

Experimental Study on Behaviour of Polymer Modified Steel Fiber Reinforced Concrete

G. Raveendra Prasad¹, K. Venkateswara Rao²

P.G Scholar (Structural Engineering), Gudlavalleru Engineering College, Gudlavalleru, AP, India¹

Associate Professor (Civil Engineering), Gudlavalleru Engineering College, Gudlavalleru, AP, India²

ABSTRACT: An experimental investigation will be carried out to study the toughness of polymer modified steel fiber reinforced concrete. The Volume fraction of steel fibers will be varied from 2% to 3.5% at the interval of 1% by weight of cement. 10%, 12.5% and 15% of styrene butadiene rubber (SBR) latex polymer used by weight of cement.

The specimens of Cubes of size 150 × 150 × 150 mm for compressive strength, prism specimens of size 100 mm × 100 mm × 500 mm for flexure strength and, specimen of size 150 × 150 × 150 mm with 16 mm diameter tor steel bar of length 650 mm embedded in concrete Cube at the centre for bond test will be prepared.

Various specimens will be tested after 28, and 56 days of curing for a M60 grade of concrete. Area under curve (toughness) will measure and will be mentioned in this work.

KEYWORDS: hooked end steel fibres, compressive strength, flexure strength, toughness, pull-out (bond) test, super plasticizer and polymer.

I. INTRODUCTION

Concrete is one of the most promising construction materials with regards to its strength, high serviceability, structural stability and relative low cost. To achieve impressive gains in safety, functionality and economy materials technology have been enabled, and functionality of structure is built to serve the common needs of society. There are clear indications that the use of fibres and polymer in concrete will increasingly continue to be the preferred choice for many repair and rehabilitation projects involving construction of bridges, Industrial floors, airport pavements, overlays, high rise buildings, TV towers, parking garages, offshore structures, historic monuments etc.

The advancement of the building industry is associated with continuous research, development and design of new and improved materials and construction of structures. The construction of mega structures requires materials with increasingly improved properties; particularly toughness is focused on the inclusion of additives, polymeric admixtures, and fibers to improve certain physical and mechanical properties, though keeping its strength, low cost and capacity to fill almost any shape.

Toughness is expressed as a ratio of the amount of energy required to deflect the beam to a specified deflection expressed as multiples of first crack energy (deflection); i.e. toughness is the energy absorption capacity of a composite. Toughness is an important attribute of fiber reinforced concrete. It is one of the important mechanical performance parameters to be insured in the design of special applications, such as, earthquake resistant structures, impact resistant structures and tunnel linings.

Toughness plays a vital role in reinforced cement concrete structures. Fiber reinforcement has been shown to improve the toughness, ductility, flexural strength and bond between steel and concrete of cementations materials, to reduce shrinkage cracking and permeability and to enhance fatigue and impact resistance. Fiber reinforcement is used to improve the ductility of cementations composites.

Control of cracking automatically improves the mechanical properties of the composite material. The most significant property of steel fiber reinforced concrete is its post-cracking strength that can impart the ability to absorb large amounts of energy before collapse. The efficiency of the fiber reinforcement of the matrix depends on the geometry, size, type, volume and dispersion of the fibres in concrete.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 5, May 2018

Inclusion of fibres in concrete improves the toughness, structural ductility, high-temperature, fire sensitivity, and impacts fatigue strength and strength in tension. It is reported that the hooked steel fibres have the highest toughness compared with straight, deformed and corrugated steel fibres.

One of the most important properties of steel fiber concrete is its ability to transfer stresses across a cracked section. This ability is mostly translated into a toughness parameter, which is a measure for the energy consumed during a bending. It has shown that there is a high degree of proportionality between the toughness and the number of effective fibres that are counted in the cracked section.

In this study toughness characteristics of steel fiber reinforced concrete modified with SBR latex polymer are investigated. Toughness results of present concrete composite under compression, flexure and bond with varying fiber volume fraction are reported and discussed.

II. LITERATURE REVIEW

1) L.N.Vairagade & V.M.Bhedi (2015)

"The paper experimental investigation steel fibers have been used to study the effect on flexural strength on M30 grades of concrete". Reinforced concrete is used for sustainable and long-lasting concrete structures.

Steel fibers are widely used as a fiber reinforced concrete all over the world. Addition of fibers to conventionally beams increases the fatigue life and decreases the crack width under fatigue loading.

It is found that the addition of steel fibers into concrete increases its flexural strength with increase in fiber content after 7, 14 and 28 days of curing. It has been observed that the flexural strength increases for 0.75% and 1.5% of steel fibers in conventional concrete whereas it decreases in case of 2%.

2) Manjunath V Melkundi & Vaijanath Halhalli

A concrete mix grade of M25 is aimed, the designed mix proportion is obtained by IS method of mix design. Then to the target strength of designed mix obtained, the steel fibers and SBR- latex are added. Various trial mixes were carried out to obtain optimum dosage of super plasticizer, silica fume and steel fiber with regards to get required workability. For SBR (10%, 15%) +SF (0.75%) +M25, the suitable mix ratio adopted is 1: 1.21: 2.07 with w/b ratio of 0.44.

Among the four mixes in the present investigation namely M25, SBR+M25, SF+M25 and SBR+SF+M25, the compressive strength obtained at 28 days are 33Mpa, 26.16Mpa, 35Mpa and 32Mpa respectively. In case of SBR-latex modified concrete there is decrease in compressive strength.

It is experimentally observed that the SBR+SF+M25` has considerable amount of increased in flexural strength.

3) M. Devidson & K. Venkateswara Rao(2017)

The paper Experimental comparative study on the mechanical properties of hooked end steel, crimped steel and glass fiber reinforced concrete.

It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure.

It is now established that one of the important properties of hooked steel, crimped steel & glass Fiber Reinforced Concrete is its superior resistance to cracking and crack propagation. The comparison of percentage increase of compressive strength for conventional concrete and hooked end steel fiber reinforced concrete at 28 days is 7.3%.

4) Bayan S. Al-Nu'man & Abdulkader (2009)

The study of Structural Behaviour of Polymer Modified Reinforced Concrete Beams with Styrene Butadiene Rubber (SBR) polymer. Two series of concrete mixtures were used; the first was with moderate compressive strength (level I) and the other with compressive strength higher than the former (level II). Two reference mixes were made also for comparative purposes.

The behaviour studied of reinforced no-fines polymer modified concrete beams. Two groups of beams were tested. The first group was made of (1:5) (cement: aggregate) with (P: C) ratio equal to (10%) and the second made of (1:6) (cement: aggregate) with (P: C) ratio equal to (10%).

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III. EXPERIMENTAL PROGRAMME

Experimental work was aimed to study the effect of polymer modification along with hooked steel fibres especially on toughness of concrete and its feasibility in the actual field of construction for considering flexural strength, compressive strength, pull-out test of polymer modified high strength and unmodified concrete.

Materials

The constituent materials used in these studies are given below:

- 1) Cement
- 2) Fine aggregate
- 3) Coarse aggregate
- 4) Hook-end steel fibres
- 5) Conplast SP 430(chemical admixture)
- 6) Styrene butadiene rubber (SBR) latex.

1) Cement

Cement is the major ingredient in assembling of concrete. The qualities of concrete will be incredibly influenced by changing the Cement content. The Cement used in this project is Ordinary Portland Cement of 53 grade conforming to IS 12269 – 1987.

Table1: Cement test result

s.no	Properties	Value observed investigation
1	Specific gravity	3.12
2	Fineness of cement	8%
3	Initial setting time	37 mints
4	Final setting time	11hrs

2) Fine aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. The sand obtained from river beds or quarries is used as fine aggregate. Locally available river sand in dry condition was used for the preparation of specimens. The grading of sand conforms to zone- II.

3) Coarse aggregate

The coarse aggregate are granular materials obtained from rocks and crushed stones. Coarse aggregate form the main matrix of the concrete, in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. But where there is no restriction 40 mm or large size may be permitted Crushed granite aggregate conforming to IS: 383-1970 was used for the preparation of concrete. Coarse aggregate of size 20mm, having the specific gravity of 2.670.

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4) Steel Fibers

The steel fiber can entirely replace traditional steel fiber reinforced concrete. This is most common in industrial flooring but also in some other pre casting applications. Typically, these are corroborated with laboratory testing to confirm performance requirements are met. Care should be taken to ensure that local design code requirements are also met which may impose minimum quantities of steel reinforcement within the concrete. There are increasing numbers of tunneling projects using precast lining segments reinforced only with steel fibers.

Table2: Properties of hooked-end steel fibers

s.no	Properties	Description
1	Length of fiber (<i>l</i>)	60mm
2	Thickness (diameter) of fiber (<i>d</i>)	0.75mm
3	Aspect ratio (<i>l/d</i>)	80
4	Tensile strength	2000MPa
5	Specific gravity	7.8
6	Modulus of elasticity	200Gpa

The advantage of steel fiber are Improved structural strength, reduced steel reinforcement requirements, Improved ductility, Reduced crack widths and control of crack widths thus improving durability, Improved impact & abrasion resistance, Improved freeze-thaw resistance of steel fibers.



Fig1: Hooked-end steel fibers

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5) Super plasticizer:

Plasticizers are used to reduce water/cement ratio and attain the same strength. The plasticizer used in this experiment is Conplast SP430 DIS. Shown in table 3 Properties of Conplast SP430 DIS.

Table3: Properties of Conplast SP430 DIS

s.no	Property	Description
1	Appearance	Brown liquid
2	Specific gravity	Typically 1.20 at 20°C
3	Chloride content	Nil to BS 5075
4	Air entrainment	Typically less than 2% additional air is Entrained at normal dosages.
5	Alkali content	Typically less than 72.0 g. Na2O Equivalent /litre of admixture. A fact sheet On this subject is available.

Conplast SP430DIS is a chloride free, superplasticising admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Plasticizers are used to reduce water/cement ratio and attain the same strength. The plasticizer used in this experiment is Conplast SP430 DIS. Shown in figure 2 Super Plasticizer

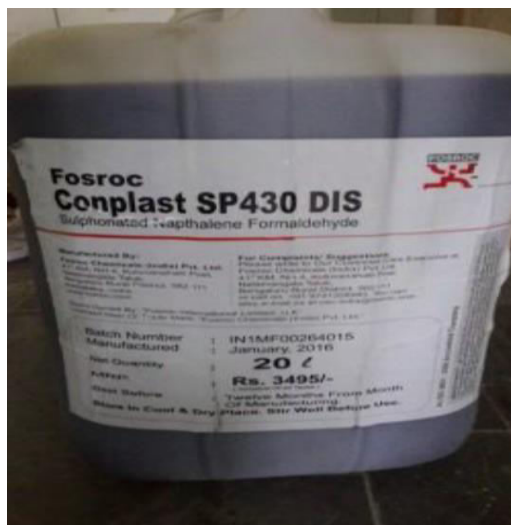


Fig2: Super Plasticizer

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6) Styrene butadiene rubber (SBR) latex:

Styrene butadiene rubber (SBR) latex is used as a polymer. This polymer is available in liquid form containing 40% solids and 60% water. The water contained in the polymer has included in the total water content of the mix i.e. reduce the amount of water contained in polymer from the quantity of w/c ratio while adding the water to the concrete mix. This is a non-epoxy thermosetting polymer. Shown in table 4 Properties of polymer

Table4: Properties of polymer

s.no	Property	Description
1	Polymer system	Polymer Latex additive (Monobond)
2	Type	Latex
3	Base	Polymer latex
4	Appearance	Milky white
5	Setting characteristics	Slow
6	Viscosity at 270c (±2)	15 sec
7	Specific gravity at 270c (±2)	1.08
8	pH	10.40

4) Process of Manufacture of Concrete

1) Batching: The measurement of materials for making concrete is known as Batching.

2) Weigh Batching: Weigh is the correct method of measuring the material. Use of weight system is batching, facilitates accuracy, flexibility and simplicity

3) Measurement of water: When weigh batching is adopted, the measurement of water must be done accurately. Addition of water by graduated bucket in terms of liters will not be accurate enough for the reason of spillage of water etc.

Preparation of Concrete Cubes

Metal moulds, preferably steel or cast iron, strong enough to prevent distortion is required. They are made in such a manner as to facilitate the removal of the moulded. Specimen without damage and are so maintained that, when it is assembled, the dimensions and internal faces are required to be accurate within the following limits.

Compacting: The testing cube specimens are made as soon as possible after mixing and in such a manner to produced full compaction of the concrete with neither segregation nor excessive bleeding

Curing: The test specimens are stored in a place free from vibration in moist air of at least 90% relative humidity and at a temperature of 270 C for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds.

5) Testing

Compressive Strength:

The test was conducted for compressive test, cube specimens of dimension 150 x150x150 use for concrete cubes were cast. The specimens were demoulded, after 24hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. After 28 days curing, cubical specimens are placed on compression testing machine having a maximum capacity of 2000 KN and a constant rate of loading of 40 kg/m² per minute is applied on test specimen. Ultimate load at which the cubical specimen fails is noted down from dial gauge reading. This ultimate load divided by the area of specimen gives the compressive strength of each cube. Shown in figure 3 Compression testing of cube

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Fig3: Compression testing of cube

Flexural Strength:

The steel mould of size 500x100x100 is well tighten and oiled thoroughly They were allowed for curing in a tank After 28 days curing, prismatic specimens are placed on flexural testing machine having a maximum of 100 KN and a constant rate of loading of 40 kg/m² per minute is applied on the test specimen by placing the specimen in such a way that the two point loading should be placed at a distance of 13.3 cm from both the ends. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading. Shown in figure 4 Flexural testing of beam.



Fig4: Flexural testing of beam

Pull-out Test (Bond Strength Test)

Pull out test was performed to find out bond strength of concrete. The specimens were cast according to ASTM standard C234-91a. Concrete cube of size 150 mm × 150 mm × 150 mm with a 16 mm diameter tor steel Bar embedded 150 mm in concrete cube as shown in Fig was used as test specimen. The verticality of 16 mm embedded tor steel rod was ensured by supporting it till the concrete hardens.

The pull out test was carried out at 28 days using Universal Testing Machine (UTM). The specimen was held between upper and middle cross-head. The rod was gripped in upper cross-head and cube was held below middle cross-head as shown in Fig. The tensile load was applied on steel bar for pull out purpose. The loads and slips were recorded at every 400 Kg interval till failure of specimen. The maximum pull-out force is recorded in the test at bond failure. The deformations (slips) were recorded with sensitive dial gauge of least count 0.01 mm. shown in figure 5 pull-out specimens.

$$\tau_{bd} = P/\pi dl$$

Where τ_{bd} = bond strength of concrete in MPa.

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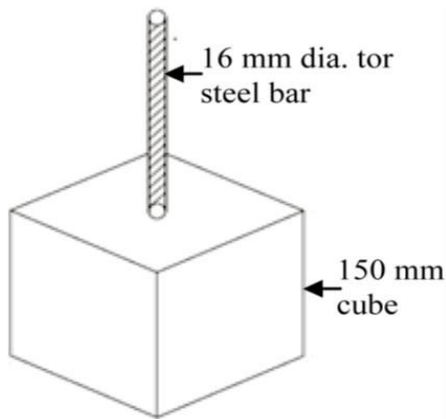
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P = pull-out force in KN.

D = diameter of steel bar embedded in concrete cube in mm.

l = length of the bar embedded in concrete in mm.



Pull out test specimen



pull out test under progress

Fig5: pull-out specimens

Toughness for compression, flexure and bond test

In the present work, to find out the toughness of fiber reinforced concrete compression test, flexural test and pull-out test were conducted on cubes, beams and pull-out specimens and results of various toughnesses in KN-mm are presented. Expressions for toughness for compression, flexure and bond at 7, 28 and 56 days in 3rd degree polynomial in terms of fiber content are mentioned in Table obtained from Figures.

IV. TEST RESULTS AND DISCUSSIONS

Compressive Strength Test Result

Tests were conducted on compressive strength after 7, 14 and 28 days of curing. The results of compressive strength for 2% to 3.5% of steel fiber are given in. shown in table 5& graph 1.

Table5: Test result for Compressive strength by using steel fibers

% of steel fibers	Compressive strength		
	7days (MPa)	14days (MPa)	28days (MPa)
conventional	46.55	55.37	70.05
2%	47.05	57.34	72.14
2.5%	48.07	59.37	75.45
3%	45.42	56.14	71.30
3.5%	44.30	54.40	69.40

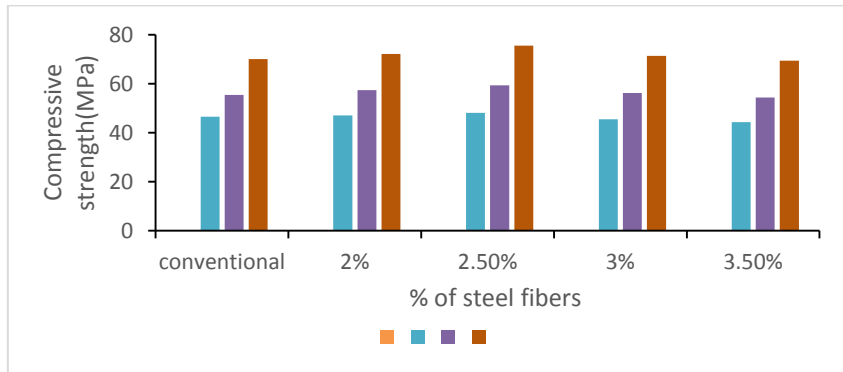
Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete etc.

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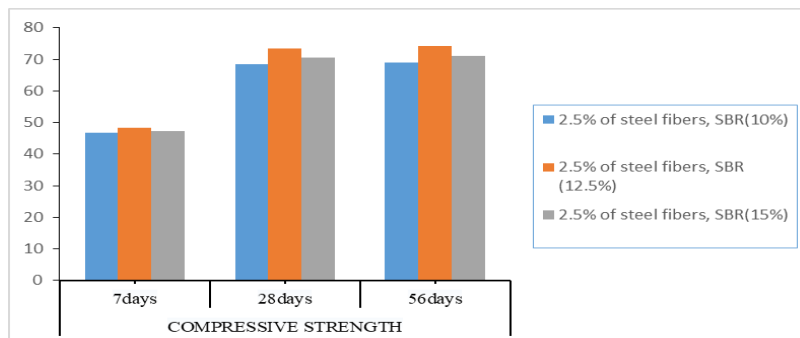
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Graph1: Comparison of compressive strength using different fibers

Table6: Compressive strength Test Results for various proportions Styrene butadiene rubber (SBR) latex and With steel fibers& graph 2.

	% of SBR	Compressive strength		
		7days (MPa)	28days (MPa)	56days (MPa)
2.5% steel fibers	SBR (10%)	46.83	68.53	68.90
	SBR (12.5%)	48.23	73.56	74.15
	SBR (15%)	47.25	70.50	71.05



Graph2: Compressive strengths for various proportions of Styrene butadiene rubber (SBR) latex With steel fibers

Flexural Strength Test Results

Tests were conducted on flexural Strength 7, 14 and 28days of curing. The results of flexural Strength for 2% to 3.5% volume of steel fibers are given in. shown in table 7&graph 3.

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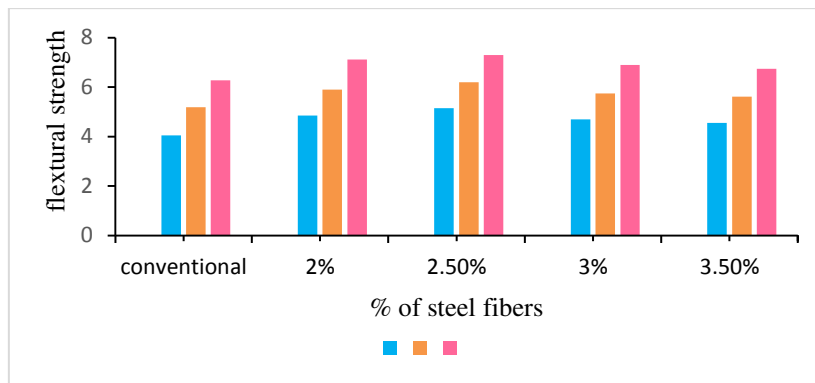
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Table7: Test result for flexural strength various percentage of steel fibers

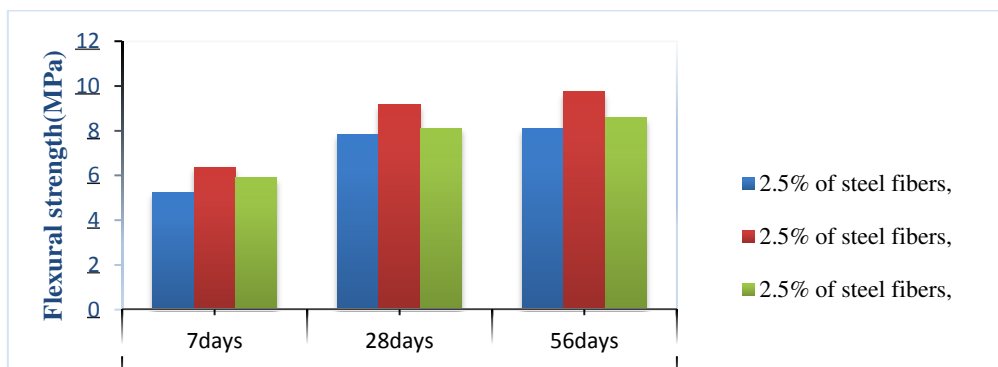
% of steel fibers	Flexural strength		
	7days (MPa)	14days (MPa)	28days (MPa)
conventional	4.00	5.19	6.28
2%	4.85	5.90	7.12
2.5%	5.15	6.20	7.30
3%	4.70	5.75	6.90
3.5%	4.55	5.61	6.74



Graph3: Comparison of flexural strength using different fibers

Table8: Flexural strength Test Results for various proportions Styrene butadiene rubber (SBR) latex and With steel fibers

2.5% of steel fibers	% of SBR	Flexural strength		
		7days (MPa)	28days (MPa)	56days (MPa)
	SBR (10%)	5.25	7.85	8.1
	SBR (12.5%)	6.38	9.18	9.77
	SBR (15%)	5.90	8.12	8.60



Graph4: Flexural strengths for various proportions of Styrene butadiene rubber (SBR) latex With steel fibers

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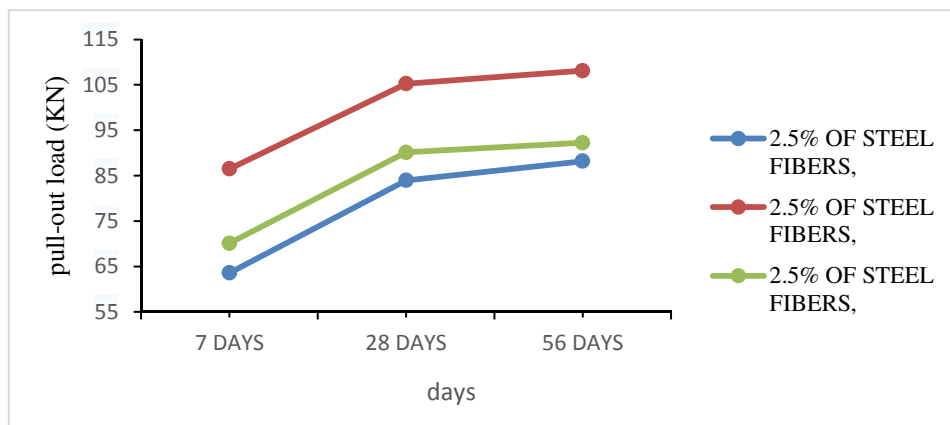
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Pull-out Test (Bond Strength Test) Results

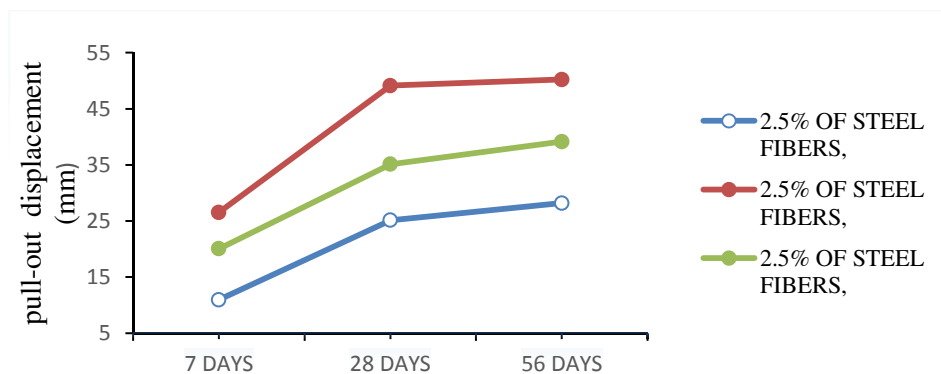
Tests were conducted on bond Strength 7, 28 and 56days of curing. The results of bond Strength for various proportions Styrene butadiene rubber (SBR) latex with 2.5% volume of steel fibers.

Table9: Pull-out (bond strength) Test Results for various proportions SBR and with steel fibers

S.NO	% of steel fibers	% of SBR	Compressive strength			Flexure strength		
			7 days (MPa)	28 days (MPa)	56 days (MPa)	7 days (MPa)	28 days (MPa)	56 days (MPa)
1	2.5% of steel fibers	10%	46.83	68.53	68.90	5.25	7.85	8.10
2		12.5%	48.23	73.56	74.15	6.38	9.18	9.77
3		15%	47.25	70.55	71.05	5.90	8.12	8.60



Graph5: Comparison of Pull-out loads V/s Steel Fibers and SBR



Graph6: Comparison of Pull-out Displacements V/s Steel Fibers and SBR

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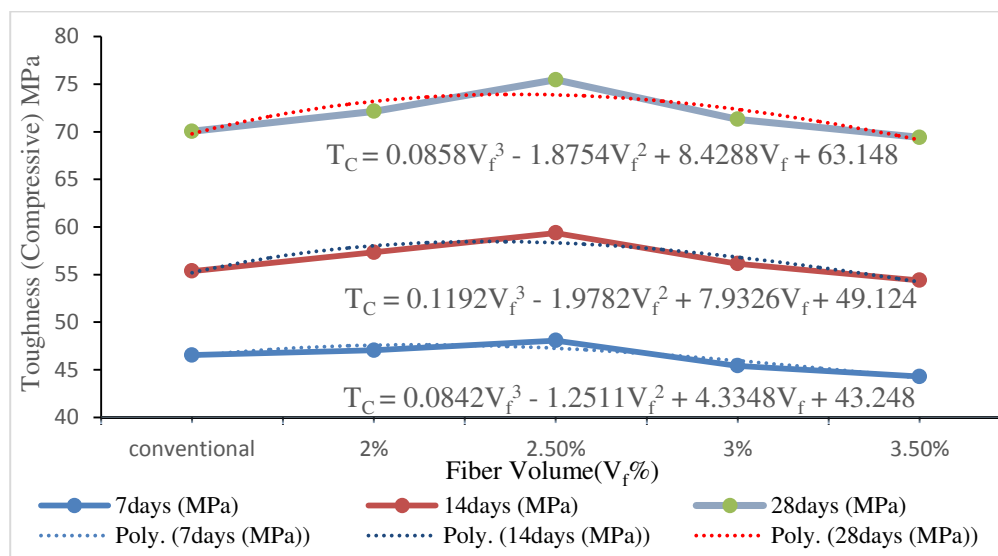
Toughness Results

In the present work, to find out the toughness of fiber reinforced concrete compression test, flexural test and pull-out test were conducted on cubes, beams and pull-out specimens and results of various toughnesses in KN-mm are presented.

Expressions for toughness for compression, flexure at 7, 28 and 56days in 3rd degree polynomial in terms of fiber content are mentioned in Table 10 obtained from graph 7 & 8.

Table10: Toughness for compression, flexure test of SFRC

S.NO	% of steel fibers	Compressive strength			Flexural strength		
		7 days (MPa)	14 days (MPa)	28 days (MPa)	7 days (MPa)	14 days (MPa)	28 days (MPa)
1	0%	46.55	55.37	70.05	4.00	5.19	6.28
2	2%	47.05	57.34	72.14	4.85	5.90	7.12
3	2.5%	48.07	59.37	75.45	5.15	6.20	7.30
4	3%	45.42	56.14	71.30	4.70	5.75	6.90
5	3.5%	44.30	54.40	69.40	4.55	5.61	6.74



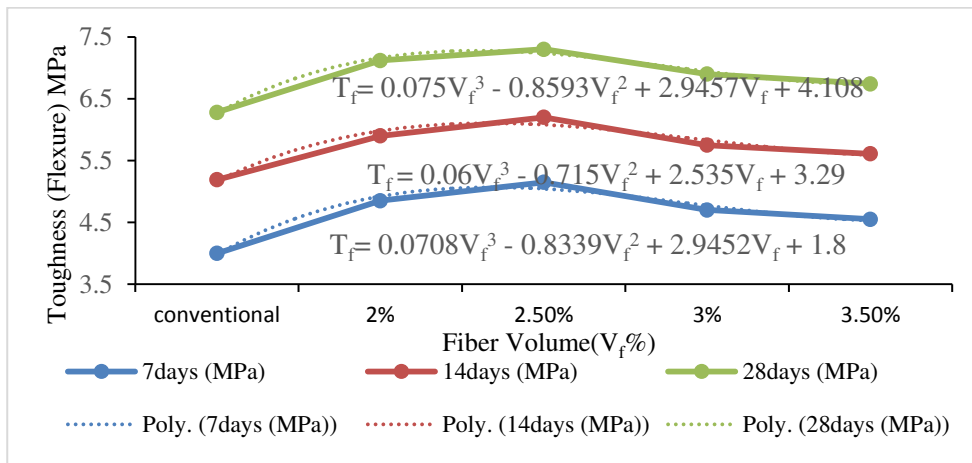
Graph7: Variation of compression toughness (Tc) with respect to SFRC

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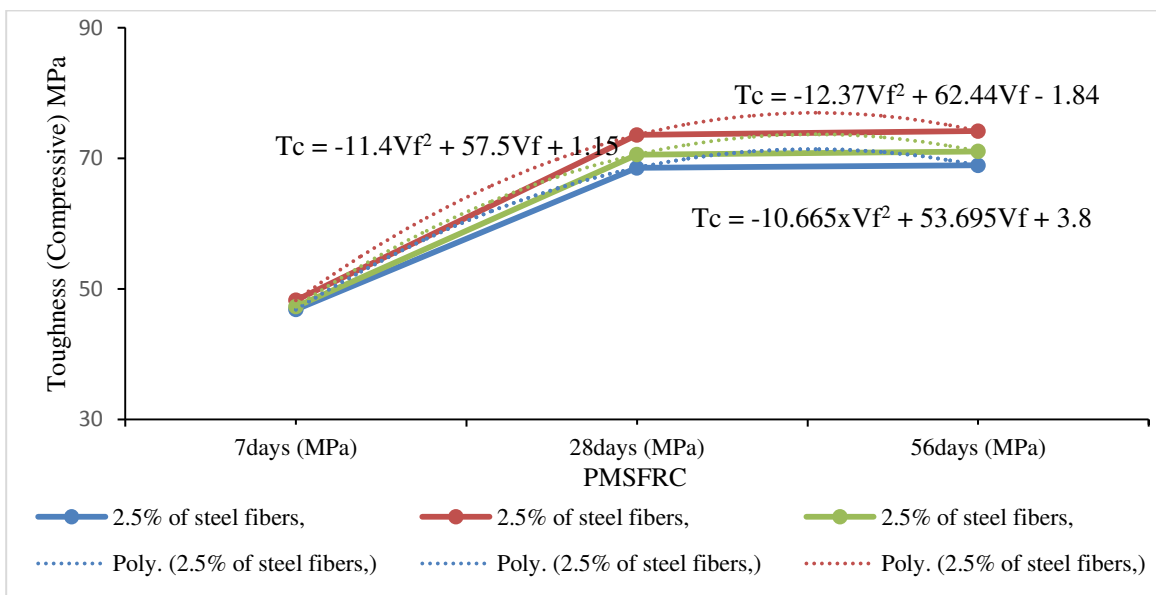
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Graph8: Variation of flexural toughness (Tf) with respect to SFRC

Table11: Toughness for compression, flexure test of PMSFRC

S.NO	% of steel fibers	% of SBR	Compressive strength			Flexure strength		
			7 days (MPa)	28 days (MPa)	56 days (MPa)	7 days (MPa)	28 days (MPa)	56 days (MPa)
1	2.5% of steel fibers	10%	46.83	68.53	68.90	5.25	7.85	8.10
2		12.5%	48.23	73.56	74.15	6.38	9.18	9.77
3		15%	47.25	70.55	71.05	5.90	8.12	8.60



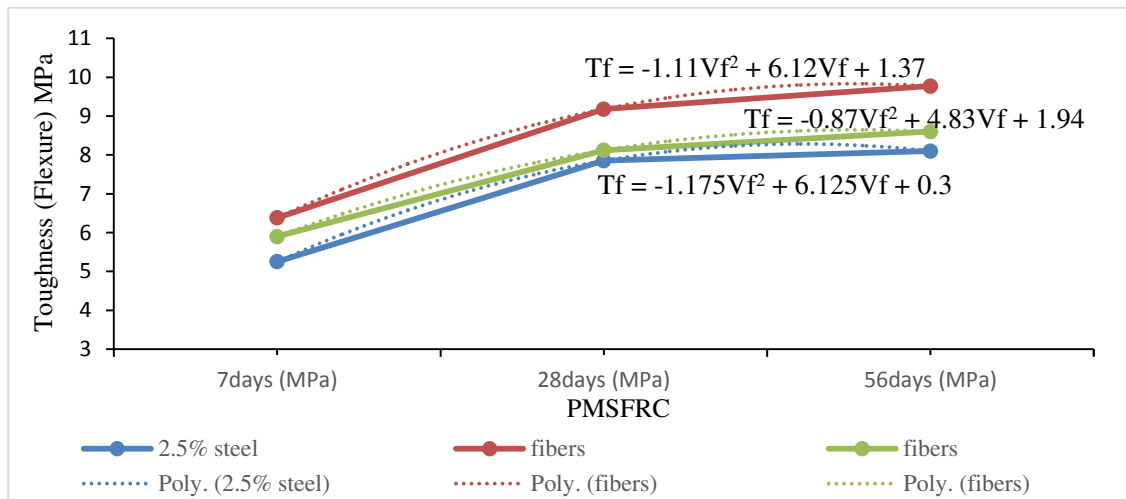
Graph9: Variation of compression toughness (Tc) with respect to PMSFRC

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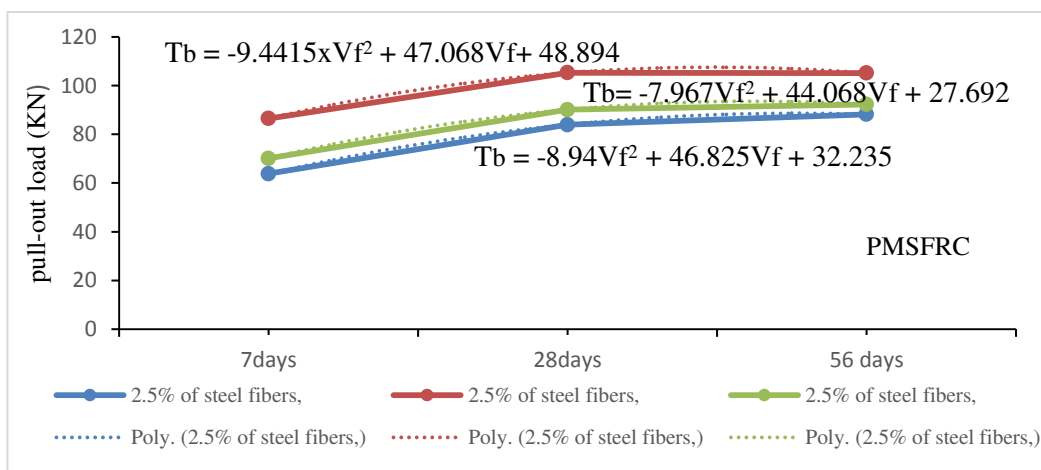


Graph10: Variation of Flexural toughness (Tc) with respect to PMSFRC

Expressions for toughness for bond at 7, 28 and 56 days in 3rd degree polynomial in terms of fiber content are mentioned in Table 12 & graph 11 & 12.

Table 12: Toughness for Pull-out Test of PMSFRC

S.NO	% of steel fibers	% of SBR	Bond strength					
			Load (KN)			Displacement (mm)		
			7 days	28 days	56 days	7 days	28 days	56 days
1	2.5% of Steel Fibers	10%	63.793	83.960	88.193	10.96	25.13	28.19
2		12.5%	86.520	105.263	108.123	26.53	49.13	50.23
3		15%	70.120	90.125	92.250	20.05	35.12	39.16



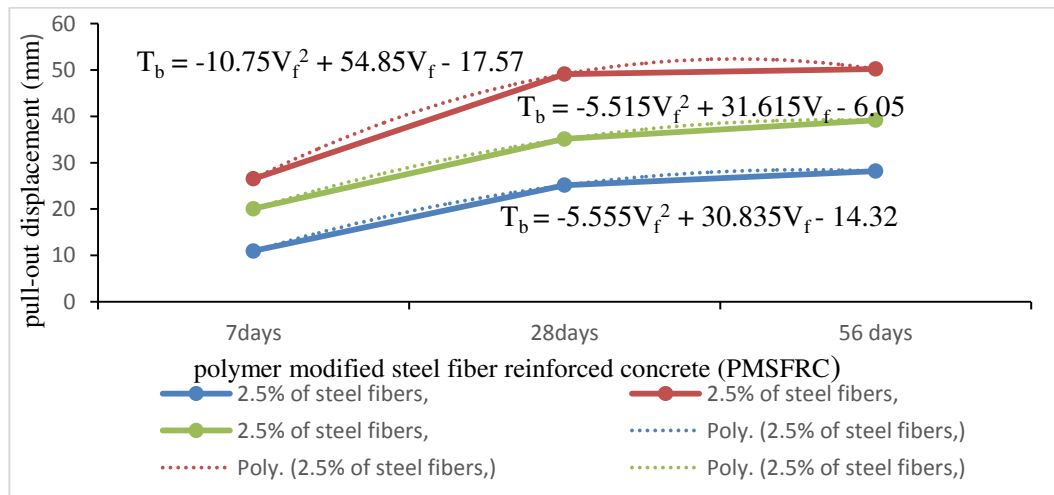
Graph11: Variation of pull-out toughness (Tb) with respect to PMSFRC

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Graph12: Variation of pull-out toughness (T_b) with respect to PMFRC

V. CONCLUSION

Following conclusions may be drawn based on the observations based on experimental investigation.

- 1) Addition of steel fibres result in higher compressive strength up to 2.5% and decreases with further increase of steel fibres.
- 2) It is experimentally observed that the SBR+ SF+ Conventional concrete has considerable amount of increased in flexural strength where compared to other matrix used.
- 3) An increase of 21% bond strength and 10% flexural strength is observed in polymer modified steel fiber reinforced concrete over conventional concrete at 28 days.
- 4) There is an improvement in the strength of concrete as the polymer content increased in the mix of various percentage of SBR latex of concrete tested in this investigation.
- 5) By the addition of SBR latex, there is an increase in the workability of concrete as the polymer content increased.
- 6) Addition of 12.5% SBR latex increased compressive strength by 5.2%, flexural strength by 3% and bond strength by 30%.

In general it is observed that fibers and polymer are very effective in improving toughness of concrete composites.

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