

Performance of Supplementary Cementitious Material based Hybrid Fibre Reinforced Concrete

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ABSTRACT: The addition of fibres into the brittle concrete shall impart tensile nature. The addition of two or more fibres in the concrete named as Hybrid Fibre Reinforced Concrete (HFRC) which derives more benefits from each of the individual fibres than the Single Fibre Reinforced Concrete (SFRC). As a part of research work, the present experimental investigation focus on the properties of HFRC using various percentages of Polypropylene and steel fibres for M15 grade of concrete. To control the propagation of micro crack to macro crack, polypropylene fibres of recron 3s (PPF - 0.1%, 0.2%, 0.3%, 0.4%) and double hooked end steel fibres (SF- 0.5%, 1.0%, 1.5% and 2%) are incorporated in concrete and optimum results are observed. To observe the transformation of concrete from brittle to ductile and to find the performance of HFRC, the stress strain behaviour of HFRC was studied by comparing with individual fibre incorporation. It is observed that hybridization of metallic and non-metallic fibres has the ability to arrest the propagation of micro and macro cracks in the cement matrix of the concrete with increased extensibility and tensile nature.

KEYWORDS: Hybrid fibres, Micro cracks, Macro cracks, Mechanical properties, Polypropylene fibre, Steel fibre, Stress strain curves, Young's modulus.

I. INTRODUCTION

Concrete is a composite material, mainly consist of coarse aggregate and fine aggregate bonded together with cement. Concrete is strong in compression and weak in tension. Now-a-days due to recent developments, concrete has become more and more compressive than the rise in the tensile nature and ductility. The addition of various classes of fibres will impart the ductile nature reducing the brittleness on the whole. The transformation of concrete from brittleness to ductile can be obtained by incorporating fibres. This makes the concrete more homogenous and isotropic [2]. Short discrete fibres, which are randomly oriented, shall improve various aspects of overall structural integrity. The major disadvantage of conventional concrete is it develops small cracks and propagates and deteriorates. Similarly, when that concrete member subjected to loading there is a rapid propagation of these cracks which leads to ultimate failure of the material. In this modern age, every structure has its durability requirements and hence to meet this purpose, modification in traditional cement concrete has become mandatory. To overcome these types of disadvantages, fibre materials are incorporated in the concrete such that the mechanical properties durability and survivability of the structure are improved [2]. This method was investigated many decades back.

Fibres has great role to control the cracking due to plastic shrinkage and due to drying shrinkage [9]. By 1960's fibres such as steel fibres, glass fibres and synthetic fibres such as polypropylene fibre and polyolefin fibres has have great importance. Basically, fibres are divided in to two categories 1) High elastic modulus like: nylon, cellulose and

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polypropylene fibres. 2) Low elastic modulus like: steel, glass, fiber, etc. Fibres having low elastic modulus are added to concrete to improve strain performance of the concrete, whereas fibre having high modulus enhances strength performance of concrete. The present study deals with the hybrid reinforced concrete [1],[4] having polypropylene and steel fibres as non- metallic and metallic fibres.

II. RELATED WORK

Related works and review on PFRC, SFRC, HFRC and SCM based HFRC.

Anand S, Leeladhar Pammar [2016]. In this study, hybrid fibers consist of glass and polypropylene. The fiber proportions of 0%, 0.25%, 0.5%, 0.75%, 1% and 1.25% by weight of cement is used. Strength parameters are tested and results were analyzed. Results show that the maximum increase in compressive strength at 1.0% of addition of hybrid fibers in HFRC is found to be 11.94% as compared to plain cement concrete. Further increase in fibers content decreased the strength of concrete. The maximum increase in split tensile strength of hybrid concrete at age of 28 days is found to be 0.75% of hybrid mix than compared to conventional concrete. Further increase in fibers content decreased the tensile strength. Strength was found to be 21.28% and 10.92% greater than plain cement concrete. During split tensile test it was found that crack formation was slower than conventional concrete. This shows that HFRC is better in arresting the propagation of cracks.

A. Sivakumar, V.M. Sounthararajan and S. Thirumurugan [2013]. Suggested that fibres are the discontinuous reinforcement which are added in concrete to improve the homogeneity and tensile resistance of concrete They investigated the influence of fibre addition in a high strength concrete mix by adding both steel and polypropylene fibres. The test results showed that synergistic improvements in compressive and flexural properties of concrete. The performance of concrete was found to be enhanced with the addition of steel fibre dosage at 1% V (volume fraction) to a maximum of 2% Vf as well as the inclusion of polypropylene fibre dosage at 0.1% Vf to a maximum of 0.3% Vf. The experimental test results showed a maximum increase in compressive strength up to 50.3 MPa with the addition of steel fibres and polypropylene fibres at 1% and 0.1% Vf fibres had resulted in improved flexural strength and split tensile strength of 11.5 MPa and 6.1 MPa compared to conventional concrete. The results also demonstrated that the realization of stress redistribution was observed due to the synergistic interaction among the fibre types added in high strength concrete matrix.

S. Kumaravel, N. Veeragurunath, D. Anandram, E.Vairavi [2015]. In the investigation of influence of hybrid fibre reinforced concrete, the mechanical properties of Hybrid Fibre Reinforced Concrete with steel (hooked end) and polypropylene fiber in various volume fractions with steel fiber of various ratios (0.5 to 1.25%) and polypropylene fiber of various ratios (0.05 to 0.125) are mixed in based on volume of concrete. The concrete mix design is used as per IS: 10262-2009 in M 25 grade. The results showed that compressive and flexural strengths of the HYFRC can improve 19% and 32% respectively than the conventional mix.

Roohollah Bagherzadeh, Ph.D, Hamid Reza Pakravan, Abdol-Hossein Sadeghi, Masoud Latifi, Ali Akbar Merati [2014]. In the investigation of adding polypropylene fibres to reinforce Lightweight Cement Composites (LWC), the primary objective was to observe the action of PP fibres with different volume fractions and fibre length and the concluded that fibre reinforcement significantly increases the tensile strength of lightweight aggregate concrete. The higher tensile strength and flexural strength it is believed to be effective in reducing shrinkage in lightweight aggregate concrete. As a result of fibres performance in cement matrix all reinforced lightweight concrete specimens show improvement in their mechanical properties. Compared to all fibre proportions and lengths, only the PP fibre with 12 mm length and proportion 0.35 % performed better in all respects compared to the physical and mechanical properties of reinforced lightweight concrete. Consequently, by increasing the volume fraction of PP fibres up to 0.3%, a noticeable improvement in physical and mechanical properties of light weight cement composite is achieved.

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V.M. Sounthararajan and A. Sivakumar [2013]. Conducted experimental study on fly ash concrete with steel fibers at a constant volume fraction of 1.5% with utilization of fly ash up to 50% replacement with cement which showed good composite performance. It was also observed to increase flexural strength for 1.5% steel fiber. Modulus of elasticity of concrete showed maximum strength increase by 35%, when compared to conventional concrete.

M. Nithyalakshmiy, K. Nivetha, I. Bharathidasan [2016]. Conducted a study on Hybrid fibre reinforced flyash based concrete where the report deals with the reinforcing efficiency of hybrid fibres in the low volume fly ash concrete up to 30% replacement of cement. Micro mechanical action of hybrid fibres in fly ash based concrete has improved with respect to different percentage of steel and polypropylene fibre addition in M30 grade. Hybrid fibres in concrete improved the matrix densification, refinement of microstructure, reduction of voids, minimize cracking due to stresses, and enhance the strength gain properties of reinforcement of corrosion resistance, alkali-silica expansion and sulphate attack. The experimental test on mechanical properties such as compressive, split and flexural strength at different ages of curing of concrete are found and compared with the conventional concrete and found to improve for all percentages.

J. Blunt, G.Jen, C.P Ostertag [2015]. Has used steel fibers and polyvinyl alcohol fibers to control micro cracks. Two steel fibers with different aspect ratios were used to control macro cracks. Ultimately, they found that hybrid fiber reinforced composites are effective in delaying corrosion initiation and reducing the rate of corrosion.

Dr.T.Ch.Madhavi, L.Swamy Raju, Deepak Mathur[2012]. An investigation made on “Polypropylene Fibre Reinforced Concrete – A Review” showed that polypropylene fibres reduce the water permeability, plastic, shrinkage and settlement and carbonation depth. Workability decreases with increase in polypropylene fibre volume fraction. However, higher workability can be achieved with the addition of High Water Reducer admixtures even with w/c ratio of 0.3. Polypropylene fibres enhance the strength of concrete. The problem of low tensile strength of concrete can be overcome by addition of polypropylene fibres to concrete. Increase in compressive strength is reported with addition of polypropylene fibres. The failure is gradual and ductile in polypropylene fibre (PF) reinforced concrete. Addition of polypropylene fibres greatly improves the fracture parameters of concrete. The compressive strength, split tensile strength, flexural strength and modulus of elasticity increase with the addition of PF fibre content as compared with conventional concrete.

III.OBJECTIVE OF EXPERIMENTAL STUDY

- To study the mechanical properties of hybrid fibre reinforced concrete by varying polypropylene and steel fibre percentage incorporation in conventional concrete.
- To find the suitability of PPF and SF addition in conventional concrete
- To enhance the tensile properties of conventional concrete by addition of metallic and non-metallic fibres
- To reduce the corrosion effect of steel fibre & the propagation of cracks in conventional concrete.

IV.EXPERIMENTAL RESULTS

4.1 Materials used: - Cement, Fine Aggregate, Coarse Aggregate, Water, Double hooked end Steel and polypropylene fibre, Admixture.

Cement: The Portland cement used in this study is characterized in the laboratory with the following physical properties.

Fine Aggregate: The Fine aggregate conforming to Zone-2 according to IS 383 was used. The fine aggregate used was obtained from a nearby river source. The sand obtained was sieved as per IS sieves (i.e. 2.36, 1.18, 0.6, 0.3, and 0.15mm).

Water: Potable water was used in the experimental work for both mixing and curing.

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Admixture: CONPLAST SP 430 is used as an admixture to improve workability at lower water cement ratio with maximum of 1% of cement weight

Fibres: Polypropylene fibres (Recron 3s) and Double hooked end steel fibres are used. The properties of polypropylene and steel fibre are shown below.

Table 4.1 Test Results on Cement

Description	Result
Fineness	5%
Specific gravity	2.72
Initial setting time	65minutes
Standard consistency	34%

Table 4.2 Test Results of Fine Aggregate

Description	Result
Fineness modulus	2.8
Bulk density	1.57 g/cc
Voids ratio	0.52
Bulking	21.6cm at 3%
Porosity	34.2%
specific gravity	2.4

Table 4.3 Tests Results of Coarse Aggregate

Description	Result
Fineness modulus	7.5
Bulk density	1.5 g/cc
Voids ratio	0.88
Porosity	50.5%
Specific gravity	3.03

Table 4.4 Properties of polypropylene fibre & Double hooked steel fibres

Description	Polypropylene fibres Recron 3s	Double hooked Steel fibres
Length	12mm	30mm
Diameter	18 micron	0.6mm
Specific Gravity	0.9 to 0.91 g/cc	7.8to7.9 g/cc
Aspect Ratio	600	50

Table 4.5 Test results of fresh conventional Concrete

Description	Result
Slump	70mm
Compaction factor	0.79

Table 4.6 Test results of fresh Concrete

Steel fibre %	Polypropylene fibre%	Slump (mm)	Compaction factor
0.5	0.1	120	0.87
1.0	0.2	100	0.78
1.5	0.3	90	0.75
2.0	0.4	60	0.65

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4.2. SAMPLE PREPARATION OF POLYPROPYLENE FIBRE REINFORCED CONCRETE:

Firstly, the required quantity of all ingredients of concrete, PPF (0.1% by volume of specimen) and admixture (1% of cement weight) are calculated for M15 grade for the respective no. of specimens. The quantity of PPF is dispersed in half off the required quantity of water and quantity of admixture is added in to remaining required water and that mixture is stirred thoroughly. Then these are mixed in the aggregate and cement composition to get a homogeneous mix and same is repeated for the preparation of samples for 0.2%, 0.3% and 0.4% of PPF.

4.3. SAMPLE PREPARATION OF STEEL FIBRE REINFORCED CONCRETE:

All the ingredients of concrete which are required for the preparation of normal concrete, SF (0.5% by volume of specimen) and admixture are calculated for M15 grade of concrete for the respective no. of specimens. Before addition of water in concrete mix the quantity of steel fibre is dispersed randomly and mixed thoroughly, then water is added to the dry concrete mixture and mixed thoroughly to prepare a homogeneous SFRC and same is repeated for the preparation samples for 0.5%, 1%, 1.5% and 2% of SF.

V.RESULTS & ANALYSIS

The results obtained from the experimental programme are tabulated and represented in the form of bar charts and graphs. The results are analyzed and based on this analysis the conclusion are drawn.

Table 5.1 Test results of hardened conventional concrete

Description	7days (MPa)	28 days (MPa)
Compressive strength	15.61	22.3
Split tensile strength	1.22	

Table 5.2 Test results of hardened PFRC

PPF %	7 days' Compressive strength of (MPa)	28 days Compressive Strength (MPa)	28 days split tensile strength (MPa)
0.1	33.7	40.69	2.72
0.2	41.7	49.925	4.02
0.3	34.29	48.57	3.465
0.4	33.42	34.22	3.4

Table 5.4 Test results of hardened HFRC

SF%	PPF %	Compressive Strength		28 days Split tensile Strength (MPa)
		7 days (MPa)	28 days (MPa)	
0.5	0.1	39.69	45.55	3.53
1.0	0.2	44.61	52.16	4.71
1.5	0.3	44.75	53.63	4.96
2.0	0.4	41.2	49.18	4.44

Table 5.3 Test results of hardened SFRC

SF %	7 days Compressive strength(MPa)	28 days Compressive strength(MPa)	28 days Split tensile Strength(MPa)
0.5	37.35	42.69	3.34
1.0	34.66	49.26	4.44
1.5	41.66	52.16	4.57
2.0	32.91	44.32	3.88

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(a) (b) (c)

Fig 1 a) Compressive Strength test for conventional concrete, b) Compressive Strength of PFRC with 0.2%PPF addition c) Compressive strength test for SFRC with 1.5% SF addition



(d) (e) (f) (g) (h)

Fig 2 d) Split tensile strength test of SFRC with 1.0% of SF, e) Stress strain test of SFRC 1.0% SF, f) Stress strain test of HFRC with (0.2%PPF+1.0%) addition of PPF and SF respectively, g) Split tensile test of HFRC with (0.2%+1.0%SF) addition of PPF and SF respectively h) Split tensile strength of PFRC with 0.2%PPF addition

5.1 BAR CHARTS:

Chart-1: Comparison of Strength Vs varying fibre percentages of PFRC

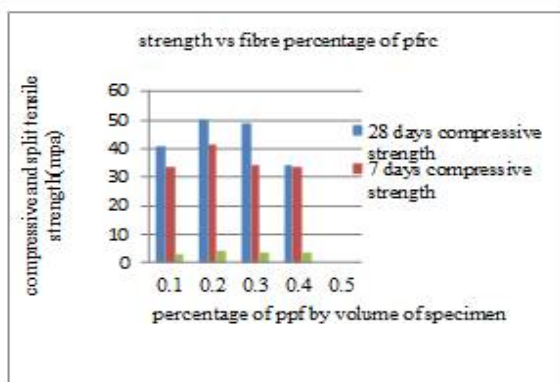
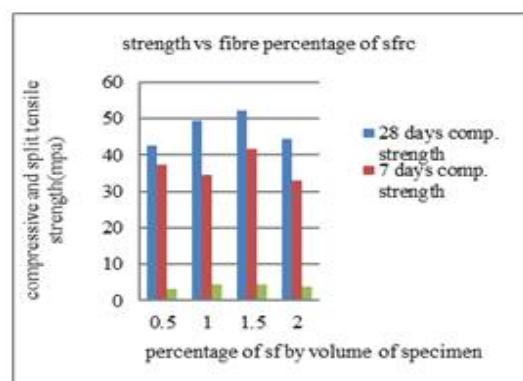


Chart-2: Comparison of Strength Vs varying fibre percentages of SFRC



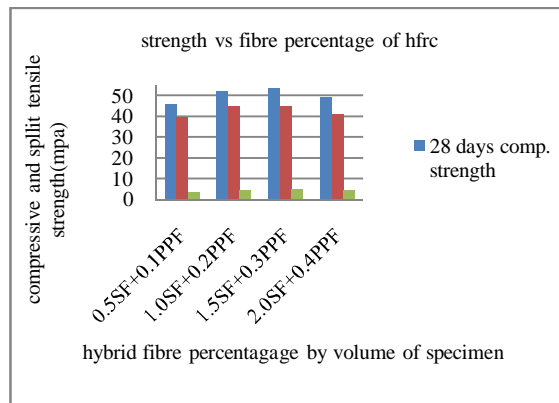
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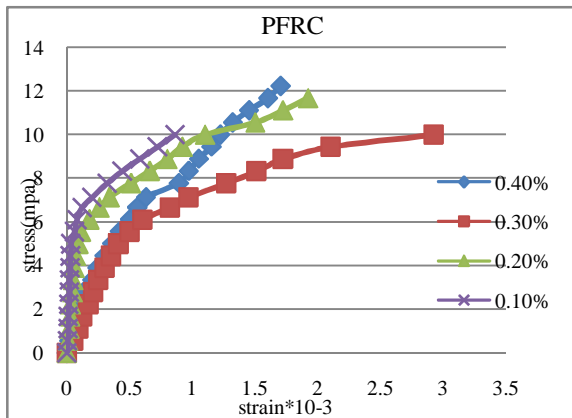
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Chart-3: Comparison of Strength Vs varying fibre percentages of HFRC

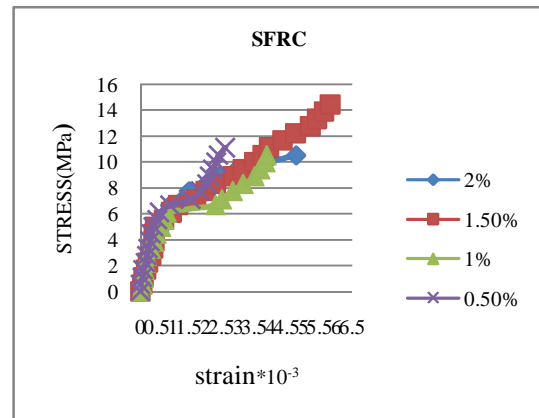


5.2 GRAPHS:

Graph-1: Stress Vs strain curves for varying % of PFRC



Graph-2: Stress Vs strain curves for varying % of SFRC



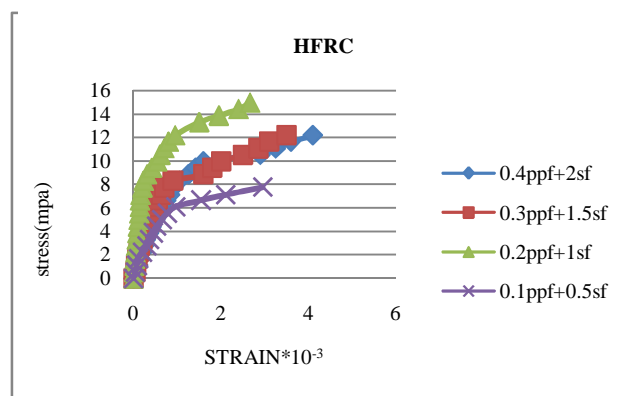
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Graph-3: Stress Vs strain curves for varying % of HFRC



VI. CONCLUSIONS

In this investigation, we observed that the strength of HFRC increased with addition of fibres up to a certain percentage then on further addition of fibres, the values decreased. And it is also observed that the workability is decreased by increasing the fibre content to the concrete.

- From table 5.2, Chart-1, the samples with 0.2% PPF shows the maximum increase at 28 days compressive strength of 55% and split tensile strength has 69% compared to conventional concrete. With the addition of high quantity of PPF, there is a possibility of ball forming in the matrix which causes voids and pores in concrete.
- From table 4.6, the workability of PFRC decreases with increase in the fibre content. This may be because of the addition of fibres causes entrapped air voids in the concrete and hence the increased air content reduces the workability
- From the Graph-1, the stress strain behaviour of PFRC is found to be developed maximum strain at 0.3% of PPF incorporation and corresponding stress is 9.99 and strain is 2.92
- From table 5.3 and Chart-2, the maximum increase in 28 days' compressive strength was 57% and split tensile strength was 73% at 1.5% SF compared to conventional concrete. The bonding of SF with the cement matrix increases, thereby causing ductile from brittle.
- From table 4.6, with the increase of SF the concrete mix becomes non- homogeneity of mix and becomes difficulty during mixing and compaction.
- From Graph-2, the stress strain behaviour of SFRC is found to be developed maximum stress at 1.5% of SFRC incorporation and corresponding stress is 14.43 and strain is 8.82
- From table 5.4 and Chart-3, it is observed that the 0.3%PPF+1.5%SF hybrid fibre has the has the maximum 28 days' Compressive strength of 58.4% and split tensile strength of 75.4% compared to the conventional concrete with the hybrid fibre incorporation in the concrete, both fibres properties are derived to the concrete. Since, with the addition of SF the propagation of macro-cracks is reduced and that of PPF will reduced the propagation of micro-cracks to macro-cracks, thereby enhancing the bonding of fibrous materials with cement matrix.
- From Graph-3, the stress strain behaviour of HFRC is found to be developed maximum stress at 0.4%PPF+2%SF of HFRC incorporation and corresponding stress is 14.985 and strain is 2.66.
- The workability of HFRC decreased with the addition of fibres to the concrete.
- However, the ease of working with the HFRC can be enhanced by addition of admixture in prescribed dosage.

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- The higher the no. of fibres bridging the cement matrix with metallic and non-metallic fibres will reduce the crack propagation in terms of width and openings. However, the bridging effect can be factored by orientation of fibres, aspect ratio, distribution of fibres in the concrete.

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