A Comparative Study Of Polypropylene, Recron And Steel Fiber Reinforced Engineered Cementitious Composites

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Abstract

This study is investigate the response of conventional reinforced concrete and fiber reinforced engineered cementitious composites members on their flexural load- deformation behavior, compressive strength and split tensile strength behavior of concrete. The behavior of flexural load- deformation, split tensile strength and, compressive strength of conventional reinforced concrete member are briefly reviewed and compared with fiber reinforced engineered cementitious composites .Compatible deformations of reinforcement and matrix leads to low interfacial bond stress and prevent the composite disintegration by bond splitting and lower spalling. Furthermore flexural strength as well as crack deformation and widths in fiber reinforced engineered cementitious composites members are found effectively independent of interfacial bond properties due to the tensile deformation characteristics of the cementitious matrix.

Key words: composite, strength, deformation, reinforcement.

Introduction

In steel fiber reinforced concrete, the bars embedded in concrete blocks (Soroushian&Bayasi 1991) to examine the bond improvement gained by using SFRC.The strength and toughness measurement on the range of normal and high strength concrete mixes with and without fiber reinforcements (Taylor et al 1996). The investigations to find out (Krishnamoorthy et al 2000) the influence of corrosion of steel fibers on the strength of SFRC. The concrete specimen was subjected to accelerated corrosion and it was found that there was no corrosion of steel fibers in SFRC even after 250 cycles of corrosion. Addition of steel fibers in concrete matrix has resulted in decreased crack width. It was also noted that the addition of steel fibers in concrete results in delayed cracking of concrete.

The study of an alternate method (Antony J.et al 2001, ACI structural journal) of attaching FRP strips to RC beams. The method utilizes the shelf powder-actuated fasteners to attach pultruded FRP strips to the concrete. Small sized beams strengthened using powder-actuated fasteners attained 65%to 70% increase in strength of the beams strengthened.

The rheology of these concrete is such that they can be reinforced by sufficient volumes of polypropylene and steel fibers to significantly increase their toughness, while their strengths in compression & tension remain relatively constant. Conventional technique for strengthening of concrete structures such as concrete jacketing, shortcreting/gunting, steel plate bonding, micro concreting, etc are cumbersome system of strengthening(Lakshmikanta G.S et al 2004) .

The material strength cannot be directly correlated to the structural strength (Dr.S.C Patodi et al 2007) which seems to increase with the higher ductility. Hence good structural performance requires a balanced material strength and ductility which RECC is able to confirm through ductile failure pattern. The composite fiber wrapping is an effective for strengthening of RC structures. The compressive strength ,split tensile strength and flexural strength of natural aggregate based (Rathish KumarP.et al) self compacting mortars is greater than Recycled –Natural aggregate based concrete . The confinement provided by CFRP improves both the load carrying capacity and ductility of the column (Mohsen Shahawy et al).

The gain in the compressive strength of CFRP confined concrete depends on the ratio of the stiffness of the FRP jacket in the lateral direction to the axial stiffness of the column. The use of quasi-isotropic polymer composite laminates (ChakrabartiP et al) increases both the rotation stiffness and the ultimate strength of fiber reinforced concrete moment frame connection.

Research Significance

Research activities presented in this paper are directed as using fiber reinforced concrete engineered cementitious composites members in structures to reduce residual deflection and prevent inelastic deformations. The resulting of using fiber reinforced concrete engineered cementitious composites members as flexural members are expected to have compatible deformations between reinforcement and matrix. This study aimed at investigating the deformations mechanisms of the composite and their effect on the response of structural members.

Materials

The concrete mix design of all specimens was based on the standard mix design data. The concrete mixture & properties are given in Table1, Table2, Table3, Table3.1, and Table3.2 respectively. The reinforcement material was applied to the volume of the concrete& horizontally provided on the tensile zone of the beam. This system consists of polypropylene, steel & recron fiber .The above fibers is an economic material that offers a combination of physical, chemical, mechanical, thermal & electrical properties not found in any other thermoplastic. The polypropylene fiber has higher compressive strength of concrete; it possesses excellent resistance to organic solvents. The fiber reinforcement was applied in the accordance with the method recommended by the manufacturer of Bosee fiber.

Table 1: Concrete mixtures & properties

Sl.No	Description of Material	Mass of materials
1	Cement	387.5 kg/m^3
2	Fine aggregate	557.9 kg/m^3
3	Coarse aggregate	1180 kg/m^3
4	Water	186 kg/m^3

Table 2

Sl.No	Concrete properties
1	Fineness test=12.33
2	Consistency=32
3	Max aggregate size =20mm
4	Initial setting time=30min

The mix was designed as per IS 10262 and the mix proportion are 1:1.44:3.05

Table 3:Properties of fibers

Table3.1:Properties of various types of polypropylene fibers

Fiber type	Length (mm)	Diameter (mm)	Tensile strength (MPa)	Modulus of elasticity (GPa)	Specific surface (m2/kg)
monofilament	30-50	0.30-0.35	547-658	3.50-7.50	91
microfilament	12-20	0.05-0.20	330-414	3.70-5.50	225
Fibrillated	19-40	0.20-0.30	500-750	5.00-10.00	58

Table 3.2 properties of fibers

Sl.No	Name of the fibers	Aspect ratio
1.	Polypropylene fiber	100
2.	Steel fiber	40-80
3.	Recron fiber	40-80

Role of Fibers

Cracks play an important role as they change concrete structures into permeable elements and consequently with a high risk of corrosion. Cracks not only reduce the quality of concrete and make it aesthetically unacceptable but also make structures out of service. Therefore, it is important to reduce the crack width and this can be achieved by adding polypropylene fibers to concrete. The bridging of cracks by the addition of polypropylene fibers is shown in Fig 1 and Fig 2.

Thus addition of fibers in cement concrete matrix bridges these cracks and restrains them from further opening. In order to achieve more deflection in the beam, additional forces and energies are required to pull out or fracture the fibers. This process, apart from preserving the integrity of concrete, improves the load-carrying capacity of structural member beyond cracking. The major reasons for crack formation are Plastic shrinkage, Plastic settlement, Freeze thaw damage, Fire damage etc.

Figure 1: monofilament fiber

Figure 2: Fibrillated fiber

Fiber mechanism

Fibers work with concrete utilizing two mechanisms, the spacing mechanism and the crack bridging mechanism. The spacing mechanism requires a large number of fibers well distributed within the concrete matrix to arrest any existing micro-crack that could potentially expand and create a sound crack. For typical volume fractions of fibers, utilizing small diameter fibers or micro fibers can ensure the required number of fibers for micro crack arrest.

The second mechanism termed crack bridging requires large straight fibers with adequate bond to the concrete. Steel fibers are considered to be a prime example of this fiber type which is commonly referred to as large diameter fibers or macro fibers. Benefits of using larger fibers include impact resistance, flexural and tensile strengths, ductility, and fracture toughness.

Fiber Matrix Interaction

The tensile cracking strain of cement matrix (less than1/50) is very much lower than the yield or ultimate strain of steel fibers .As a result, when a fiber reinforced composite is loaded, the matrix will crack long before the fibers can be factured.

Once the matrix is cracked, the tensile stress, the peak stress and the peak strain increases continuously and they are higher than those of matrix alone and during the inelastic range between first cracking and the peak, multiple cracking of matrix occurs.

Experimental study

The concrete mix M_{30} investigated in this study is prepared with standard 43 grade ordinary Portland cement and fibres which are conformed to Indian standards. Mix design was carried out according to IS 10262-1982

The materials were weighted accurately using a digital weighing instrument. For plain concrete, fine aggregate, coarse aggregate, cement& water were added and were mixed thoroughly using hand mix. Steel fibers were manually sprinkled inside the concrete after thorough mixing of the ingredients of the concrete. Recron fiber was added to the concrete mix after soaking in water for about 5 minutes as recommended by the manufacturer.

Compressive strength

Standard cube specimens are casted and tested for compressive strength after 7 days and 28 days. For preparing the specimens, the permanent steel moulds size of 150mmx150mmx150mm were used. Before mixing the concrete, the moulds were kept ready. The sides and the bottom of the mould were properly oiled for easy remoulding. After pouring concrete into the mould, Table vibrator was used to compact the concrete and then the top surface was given a smooth finish.

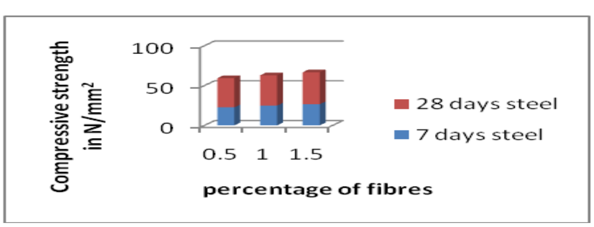
The test specimens were stored in a place free from vibration and kept at a temperature of 27˚±2˚C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients. After this period, the specimen were marked and removed from the moulds and immediately submerged in clean fresh water and kept there until taken out prior to test. The specimens dried for testing.

This test was conducted as per IS 516-1959. The cubes of standard size 150mm x150mm x150mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of Compression Testing Machine (CTM) of capacity 40 tones without eccentricity and a uniform rate of loading was applied till the failure of the cube. The maximum load was noted and the compressive strength was calculated. The experimental result shows that the Compressive Strength of Steel Fiber Reinforced Concrete was greater than Recron Fiber Reinforced Concrete from 0.5%, 1.0%, 1.50% and 2.0% of mix from the Table 4, Table 4.1, and Table 4.2 respecetively; also explain from the graph 1, graph 2, and graph 3.

The compression strength of concrete is a vital parameter as it decides the other parameters like tension, flexure etc. The effect of polypropylene fiber on the compressive strength of concrete has been discussed in many literatures and observed that polypropylene fiber either decreases or increases the compressive strength of concrete, but the overall effect is negligible in many cases. In fact, the effect of a low volume of polypropylene fiber on the compressive strength of concrete may be concealed by the experimental error.

Table 4

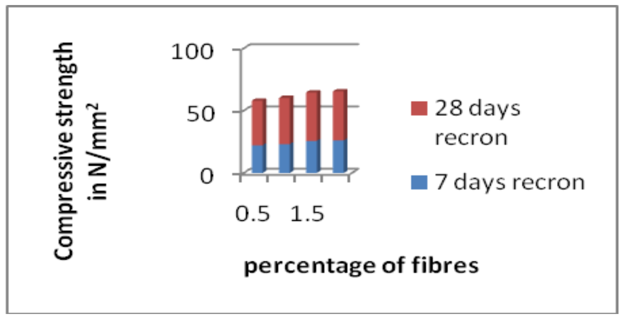
Typesof concrete	Compressive strength (N/mm^2)	
	7 days curing	28 days curing
0.5% steel	22.67	36.62
1.0% steel	24.85	37.93
1.5% steel	26.60	40.11



Graph 1

Table 4.1

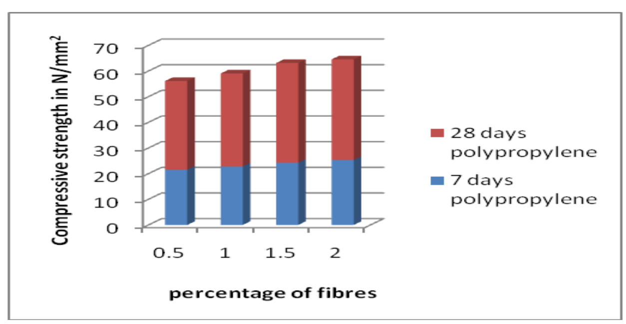
Types of concrete	Compressive strength (N/mm^2)	
	7 days curing	28 days curing
Control concrete	21.8	34.88
0.5% recron	22.24	35.75
1.0% recron	23.10	37.06
1.5% recron	25.72	38.80
2.0% recron	26.16	39.24



Graph 2

Table4.2

Types of concrete	Compressive strength (N/mm^2)	
	7 days curing	28 days curing
Control concrete	20.5	32.33
0.5% polypropylene	21.54	34.58
1.0% polypropylene	22.8	36.24
1.5% polypropylene	24.27	38.85
2.0% polypropylene	25.29	39.25



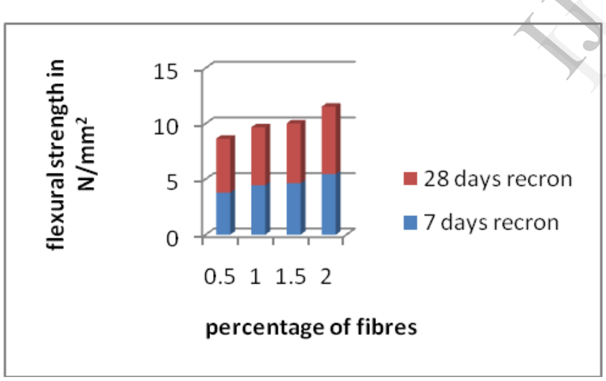
Graph 3

Flexural strength

The Specimen of size 500mm x100mm x 100mm is placed on the bed of the testing machine (i.e.) on two Steel Rollers of 38mm diameter. The Specimen is placed such that the Span between two supports is 40 cm. The load is applied using the Flexural Strength Machine. The load at failure was noted. The results of these flexural tests have been presented in Table 5,Table 5.1andtable 5.2 respectively. From the graph it is revealed that the performance of fibre reinforced concrete increased from 0.5%, 1.0%.1.5%& 2.0% compared to the conventional concrete.

Table 5

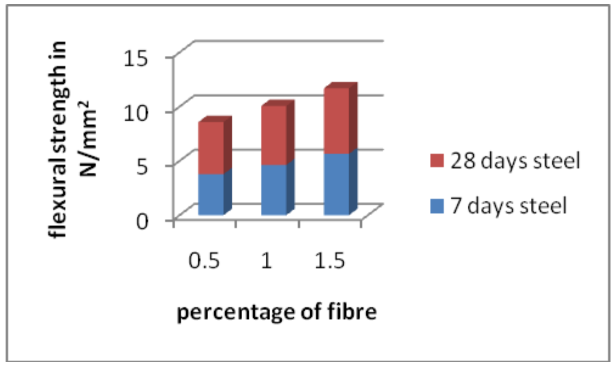
Types of concrete	Flexural strength (N/mm^2)	
	7 days curing	28 days curing
Control concrete	3.48	4.5
0.5% recron	3.78	4.86
1.0% recron	4.45	5.22
1.5% recron	4.62	5.4
2.0% recron	5.46	6.07



Graph 4

Table 5.1

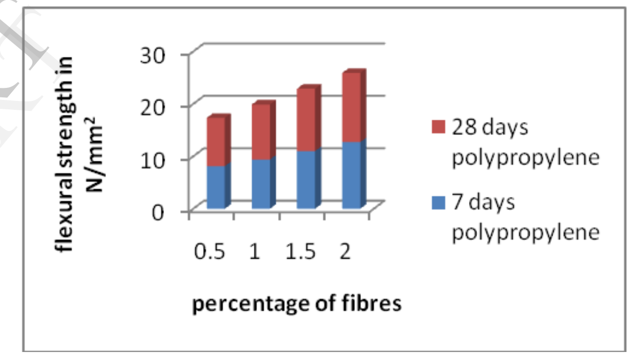
Types of concrete	Flexural strength (N/mm^2)	
	7 days curing	28 days curing
0.5% polypropylene	8.12	9.22
1.0% polypropylene	9.4	10.5
1.5% polypropylene	11.0	11.9
2.0% polypropylene	12.7	13.2



Graph 5

Table 5.2

Types of concrete	Flexural strength (N/mm^2)	
	7 days curing	28 days curing
0.5% steel	3.78	4.8
1.0% steel	4.62	5.44
1.5% steel	5.65	6.04



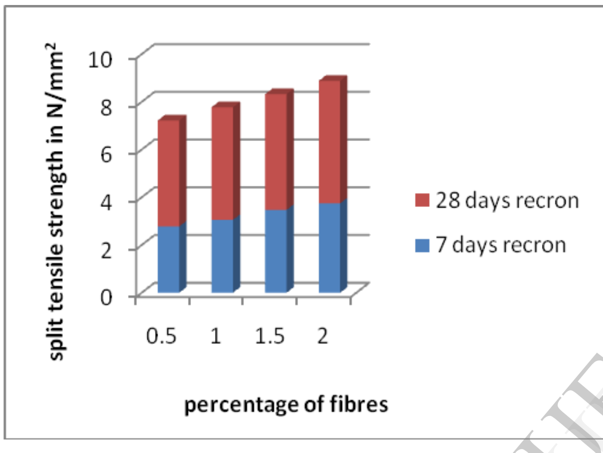
Graph 6

Split tensile strength

This test was conducted as per IS 5816-1999. The Cylindrical Specimen of standard size 150mm diameter and 300 mm height was placed on the CTM with capacity of 40 tones, with the diameter horizontal. The load was applied till the specimen fails. The failure of the Specimen is noted by the formation of cracks. The maximum load was noted down and the Split tensile strength was calculated. From the results the Split Tensile Strength of Steel Fiber Reinforced Concrete was greater than Recron Fiber Reinforced Concrete at all percentage of mix and have been shown the table 6,table 6.1,and table 6.2 respectively.

Table 6

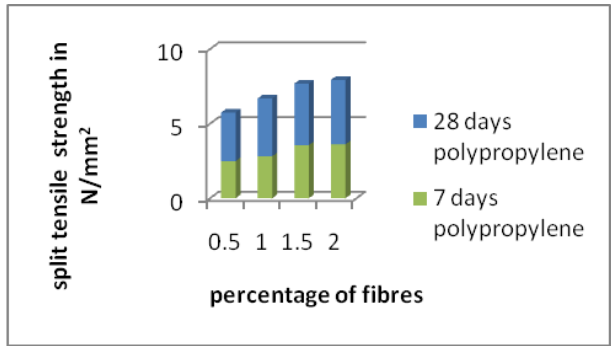
Types of concrete	Split tensile strength (N/mm^2)	
	7 days curing	28 days curing
0.5% polypropylene	2.49	3.25
1.0% polypropylene	2.82	3.87
1.5% polypropylene	3.56	4.12
2.0% polypropylene	3.61	4.32



Graph 6

Table 6.1

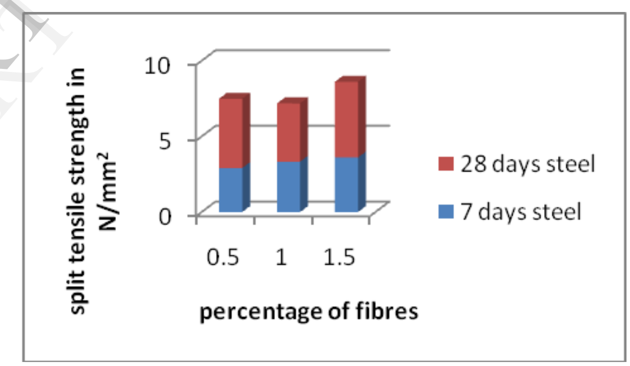
Types of concrete	Split tensile strength (N/mm^2)	
	7 days curing	28 days curing
Control concrete	2.64	4.16
0.5% recron	2.78	4.44
1.0% recron	3.05	4.72
1.5% recron	3.47	4.85
2.0% recron	3.75	5.13



Graph 7

Table 6.2

Types of concrete	Split tensile strength (N/mm^2)	
	7 days curing	28 days curing
0.5% steel	2.91	4.58
1.0% steel	3.33	3.85
1.5% steel	3.61	5.00



Graph 8

Conclusions

An experimental study was conducted on cubes, cylinders, beam, for compressive, split tensile strength, flexural test respectively by mixing various percentages of polypropylene, recron & steel fiber. Based on the investigation the following conclusions were drawn. They are

- The Compressive Strength of Steel Fiber Reinforced Concrete was 1.35% greater than Recron Fiber Reinforced Concrete at all percentage of mix.
- The Split Tensile Strength of Steel Fiber Reinforced Concrete was 0.15% greater than Recron Fiber Reinforced Concrete at all

percentage of mix

- The Flexural Strength of Steel Fiber Reinforced Concrete was greater than Recron Fiber Reinforced Concrete at all percentage of mix, except at 0.5%. In 0.5%, the Flexural Strength was same for both Concrete.
- The Split Tensile Strength of Steel Fiber Reinforced Concrete was 0.81% greater than polypropylene Fiber Reinforced Concrete at all percentage of mix.
- The Flexural Strength of Steel Fiber Reinforced Concrete was greater than Recron Fiber Reinforced Concrete at all percentage of mix, except at 0.5%. In 0.5%, the Flexural Strength was same for both Concrete. For polypropylene fiber reinforced concrete the Flexural Strength was 2.15% greater than Steel Fiber Reinforced Concrete.
- For Recron, up to 2.0% mix was done as the Workability of 2.5% mix was "Very low", which is not recommended.
- For Steel, up to 1.5% mix was done as the Workability of 2.0% mix was "Very low", which is not recommended

Hence Steel Fiber has greater strength when compared to Recron Fiber, in Compression, Split Tension and Flexure. So, Steel Fiber can be used to achieve greater strength with V_f up to 1.5% by weight of Cement, if used without any Admixtures.

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