

# Characteristics And Behaviour of Hybrid Fiber Reinforced Concrete

Saravanan. N<sup>1</sup>, Arunvaratharaj T<sup>2</sup>, Parthiban L<sup>3</sup>, Geetha H<sup>4</sup>

<sup>1,2,3,4</sup> *Asst. prof, Department of Civil Engineering, Roever Engineering College, Perambalur*

**Abstract**—This project report represents the characteristics and behavior of hybrid fiber reinforced concrete which is added with polypropylene and steel fibers. Concretes containing different types of hybrid fibers and volume fractions (0, 0.5, 1.0, and 1.5) were compared in terms of compressive, splitting tensile and flexural properties. This study aims to characterize and quantify the behavior of hybrid fiber reinforced concrete. For this purpose nine mixes, one plain control mix and eight fiber reinforced mixes were prepared. Six of the mixes were reinforced in a hybrid form. Four different types of fibers were used in combination, two of which were macro steel fibers, and the other two were micro fibers. Two types of hybrid composites were constructed (cube and Cylinder) using fiber combinations of polypropylene and steel fibers. Test results showed that the fibers, when used in a hybrid form, could rest in superior composite performance compared to their individual fiber reinforced concretes. Among the two types of hybrids, the Steel fiber combination gave concrete of the highest strength and flexural toughness because of the similar modulus and the synergic interaction between the two reinforcing fibers. Various analysis were carried out to quantify the determined mechanical properties and to describe the effects of fiber inclusion on these mechanical properties.

## I. INTRODUCTION

### 1.1 General

The most widely used construction material today. It is versatile, has desirable engineering properties, can be molded into any shapes and more importantly is produced with cost-effective materials. There is an old saying that broken stone, sand, and cement make good concrete. But the same proportion of broken stone, sand and cement also make bad concrete. To make good concrete now variety of innovative materials such as fibres, admixtures and construction chemicals, pozzolana and different concrete making techniques are Concrete is by far adopted in present day

construction. In recent years, intensive research has resulted in advances and innovation in the technology of fibres such as glass, polypropylene, carbon etc., and more basic knowledge has been gained on the behavior of cement concrete containing these fibres. Concrete containing hydraulic cement, water, aggregate, and discontinuous discrete fibres is called fibre-reinforced concrete. The incorporation of short discrete fibres (steel, polypropylene, glass, carbon) can lead to use full improvements in the mechanical behavior of tension weak concrete. Fibre reinforced concrete has been studied over the last few decades because it is found to improve the failure mode and increase the resistance of plain concrete. Plain concrete is known as a brittle material, weak in tension and have low resistance to cracking. This can be overcome by adding short discontinuous or fibrillated fibres such as synthetic, steel, natural, and glass fibres in concrete. Each

type of fibre lends different properties and benefits to the concrete. Apart from being used as reinforcement, fibres are also effective in arresting cracks from forming and propagating at micro cracks and macro cracks level. Fibre helps to reduce the widening of crack because of the mechanical bond between the cement paste and fibre. Fibre added in concrete has also been found to be effective in controlling cracking due to plastic shrinkage and drying shrinkage. The presence of more than one type of fibres in concrete can further enhance the mechanical properties compared to the existing single type fibre in a single mixture. This can be achieved by fully utilizing the properties of each fibre effectively in the concrete mixture. In this study, the combined fibres in concrete are known as hybrid fibre reinforced concrete composite. The failure mode of HFRC is not abrupt. This is because the load carrying capacity beyond the first crack increases when the randomly oriented fibres

crossing the cracked section resisted the cracks from spreading and avoid the section from splitting. The strength of concrete increases with the addition of steel fibres, but in order to produce concrete with homogenous tensile properties, the formation of micro cracks must be eliminated. Synthetic fibre such as polypropylene fibre (PPF) is effective to reduce the formation of micro crack, where as steel fibre (SF) is found good for arresting macro crack.

The hybridization of fibres can control the formation of micro and macro Tracks. Fibres such as PPF when added in concrete will reduce the compressive strength, but at the same time increase both the tensile and flexural strengths . Meanwhile, SF offers improve tensile strength by the increase ductility, reduce crack formation and increase fatigue resistance . Therefore, combining SF and PPF in plain concrete may improve the mechanical properties of concrete , which is also the main concern of this study. Therefore, the main objective of this study is to determine the mechanical properties of HFRC which combines SF and PPF in concrete.

### 1.2 Objective and Research Significance

The aim of this study is first to develop hybrid fiber reinforced concrete (HFRC), and then to characterize and quantify the benefits obtained by the concept of hybridization. Compressive strength, flexural tensile strength, impact resistance, and toughness in bending are the measured mechanical properties of the HFRC mixes in this study. To open new application areas, FRC should be designed so as to perform with adequate strength, sufficient ductility, high durability, and adequate workability. Utilizing the concept of hybridization, a concrete with superior properties can be developed. Ductility and strength of concrete can be improved at lower fiber contents, where fibers are used in combination rather than reinforcement with a single type of fiber. Limiting the high aspect ratio fiber content, without compromising the ductility and the strength of the concrete, problems associated with workability can be eliminated. Durability problems concerning one type of fiber may be offset with the presence of a second type of fiber. Results obtained from this study are expected to contribute to the efforts made to characterize the mechanical properties of HFRC. With the appropriate interpretation of the obtained results, it can be possible to make various optimization analyses like optimization for a desired

mechanical property or optimization for a certain fiber type and content.

### 1.3 Steel Fiber Reinforced Concrete (SFRC)

The early theoretical studies, initiated by Romualdi, Batson, and Mandel, in the 1950's and 1960's focused mainly on the characteristics of steel fiber reinforced concrete (SFRC). Only straight steel fibers were used in the beginning. Though remarkable improvements in toughness and ductility were obtained, problems in mixing and workability were encountered. These problems were overcome with the advent of deformed steel fibers and high range water reducers. Today steel is the most commonly used fiber type for concrete reinforcement, with the exception of asbestos fibers . Though modest improvements in strength can be obtained, the primary purpose of steel fiber inclusion to concrete is to increase toughness and ductility. Steel fibers are used for crack control, to replace secondary reinforcement, which is also used for this purpose. The increase in toughness can prevent or minimize cracking due to temperature changes, relative humidity etc. Steel fiber inclusion also increases the resistance to dynamic loading.

It is possible to produce steel fibers in many ways. Round fibers are produced by cutting or chopping wires. Flat fibers may be produced either by shearing sheets or flattening wires. Crimped and deformed steel fibers of various shapes are also produced, in which deformations may extend through the length of the fiber or may be limited to the end portions. Some fibers are collated into bundles using watersoluble glue dissolving during the mixing process, in order to ease handling and mixing. Depending on the type of steel and the type of production technique, steel fibers may have tensile strengths of about 280-2800 MPa, and ultimate elongations of about 0.5% to 3.5% . Steel fiber types with different geometric properties (a) straight (b) waved (c) crescent (d) Class C hooked end (e) hooked end (f) single hooked end

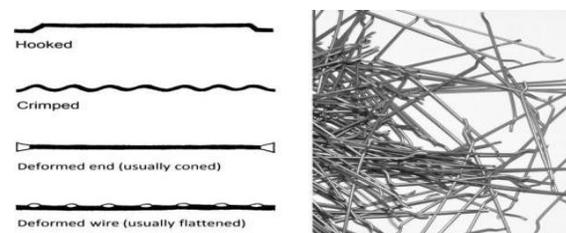


Fig.1 Steel Fibres

1.4 Polypropylene Fiber Reinforced Concrete (PPFRC)

Synthetic fibers have attracted more attention for reinforcing cementitious materials in the recent years. In this part emphasis is given on polypropylene fibers, as they were used throughout the experimental program. Polypropylene fibers were suggested as an admixture to concrete in 1965 for construction of blast-resistant buildings for the U.S Corps of Engineers. Results of this research work showed that polypropylene fibers could be practical for reinforcing concrete, since polypropylene is cheap, abundantly available, and possess a consistent quality. Considerable improvements in strain capacity, toughness, impact resistance, and crack control of concrete can be obtained through the use of polypropylene fibers. Polypropylene fibers are manufactured in various shapes and different properties. The polypropylene fibers are made of high molecular weight isotactic, a type of polymer chain configuration where in all side groups are positioned on the same side of the molecule, polypropylene. The macromolecule has a sterically regular atomic arrangement, thus polypropylene fibers can be produced in a crystalline form, and then processed by stretching to achieve a high degree of orientation, which is necessary to obtain good fiber properties. The polypropylene fibers can be produced in three different geometries, monofilaments, film, or extruded tape. The polypropylene film consists of amorphous material and crystalline micro fibrils. However these films are weak in the lateral direction. Thus using specially designed machines, splits are induced in the longitudinal direction and fibrillation is facilitated. It is used at present as discontinuous fibrillated material for the production of FRC by the mixing method, or as a continuous mat for production of thin sheet elements. The modulus of elasticity of both the monofilament and the fibrillated polypropylene is usually about 3.5 GPa, and the tensile strength is about 560 to 770 MPa. The geometry of fibrillated polypropylene is difficult to quantify. It can be described in terms of film thickness and the width of the individual filaments, or alternatively by measuring the specific surface area by adsorption techniques.



Fig.2 Polypropylene Fibre

Properties of Steel Fibre

- Type : Hooked end
- Diameter : 0.3mm
- Length : 30mm
- Aspect ratio : 100
- Appearance : Clear, Bright, Flat and Hooked Steel fibre
- Application : Industrial floors, Tunnel shot create
- Density : 7850 kg/m<sup>2</sup>

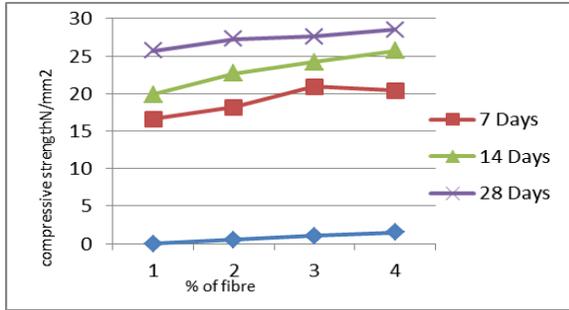
Properties of Polypropylene Fibre

- Appearance : Polypropylene Fibre
- Specific Gravity : 0.91 g/cm<sup>3</sup>
- Alkali Content : Nil
- Sulphate Content : Nil
- Chloride Content : Nil
- Fibre Thickness : 6 Denier
- Young's Modulus : 5500 – 7000 MPA
- Tensile Strength : 360 MPA
- Melting Point : 160<sup>oc</sup>
- Fibre Length : 12mm

1.5 Result and discussion

Compression Test Results				
Days/VF	0%	0.5%	1%	1.5%
7 Days	16.6	18.2	22.4	22.8
14 Days	20.2	23.5	25.1	27.9
28 Days	26.7	28.3	29.6	31.4

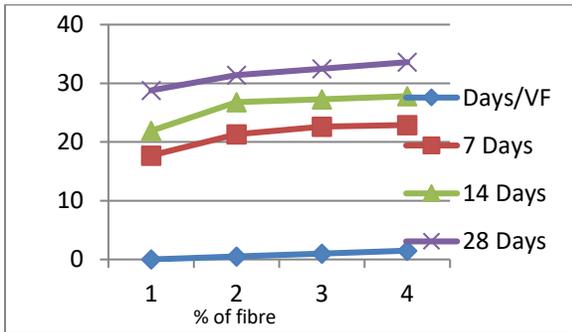
Table.1 Compression test on cube combination (SF = 80%, PP=20%)



Graphical representation on Compression test (SF = 80%, PP=20%)

Table.2 Compression test on cube combination (SF=70%, PP=30%)

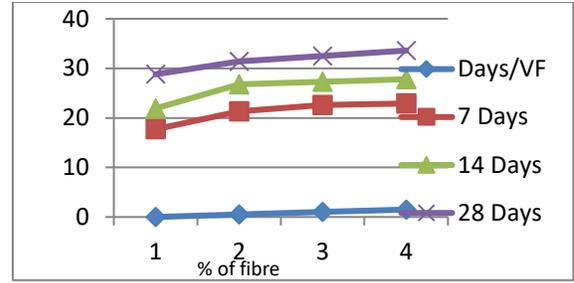
COMPRESSION TEST RESULTS				
Days/VF	0%	0.5%	1.0%	1.5%
7 Days	17.7	21.3	22.6	22.9
14 Days	21.9	26.8	27.3	27.8
28 Days	28.8	31.4	32.5	33.6



Graphical Representation of Compression Test (SF=70%,PP=30%)

Days/VF	0%	0.5%	1.0%	1.5%
7 Days	16.6	18.2	20.9	20.4
14 Days	19.9	22.7	24.2	25.7
28 Days	25.7	27.3	27.6	28.5

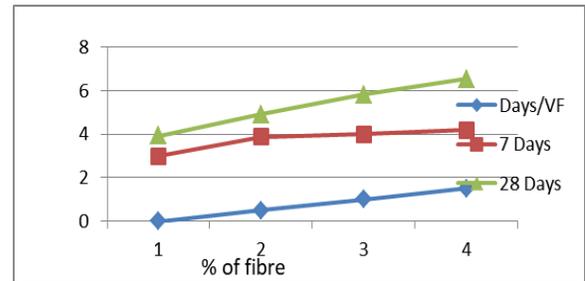
Table .3 Compression test on cube combination (SF = 60%, PP=40%)



Graphical Representation of Compression Test (SF=60%,PP=40%)

Split tensile test Result				
Days/VF	0%	0.5%	1%	1.5%
7 Days	2.98	3.88	4.00	4.19
28 Days	3.92	4.90	5.81	6.53

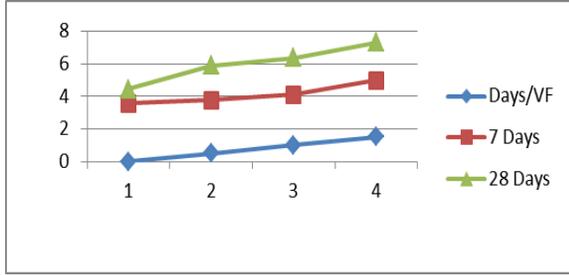
Table.4 Split tensile test on cylinder volume fractions (SF = 80%, PP=20%)



Graphical presentation on Split tension test (SF=80%, PP=20%)

SPLIT TENSILE TEST RESULTS				
Days/VF	0%	0.5%	1.0%	1.5%
7 Days	3.58	3.77	4.09	4.96
28 Days	4.44	5.90	6.34	7.29

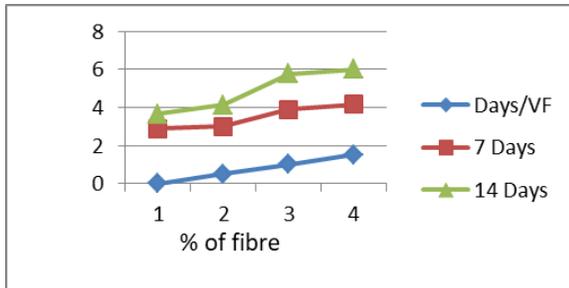
Table.5 Split tensile test on cylinder volume fractions (SF = 70%, PP=30%)



Graphical presentation on Split tension test (SF=70%, PP=30%)

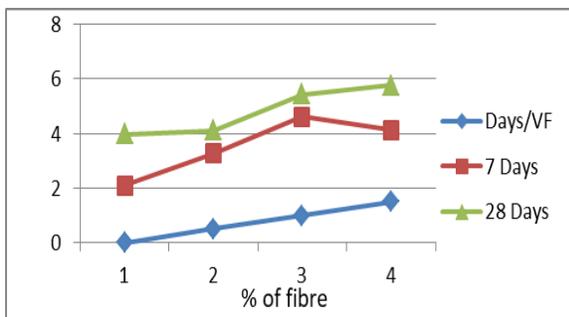
SPLIT TENSILE TEST RESULTS				
Days/VF	0%	0.5%	1.0%	1.5%
7 Days	2.87	3.01	3.89	4.16
14 Days	3.66	4.13	5.77	6.01

Table.6 Split tensile test on cylinder volume fractions (SF = 60%, PP=40%)



Graphical presentation on Split tension test (SF=60%, PP=40%)

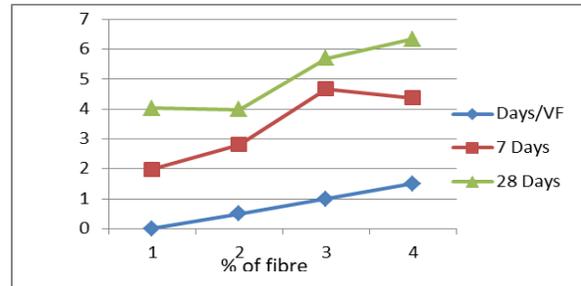
Table.7 Flexural test on prism volume fractions (SF = 80%, PP=20%)



Graphical Representation on Flexural Test (SF=80%, PP=20%)

FLEXURAL TEST RESULTS				
Days/VF	0%	0.5%	1.0%	1.5%
7 Days	1.98	2.81	4.67	4.37
28 Days	4.03	3.98	5.70	6.34

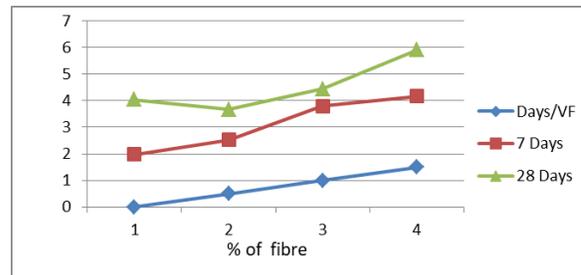
Table.8 Flexural test on prism volume fractions (SF = 70%, PP=30%)



Graphical Representation on Flexural Test (SF=70%, PP=30%)

FLEXURAL TEST RESULTS				
Days/VF	0%	0.5%	1.0%	1.5%
7 Days	1.98	2.53	3.80	4.17
28 Days	4.03	3.67	4.43	5.90

Table.13 Flexural test on cube volume fractions (SF = 60%, PP=40%)



Graphical Representation on Flexural Test (SF=60%, PP=40%)

## II. CONCLUSION

Based on the research studies the following conclusions can be made:

- The performance characteristics of polypropylene and steel fibers were dependent on the optimum

fiber dosage up to 0.45% and 2% since fiber addition resulted in loss of workability.

- Compressive strength of material increases with increasing fiber content. Strength enhancement ranges from 8% to 16% for PFRC.
- During the test it was observed that the FRC specimen has grater crack control due to reduction in crack widths and spacing. The flexural strength increases with increase in fiber content.
- The increase in compressive strength was found to be around 24% with the use of polypropylene and steel fibers compared to the reference concrete.
- Compressive strength was found out to be maximum for a mix of 0.3% PP and 1% SF.
- The maximum increase in flexural strength was found to be around 43 % and the role of polypropylene and steel fibers in preventing the crack formation were realized.

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