STUDY OF FLEXURAL BEHAVIOR OF HYBRID FIBRE REINFORCED CONCERETE

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Abstract: Plain concrete has numerous micro-cracks and is brittle in tension. As soon as the load is applied, microcracks begin to propagate in the concrete matrix. Micro- and macro-crack propagation is slowed by the inclusion of randomly spaced discontinuous fibres. Plain concrete's mechanical qualities, such as impact resistance, fracture resistance, and dynamic load resistance, are also improved by the addition of fibres. The present study used HFRC (monofilament and fibrillated polypropylene fibres) with lengths of 12mm and an aspect ratio of 300 in cast concrete in equal percentages of 0.9 percent by weight is added in concrete with a combination of (50%-50%) at each volume fraction, and Compressive strength, flexural strength, and split tensile strength tests were all carried out. The results show an increase in percentage of 0.9% of hybrid fibre reinforced specimen compared with the control specimen. There is an increase of about 15.85% in ultimate load of beams with fibres compared to control specimen. The compressive strength of hybrid fibre specimen is 24.35% more than the control specimens and the tensile strength of the hybrid fibre specimen is 11.74 % more than the control specimen. The variation in crack number and their propagation and the increment in the ultimate load is mainly due to the hybrid fibres used in beam.

Keywords: Monofilament & Fibrillated polypropylene fibres, Compressive strength, Flexural strength and split tensile strength.

1. Introduction

When fibers of more than two type were combined in a combined matrix to form a composite which could take advantage from each of the constituent fibers and demonstrates a dynamic response, it is called hybrid composite. The addition of short discontinuous fibers improves the mechanical characteristics of concrete significantly which increases elastic modulus, reduces brittleness, and regulates fracture initiation, growth and propagation. Concrete is the utmost commonly used in the construction of the buildings in the world. Concrete is stronger in compression but weak in tension. Ordinary cement concrete has low tensile strength, ductility and resistance to abrasion. Internal microcracks, resulting in brittle concrete fracture. Many studies have been conducted to improve the brittle fracture behavior concrete by incorporating additional ingredients into the mix. Short discontinuous and discrete fibers are added to plain concrete to improve post cracking behavior.

1.1 Effects of fiber in concrete

- Synthetic fibers are most commonly added to concrete in order to reduce the shrinkage cracks.
- Shrinkage cracks are small, uneven fissures that appear in concrete within the first 24 hours after placing.
- Gradual decrease in the permeability and reduction in bleeding of water
- Greater strength in impact, abrasion in concrete can be achieved.
- Rebar's can be completely replaced by the synthetic fibers

1.2 Benefits of fiber reinforced concrete

- Reduces shrinkage cracks in plastic and improves impact and abrasion resistance.
- Reduction in crack width thus improving durability.
- Fibers act as a multi-dimensional reinforcement and helps in the uniform distribution of tensile stress.
- In scenario of a severe fire, improve resistance to explosive spalling.
- Fibers are naturally hydrophobic; they don't absorb water. As a result, water seepage can be controlled.
- It acts a secondary reinforcement for a concrete.
- The rate of speed of construction is also high.
- Fibers are light in weight and easy to handle.
- Reduces steel corrosion, segregation, and bleeding of concrete during placement.

- For bar bending work, there is a low inventory space requirement and human power is minimized.

1.3 Polypropylene fiber reinforced concrete

Polypropylene fibers are hydrophobic, and they will not absorb water and are not corrosive in nature. They have good resistance to alkali, chemicals, and chloride, as well as they have low conductivity. By these characteristics polypropylene fiber has no outcome on the water requirement of new concrete. They don't interfere with cement hydration and so doesn't have an adverse effect on the effects of all ingredients in the concrete mixture. The lightest synthetic polymer is polypropylene. As a result, in the case of polypropylene, the fiber count for a given weight is maximum. They are also available in a triangular cross-section, unlike other fibers. A triangular fiber as 29% greater surface area than a circular fiber, according to a simple calculation. The higher the surface area, the greater the reinforcement, and it is easy to use and disseminate. Fibers ranges in length from 6mm to 24mm, longer fibers hold various components of concrete together, but shorter fibers increase the number of fibers, resulting in improved reinforcement, crack prevention and increased concrete strength. These polypropylene fibers can be used in structural field to reduce or replace steel in concrete, especially in floors and in some precast. To achieve better outcomes, customized fiber bending can be given. The long fibers provide better anchoring and strengthening, as well as increasing the number of fibers in a given dosage, avoiding fracture formation. It is suitable for load bearing structures made of heavy structural concrete. It is the most often used macro fiber, and it provides better results.

1.4 Application of fiber reinforced concrete

- Resistant to shrinkage and cracking floors, driveways, and walkways are preferred.
- Structures and pavements subjected to shatter, impact, abrasion, and shear are excellent for fiber reinforced concrete with improved toughness.
- It is used to reduce permeability and freeze thawing conditions in water retention and reservoir constructions through crack management and shrinkage.
- Its usage as alternative for temperature steel in sanitary sewage tunnels and minimizes corrosion and improves ductility.
- To make airport runways more resilient to fuel leaks, low permeable, shatter-resistant fiber reinforced concrete is employed.
- Fiber makes concrete projects easier and safer by avoiding segregation and making the concrete more cohesive.

1.5 Advantages and Limitation of Fiber Reinforced Concrete

- It improves concrete's impact and shatter resistance, as well as its fatigue endurance and shear strength.
- Installing reinforcement does not necessitate the use of any specific equipment.
- Improve the toughness, resistance to cracks, ductility for long term, and energy absorption capacity of concrete.
- In concrete applications, reduce labor and material expenses.
- Concrete reinforcement in multiple directions is provided.
- All types of cement and concrete combinations are compatible with it.
- Reduce the amount of shrinkage in the plastic and the size of the cracks that emerge.

2. Literature Survey

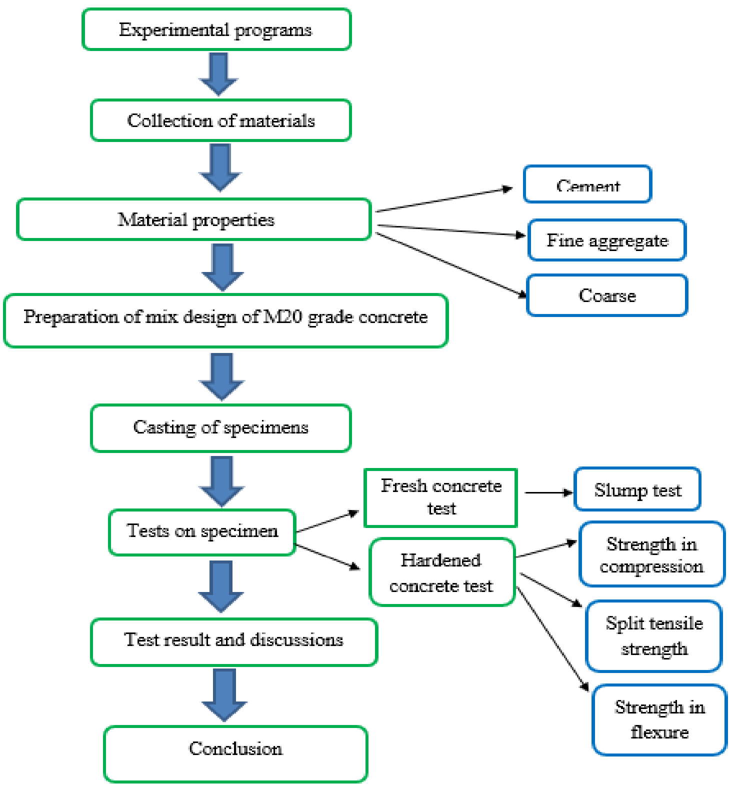
Maheswaran Chellapandian evaluated the influence of the structural fibers on behavior of beams in shear which are reinforced with Glass fiber reinforced polymer (GFRP) rebar. Finding the proficiency of the macro synthetic polyolefin (PO) polymers and fusion of PO fibers and steel fibers in enhancement of shear behavior in beams is the main objective of this study. The fibers percentages used in this study are 0.35%, 0.70% and 1% of the volume of the concrete. The end results designated that the stiffness of the beam, ductility and the peak load resisted increased compared to the control beams.

Divya S Dharan polypropylene fiber blended (24mm,40mm,55mm) in various percentage (0.5%, 1%, 1.5% and 2%) were added to concrete in this project. Properties like workability, strength in compression, resistance to flexure, strength in tensile and elasticity modulus. Cubes and cylinders were casted and validated at the end of 7th and 28th day also 100 X 100 X 500mm beams were casted and tested after 28 days to determine flexural strength. The results indicated that when related to conventional concrete, the strength in compression of 1.5% blended length polypropylene fiber reinforced concrete, there a 22% increment in tensile strength, 24 % increase in flexural strength and 11 % increase in modulus of elasticity.

2.1 Objectives

- To study the strength properties like compressive, split tensile.
- To study the flexural behavior of hybrid fiber reinforced concrete.

2.2 Methodology



2.2.1 Mix Design

Table 1 Material quantity in concrete mix

Particulars	
Slump	75mm
Water/ cement ratio	0.50
Water	209 liters
Cement	418 kg/m^3
Coarse aggregate	1254 kg/m^3
Fine aggregate	627 kg/m^3
Hybrid fibers	0.9 kg/m^3

2.2.2 Material Test

Table.2 Properties of material test

Materials	Properties
Cement	OPC 53 grade conforming to IS :12269
	M20 grade
	Specific gravity- 3.15
	20mm size

Coarse aggregate	Specific gravity- 2.65
	Water absorption- 0.8%
	Specific gravity- 2.5
	Water absorption- 2%
Steel	Fe 500 grade

2.2.3 Polypropylene Fiber Reinforced Concrete

Polypropylene fibers of 2 different types are used in this study. One is Synthetic Fibrillated Mesh Fiber and other is Synthetic Monofilament Fiber. The fibers are provided by Kalyani polymers private limited which is located in Bangalore, India. The fibers come in form of 0.9kg per cubic meter of concrete. Length of the fiber is 12mm.The parameters and specification of fibers are listed in a table below.

Table 3 Synthetic Fibrillated Mesh Fiber Properties

Parameters	Specifications
Material	Polypropylene
Colour	Natural
Specific Gravity	0.91
Melting point	165°C
Diameter / Thickness	40 Microns
Tensile Strength	600 Mpa
Young's Modulus	3.5 Gpa
Aspect Ratio	> 150

Fig 1 Synthetic Fibrillated Mesh Fiber

Table 4 Synthetic Fibrillated Mesh Fiber Properties

Parameters	**Specifications**
Material	Polypropylene
Colour	Natural
Specific Gravity	0.91
Melting Point	165°C
Diameter / Thickness	20 Microns
Tensile Strength	1000 Mpa
Young's Modulus	4 Gpa
Aspect Ratio	>300

Fig 2 Synthetic Monofilament Fiber

3.0 Experimental Setup

The test specimens were made using mix ratio of 1:1.5:3, which is equivalent to M20 grade concrete. To evaluate the e strength of concrete in compression, a standard cube specimen of 150mm X 150mm X 150mm was employed. For split tensile strength, cylinder with a diameter of 150mm and height of 300mm, and for flexural test, beam specimen of 200mm depth 150mm width and 2000mm length are used.

3.1 Compressive Strength

The test was performed was performed on a 150mm X 150mm X 150mm cube specimen. The compressive test was carried out by placing the cube in the CTM machine having a capacity of 20 ton.

Fig 3 Compressive test of cube specimen

3.2 Split Tensile Strength

Cylindrical specimen having dimension 150mm diameter and 300mm height were prepared to determine tensile strength. The specimen is kept under CTM machine of capacity 20tons.

Fig 4 Split Tensile test of cylindrical specimen

3.3 Flexural Strength

The simply supported RC beam is tested under the four-point loading as shown in the figure. Firstly, the beam is lime washed to show the fine textures of the crack pattern and to make fractures obvious. A 50-ton capacity of loading frame was used to test all the beam specimens without and with fiber. The effective span of all the beams was 2000mm. 3 dial gauges were to determine deflection of beam. Three dial gauges are used for deflection measurement. one dial gauge is placed exactly at the center of the beam and other two at the both sides of the central one at a distance of 600mm from the support. The load is applied for every 2KN.

Fig 5 Experimental setup of beam

Table 5 Load analysis of beam

Specimen	First crack load (kN)	Ultimate load (kN)	Average ultimate load (kN)	Increase in strength, %
CB1	18	80	83	15.85
CB2	20	82		
FB1	24	96	95	
FB2	26	94		

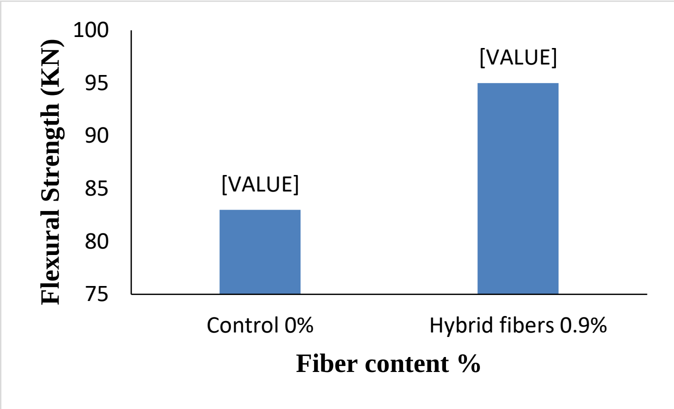


Fig 6 variation of flexural strength of concrete

Beam specimens were casted to test the flexural strength. Control specimens which are tested were failed at a load of 83KN. The specimens with 0.9% hybrid fibers failed at a load of 95KN. As a result, the specimens with 0.9% hybrid fibers increased in flexural strength up to 15.85%.

4.Result and Discussions

4.1 Compressive Test

A total of 6 specimens were tested, three control specimens and other 3 specimens were fiber concrete mix. The results of compression strength are taken for 28 days. It is noticed that by adding fiber in concrete, compressive strength increases compared to control specimen as shown in the figure.

The strength in compression of specimen is formulated by:

strength in compressive (Mpa) = $\frac{P}{\frac{c}{s}\text{ of cube}}$ Where, P is load at failure

Table 6 Compressive strength of the specimens

Type of specimen	Specimens	Compressive strength (Mpa)	Avg. compressive strength (Mpa)	Increase in strength, %
Control	C1	21.78	23.49	24.35
	C2	25.90		
	C3	22.78		
0.9% hybrid fibers	F1	29.64	29.21	
	F2	27.46		
	F3	30.52		

Cube specimens were casted to test the compressive strength. Control specimens which are tested were failed at a load of 23.49 MPa. The specimens with 0.9% hybrid fibers failed at a load of 29.21 MPa. As a result, the specimens with 0.9% hybrid fibers increased in compressive strength up to 24.77%.

4.2 Split Tensile Test

A cylinder that splits across the vertical diameter is used to test the tensile strength of concrete. Three cylinders tested in each category and the average value is provided. Table shows the results of observing the failure load and calculating the strength. Totally 6 samples were tested after 28 days of curing in that 3 were control specimens and their average value is reported. When compared to normal concrete, adding hybrid fibers to concrete increased tensile strength. As a split tensile strength, the following formula was used:

Strength in tensile (Mpa) = $\frac{2P}{\pi DL}$

Where, P is load at failure D is cylinder diameter, L is cylinder length

Table 7 Tensile strength of specimen

Type of specimen	**Specimens**	**Tensile strength (Mpa)**	**Avg. Tensile strength (Mpa)**	**Increase in strength, %**
Control	C1	2.20	2.33	11.58
	C2	2.29		
	C3	2.50		
0.9% hybrid fibers	F1	2.56	2.60	
	F2	2.62		
	F3	2.60		

Cylinders were casted to test the split tensile strength. Control specimens which are tested were failed at a load of 2.33 MPa. The specimens with 0.9% hybrid fibers failed at a load of 2.60 MPa. As a result, the specimens with 0.9% hybrid fibers increased in tensile strength up to 11.58%.

5.Conculsion

The study was carried on flexural strengthening of beam specimens with hybrid FRC. Two groups of beams, the first of which consists of two control specimens (CB) (CB-1 and CB-2) and the second group (FB) has two beams (FB1 and FB2) that are reinforced with hybrid fiber reinforced concrete. Based on the tests conducted on beams and cylinders and cubes the following findings were made.

- HFRC (polypropylene) of 0.9% mix shows a rise in compressive strength compared with the control specimen.
- There is an increase of about 15.85% in ultimate load of beams with fibers compared to control specimen.
- The compressive strength of hybrid fiber specimen is 24.35% more than the control specimens and the tensile strength of the hybrid fiber specimen is 11.74 % more than the control specimen.
- The various properties like failure load, compressive strength, split tensile strength were better in beams with fibers.
- The hybrid fibers utilized in the beam are primarily responsible for the variation in crack number and propagation, as well as the increase in ultimate stress.

References:

1. Amal Dev, Maheswaran Chellapandian, and Shanmugam Suriya Prakash (2020), “Effect of Macrosynthetic and Hybrid Fibers on Shear Behavior of Concrete Beams Reinforced with GFRP Bars”, American Society of Civil Engineers (ASCE), Volume 07.pp. 04020031-1-04020031-16.

2. Ibrahim G. Shaaban, Mohamed Said, Sadaqat U. Khan, Mohamed Eissa, and Khalifa Elrashidy (2021), “Experimental and theoretical behavior of reinforced concrete beams containing hybrid fibres”, Elsevier Journal, Volume 32.pp. 2143-2160.

3. Divya S Dharan and Aswathy Lal (2016), “Study the Effect of Polypropylene Fiber in Concrete”, International Research Journal of Engineering and Technology (IRJET), Volume 06.pp. 616-619.

4. Parveen and Ankit Sharma (2013), “Structural Behavior of Fibrous Concrete Using Polypropylene Fibers”, International Journal of Modern Engineering Research (IJMER), Volume 03.pp. 1279-1281.

5. K.Nagamani and Asvin Raj.K (2016), “ Experimental Study on Effect of Fibers for Reinforced Concrete”, International Journal of Engineering Research & Technology (IJERT), Volume 04.pp. 1-5.

6. Manu P.P and Eldhose Cheriyan (2019), "Flexural Behavior of Hybrid Steel Basalt Fiber Reinforced Concrete", International Research Journal of Engineering and Technology (IRJET), Volume 05.pp. 760-764.

7. A. Annadurai and A. Ravichandran (2016), "Flexural Behavior of Hybrid Fiber Reinforced High Strength Concrete", Indian Journal of Science and Technology, Volume 09. pp. 1-5.

8. Abid.S. Mulla and Akshata A. Mulgund (2016), "An Investigation on Mechanical Properties of Hybrid Reinforced Concrete", International Research Journal of Engineering and Technology (IRJET), Volume 05. pp.2680-2687.

9. Amit Rana (2013) "Some studies on steel fiber reinforced concrete", International Journal of Emerging Technology and Advanced Engineering (IJETAE), Volume 03. pp.120-127.

10. Denvid Lau and HoatJoen Pamb (2010), "Experimental study of hybrid FRP reinforced concrete beams", Engineering Structures, Volume.32, pp.3857–3865.

11. V. Ramadevi, and D.L. Venkatesh Babu (2012), "Flexural behavior of hybrid (steel and polypropylene) fiber reinforced concrete beams," European Journal of Scientific Research, Volume. 70. pp. 81-87.