opposite direction.

Cylinder Compressive Strength Test

Three cylindrical specimens, each 150 mm in diameter and 300 mm in height, were tested for compressive strength at 7, 14, 28, and 56 days for each kind of hybrid fiber reinforced

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concrete mix. A 2000 kN compression testing machine was used. IS: 516 - 1959 was used as the basis for the testing protocol.

Split Tensile Strength Test

One alternative approach to measuring the tensile strength of cylindrical specimens is the split tensile strength test. At the age of 28 days, a Compression Testing Machine with a capacity of 2000 kN was used to test the strength of three identical cylindrical samples of 150 mm in diameter and 300 mm in length made from each kind of hybrid fiber reinforced concrete mix. Using IS: 5816 - 1970 as a guide, we performed a split tensile strength test. Gradually increasing the force until the specimen cracked, measurements were taken.

After 28 days, the splitting tensile strength was calculated using the relationship.

$$fct = \frac{2P}{\pi d l}$$

where,

f_{ct}=The Specimen's Breaking Tensile Strength

P=Samples Subjected to Maximum Load

L=Size of the Sample

D=The Specimen's Cross-Sectional Size

Flexural Strength Test

At 28 days, three replicate 100 mm x 100 mm x 500 mm prismatic specimens were cast from each fiber reinforced concrete mix and subjected to a flexural strength test, as required by IS: 516 - 1959. The specimen was positioned in the middle of a 1000 kN capacity Universal Testing Machine. It was loaded at both ends. This formula was used to determine the flexural strength:

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

f_b = Specimen Flexural Strength

P = Specimen Subjected to the Greatest Possible Load (N)

L = Distance Covered (mm)

B = Specimen Width as Measured

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D = Failure Depth (in mm) Measured From the Center of the Specimen

3. Results

Cube Compressive Strength

The outcomes of the compressive strength tests were studied. The analysis results are described below. Compressive strength test findings for cube specimens of control and HFRC mixes at various ages, including 7, 14, 28, and 56 days, are graphically displayed in Figure The addition of hybrid fibers by volume fractions of 0% steel fiber + 1% PVA fiber, 0.25% steel fiber + 0.75% PVA fiber, 0.5% steel fiber + 0.5% PVA fiber, 0.75% steel fiber + 0.25% PVA fiber, or 1% steel fiber + 0% PVA fiber results in an increase in cube compressive strength of 3.56%, 9.89%, 11.42%, 21.08%, and 14.83% at 28 days compared to the control mix. HFRC 0.

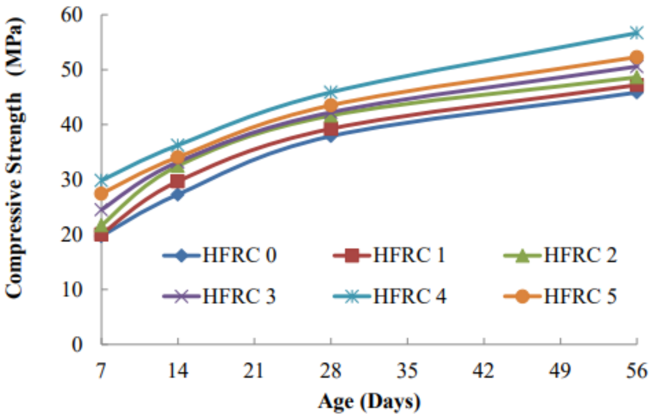

Figure 1: sComparison of Cube Compressive Strength at 7, 14, 28, and 56 Days between Control Concrete & HFRC

The maximum cube compressive strength of 45.89 MPa was achieved by the mix HFRC 4, which included 0.75% steel fiber and 0.25% PVA fiber, compared to a cube compressive strength of the control concrete mix HFRC 0, an increase of 21.08%. Table displays the calculated compressive strength activity indices for HFRC mixtures. For every given amount of curing time, the ratio of HFRC mix compressive strength to control concrete mix compressive strength is known as the "compressive strength activity index."

Table2: HFRC Cube Activity Index for Compressive Strength

Sl. No.	Mix Identification	Volume of Fiber (%)		Activity Index			
		PVA Fiber	Steel Fiber	7days	28days	14days	56days
1	HFRC1	1.00	0.00	1.02	1.04	1.09	1.03
2	HFRC0	0.00	0.00	1.00	1.00	1.00	1.00

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3	HFRC4	0.25	0.75	1.51	1.21	1.33	1.24
4	HFRC2	0.75	0.25	1.10	1.10	1.19	1.06
5	HFRC5	0.00	1.00	1.39	1.15	1.25	1.14
6	HFRC3	0.50	0.50	1.24	1.11	1.22	1.10

The increase in cube compressive strength of HFRC mixes expressed in percentage as compared to that of control concrete mix is presented in Table. The percentage increase in cube compressive strength is more in respect of HFRC 4 produced with the addition of 0.75% steel fiber&0.25%PVA fiber.

Table3: Compressive Swelling of a Cube as a Function of The Superiority of HFRC over Control Concrete in Terms of Tensile Strength

S. No..	**MixIdentification**	**Volume ofFiber(%)**		**There is an increase in compressive strength between the treated and control concrete. (%)**			
		PVA Fiber	**SteelFiber**	**7days**	**28days**	**14days**	**56days**
1	HFRC3	0.50	0.50	24.25	11.42	21.62	10.29
2	HFRC1	1.00	0.00	1.57	3.56	8.72	2.94
3	HFRC5	0.00	1.00	39.12	14.83	24.88	14.04
4	HFRC2	0.75	0.25	9.89	9.89	19.05	6.04
5	HFRC4	0.25	0.75	51.34	21.08	32.83	23.57
6	HFRC0	0.00	0.00	0.00	0.00	0.00	0.00

Cylinder Compressive Strength

In Figure, we see a visual representation of the compressive strength in a cylinder of hybrid fiber reinforced concrete mixtures at 7, 14, 28, and 56 days. Hybrid fiber reinforced concrete mixes show an increase in cylinder compressive strength of 2.68%, 7.16%, 9.56%, 19.05%, and 13.85% at 28 days when hybrid fibers are added at volume fractions of 0% steel fiber + 1% PVA fiber, 0.25% steel fiber + 0.75% PVA fiber, 0.5% steel fiber + 0.5% PVA fiber, 0.75% steel fiber + HFRC 0.

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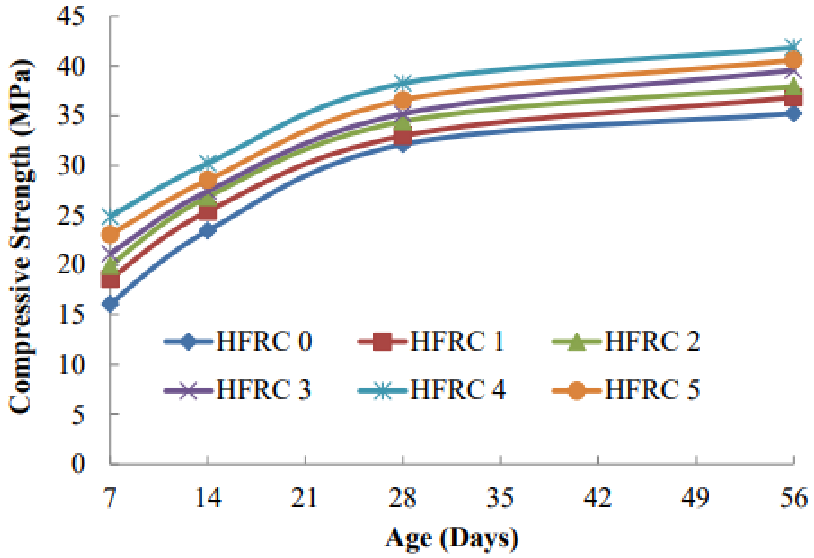

Figure 2: Compressive Strength Growth in Cylinders of Control and HFRC at 7, 28, and 56 Days

The maximum cylinder compressive strength was also found in the HFRC 4 hybrid fiber reinforced concrete mix, which included 0.75 percent steel fiber and 0.25 percent PVA fiber, and which was 38.24 MPa, representing a 19.05% improvement over the cylinder compressive strength of the HFRC 0 control mix. Cylinder compressive strength test results analysis reveals that 0.75 percent steel fiber & 0.25 percent PVA fiber by volume fraction is the optimal dosage of hybrid fibers to concrete mix for achieving maximum cylinder compressive strength. Table displays the activity indices for cylinder compressive strength in relation to HFRC mixtures.

Table4: HFRC Activity Index for Cylinder Compressive Strength

Sl.No	Mix Identification	Volume of Fiber(%)		Activity Index			
		PVA Fiber	Steel Fiber	7days	28days	14days	56days
1	HFRC3	0.50	0.50	1.32	1.10	1.17	1.12
2	HFRC1	1.00	0.00	1.16	1.03	1.08	1.05
3	HFRC5	0.00	1.00	1.43	1.14	1.22	1.15
4	HFRC2	0.75	0.25	1.24	1.07	1.14	1.08
5	HFRC4	0.25	0.75	1.55	1.19	1.29	1.19
6	HFRC0	0.00	0.00	1.00	1.00	1.00	1.00

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In Table, we see the % increase in HFRC mixes' cylinder compressive strength in comparison to the control concrete mix. The HFRC 4 made with the inclusion of 0.75 % steel fiber & 0.25 % PVA fiber has a higher percentage improvement in cylinder compressive strength.

Table5: Cylinder Volume Growth Rate HFRC Compressive Strength Compared to Control Concrete

S. No..	Mix Identification	Volume of Fiber(%)		There is an increase in compressive strength between the treated and control concrete. (%)			
		PVA Fiber	SteelFiber	7days	28days	14days	56days
1	HFRC3	0.50	0.50	31.51	9.56	16.89	12.29
2	HFRC5	0.00	1.00	43.46	13.85	21.66	15.12
3	HFRC2	0.75	0.25	24.28	7.16	14.50	7.66
4	HFRC4	0.25	0.75	54.79	19.05	28.83	18.73
5	HFRC1	1.00	0.00	15.63	2.68	8.32	4.54

SplitTensileStrength

In Figure, we have a bar chart depicting the values of the split tensile strength of the control concrete mix and the hybrid fiber reinforced concrete mixes after 28 days. At the end of 28 days, the split tensile strength of cylinders made from HFRC concrete mixes ranges from 3.17 N/mm2 to 4.25 N/mm2 . Split tensile strength is increased by 8.20%, 14.20%, 19.24%, 24.07%, and 27.13% for HFRC mixes 1, 2, 3, 4, and 5, respectively, when compared to control concrete. Table displays the % increase in split tensile strength between HFRC mixes or control concrete.

Table6: Improvement in HFRC Split Tensile Strength Relative to Control Concrete Expressed as a Percentage

S. No.	Mix Identification	Volume of Fiber(%)		Split Tensile Strength of 28-Day-Old Concrete Improves Over Control After (%)
		PVAFiber	SteelFiber	
1	HFRC 2	0.75	0.25	14.20
2	HFRC 0	0.00	0.00	0.00

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3	HFRC 5	0.00	1.00	27.13
4	HFRC 3	0.50	0.50	19.24
5	HFRC 1	1.00	0.00	8.20
6	HFRC 4	0.25	0.75	34.07

Table compares the control concrete or HFRC mixes' activity indices for split tensile strength.

Table 7: Hybrid Fiber Reinforced Concrete's Activity Index for Split Tensile Strength

S. No..	MixIdentification	VolumeofFiber(%)		Activityindex
		PVAFiber	SteelFiber	
1	HFRC2	0.75	0.25	1.14
2	HFRC0	0.00	0.00	1.00
3	HFRC4	0.25	0.75	1.34
4	HFRC1	1.00	0.00	1.08
5	HFRC3	0.50	0.50	1.19
6	HFRC5	0.00	1.00	1.27

Flexural Strength

Figure is a bar chart depicting the flexural strength values of 28-day-old prism specimens of both the control concrete mix and the hybrid fiber reinforced concrete mixes. Flexural strength is increased by 10.31%, 15.71%, 19.07%, 30.54%, & 25.88% for HFRC mixes HFRC 1, HFRC 2, HFRC 3, and HFRC 4, and by 10.31%, 15.71%, 19.07%, 30.54%, and 25.88% for HFRC 5. The maximum value for flexural strength is found in HFRC 4, which is composed of 0.75 percent steel fiber and 0.25 percent PVA fiber.

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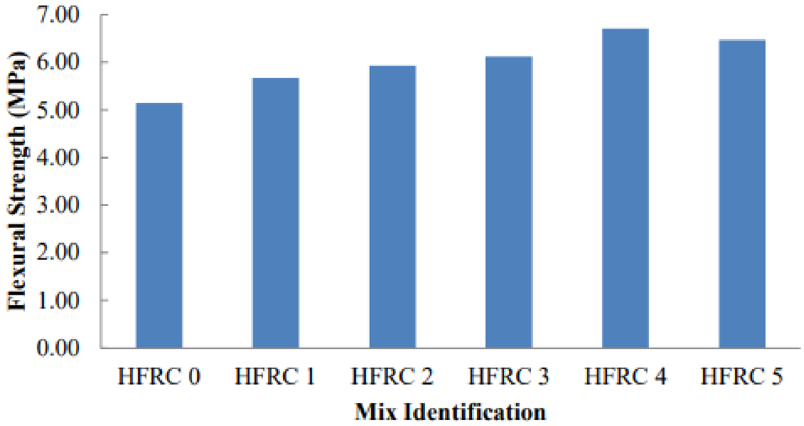

Figure3: Strength at 28 Days of Flexure for Control or Hybrid Fiber Reinforced Concrete

How Mechanical Properties of HFRC Are Linked

In order to better understand the link between the cube compressive strength and the split tensile strength and the cube compressive strength and the flexural strength of hybrid fiber reinforced concrete mixtures, empirical equations have been formulated. It is clear from comparing the cube compressive strength and also the split tensile strength of HFRC in Figure that there is a strong correlation between the two. This correlation between the two measures of fortitude may be written out as:

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

$$R^2 = 0.9615$$

Where,

f_{th}=The Tensile Split Strength of HFRC(MPa)

f_{ch}=Strength of HFRC Cube Compression (MPa)

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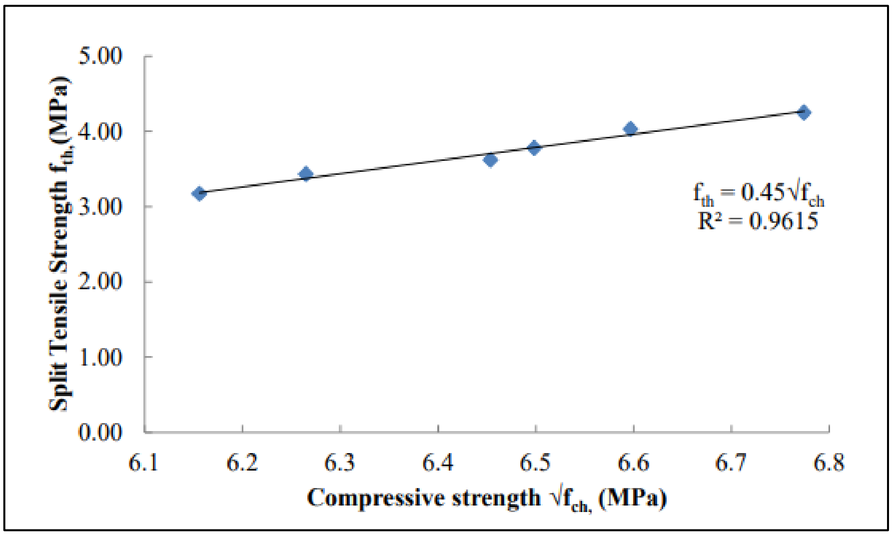

Figure4: Split tensile strength and compressive strength of high-performance reinforced concrete (HFRC)

The connection between flexural strength and cube compressive strength of HFRC is shown graphically in Figure. You may explain the connection between the two types of toughness in the following way:

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

$$R^2 = 0.9445$$

Where

f_{fh}=High-Strength Flexible Composites (MPa)

f_{ch}=Strength of HFRC Cube Compression (MPa)

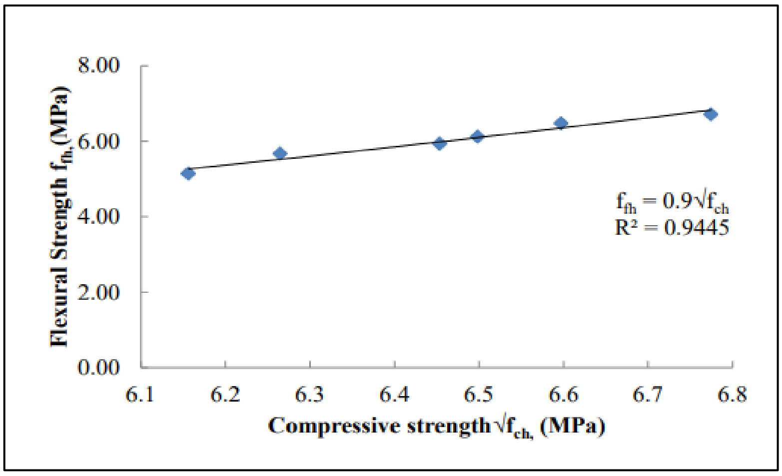

Figure 5: The Flexural and Compressive Strength of High-Performance Concrete (HFRC) and Its Connections

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4. Conclusion

Experimental findings on the strength properties of a concrete mix with hybrid fiber reinforcement are given. The best strength is achieved in Hybrid Fiber Reinforced Concrete, which is made by incorporating hybrid fibers at a volume fraction of 1%, with a mix proportion of 0.75 percent Steel fiber and 0.25 percent PVA fiber by volume of concrete. By using a hybrid fiber combination of 0.75 percent steel fiber and 0.25 percent PVA fiber by volume of concrete, compressive strength is enhanced by 21.08% compared to control concrete, and compressive strength in cylinders is raised by 19.05%. The tensile strength increases dramatically when HFRC blends are separated. Compared to a control concrete mix, the split tensile strength of 28-day-old HFRC 4 mix with 0.75 percent steel fiber and 0.25 percent PVA fiber is 34 percent higher (HFRC 0). The flexural strength of HFRC mixtures is enhanced. In comparison to the control concrete mix, the flexural strength of HFRC 4 mix (0.75% steel fiber and 0.25% PVA fiber) is 1.31 times greater after 28 days (HFRC 0).

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