Properties of Fibre Reinforced Concrete- A Comparative Studies of Steel Fibre and Poly-Fibre

Pawan Kumar Tiwari*, Arabinda Sharma
Civil Engineering Department
BRCM College of Engineering and Technology

***Abstract*- Fibres are generally used as resistance of cracking and strengthening of concrete. This paper is concerned with experimental study of fibres which are used in mixture of normal concrete i.e. steel fibres as well as synthetic (polymeric) fibres. The steel fibre and polymeric fibre, both with the same concrete design mix, have used to make cube specimens for compressive test, beam specimens for a flexural test. The experimental data results that steel fibre reinforced concrete is stronger in flexure at early stages, while both fibre concrete types displayed comparatively the same performance in compression and 28-day flexural strength. In terms of post-cracking control steel was preferable.**

Keywords— S*teel fibre, synthetic fibre, fibre reinforced concrete, experimental study*

I. INTRODUCTION

Steel and polymeric fibres are the two most commonly used fibre concrete in the world [2]. In FRC, more than thousands of small fibres are dispersed randomly in concrete during mixing and these improve concrete properties in many ways. They can be circular, triangular or flat in cross-section. The fibre is often described by a convenient parameter called aspect ratio. The aspect ratio of the fibre is the ratio of its length to its diameter [3]. This paper is convenient to address some experimental data to create a base for better knowledge to understand the comparative results on these structural materials. This study is therefore based on the comparative behaviour of the steel and polymeric fibre concrete types in the same design mix and the fibre weight after 7, 14 and 28 days to their performance in flexure, compression and tensile splitting.

Concrete is the second most consumed construction material [4].concrete, in unreinforced condition, has some common properties: strong in compression and weak in tension. Therefore, some steel bars are used to resist any tensile or compressive forces to concrete [5]. FRC composite properties, such as crack resistance, reinforcement and increase in toughness are dependent on the mechanical properties of the fibres, bonding properties [6]. If the modulus of elasticity of the fibres are higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. According to Yazici, Inan and Tabak [7], the addition of steel or polymeric fibres in concrete mix improves the tensile, flexural, fatigue, wear strength, deformation resistivity, load bearing capacity after cracking and toughness properties of the resulting product. For instance, steel fibres are added to concrete mainly to improve the crack development, but do not provide the concrete with a meaningful post-cracking strength that can be taken into consideration during design.

II. LITERATURE REVIEW

Polypropylene (synthetic) fibres were first suggested as an admixture to concrete in 1965 for the construction of blast resistant buildings for the US Corps of Engineers [8]. In general, the reinforcement of brittle building materials with fibres has been known from ancient period such as putting straw into the mud for housing walls or reinforcing mortar using animal hair etc. Many materials like jute, bamboo, coconut, rice husk and sawdust have also been used for reinforcing the concrete. Similarly, the steel fibre reinforcement not only improves the toughness of the material, the impact and the fatigue resistance of concrete, but it also increases the material resistance to cracking and, hence to water and chloride ingress with significant improvement in durability of concrete structures. In the present scenario, many countries like USA, UK and developed countries are working these phenomenal materials. They made different Codes for making this type of special concrete.

III. MATERIAL PROPERTIES

The raw materials used include: Water, fine aggregates, coarse aggregates, cement, steel (mild) and synthetic fibre (polypropylene).

Cement: Ordinary Portland cement (OPC) is as for most important type of cement. This is classified in three grades i.e. 33 Grade, 43 Grade and 53 Grade depending upon the strength of cement at 28 days when tested as per IS 4031-1988. Ordinary Portland cement of 53 grade of ULTRATECH cement is used in this experimental work. Each bag of cement is 50kg.

Table 1: Property of cement

No.	Property	Value observed in Investigation	Standard Value for OPC
1.	Fineness	1.70	Not exceed 10
2.	Specific gravity	3.145	-
3.	Consistency (%)	30.00	-
4.	Initial setting time(min.)	88	Less than 30
5.	Final setting time(min.)	176	More than 600
Compressive Strength (N/mm^2)			
1.	3-days	30.68	Less than 27
2.	7-days	50.74	Less than 37
3.	28-days	58.89	Less than 53

Fine aggregates*:* it should be passed through IS sieve 4.75mm. It should have fineness modulus 2.50-3.50 and silt contents should not be more than 4%. Coarse sand should either river sand or pit sand; or combination of these two. In our region, fine aggregates can be found from bed of Mahanadi river (situated in Raipur,Chattigarh-India). It confirms to IS 383-1970 which comes under zone-II.

Coarse aggregate: it should be hard, strong, dense, durable and clean. It must be free from vein, adherent coatings and injurious amount of disintegrated pieces, alkalis, vegetable matters and other deleterious substances. It should be roughly cubical in shape. Flaky pieces should be avoided. It should confirm to IS 2838(I)

Water: water should be free from acids, oils, alkalis, vegetables or other organic impurities. Soft water also produces weaker concrete. Water has two functions in concrete mix. Firstly, it reacts chemically with the cement to form the cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a lubricant in the mixture of fine aggregates and cement.

Synthetic Fibre (Polypropylene):

Table 2: Properties of Polypropylene Fibres

Property	Description
Fibre length	60mm and 120mm
Type/Shape	Macro/ monofilament
Specific Gravity	0.91
Aspect Ratio	60, 120
Acid and salt resistance	High
Melting Point	1640 ^{0}C
Ignition Point	>5500 ^{0}C
Thermal conductivity	Low

Steel Fibre

Table 3 Properties of Steel Fibres

Property	Description
Fibre length	25-35mm
Acid and salt resistance	Low
Diameter	0.05mm
Aspect ratio	50, 60

Admixture: An admixture is defined as a material, other than the cement, water and aggregate is added to the batch ingredient of concrete and is added to the batch immediately before and during mixing.

Super Plasticizers: super plasticizers constitute a relatively new category and improved version of plasticizers. They are chemically different from normal plasticisers. Use of super plasticisers permits the reduction of water content to extent up to 30% without reducing workability in contrast to the possible reduction up to 15% in case of plasticizers.

IV. EXPERIMENTAL METHODOLOGY

Compressive Strength Test: For compressive strength test, cube specimens of dimensions 150 x 150x 150mm were cast for M40 grade concrete. Super plasticized (0.6% to 0.8% weight of cement) was added to this. The moulds were filled with 1%, 2% and 3% by fibres (i.e. steel fibre and polypropylene fibre). This test is performed with reference to IS516-1959. The load was applied at a rate of approx. 140 Kg/mm^2/min. Until the resistance of the specimen to the increasing load, by using Compression Testing Machine. The failure load was noted.

$$\textbf{Compressive strength} = \frac{\textbf{Failure Load}}{\textbf{Cross-sectional Area}}$$

Table 4 Compressive strength of FRC with 0% fibres M40 rade

	Compressive Strength(N/mm^2)	Avg. Compr. Strength(N/mm^2)
Sample M.1	47.8	45.6

Table 5: Compressive strength of SFRC with 1%, 2% and 3% fibres M40 Grade

Steel Fibres							
Different Aspect Ratios of Fibres		1%		2%		3%	
		Compressive Strength((N/mm²))					
			Avg.		Avg.		Avg.
50	Samples-CS1.1	51.2		53.1		55.6	
	Samples-CS2.1	53.2		54.8		55.0	
	Samples-CS3.1	54.1	52.8	54.0	53.9	54.0	54.8
60	Samples-CS1.2	53.2		54.8		56.0	
	Samples-CS2.2	52.1		54.5		55.8	
	Samples-CS3.2	54.4	53.2	58	55.7	58.0	56.6

Table 6: Compressive strength of PFRC with 1%, 2% and 3% fibres M40 Grade

Polypropylene Fibres							
Different Aspect Ratios of Fibres		1%		2%		3%	
		Compressive Strength(N/mm²)					
			Avg.		Avg.		Avg.
120	Samples-CP1.1	37.0		48.8		49.4	
	Samples-CP2.1	38.4		44.4		50.8	
	Samples-CP3.1	36.4	37.2	49.5	47.5	43.5	47.9
239.6 (Approx. 240)	Samples-CP1.2	40.5	44.9	44.8	49.6	49.4	51.6

Flexural Strength Test: For flexural strength test, beam of dimension 100 x 100 x 500mm were cast. The specimens were de-moulded after 24 hours of casting and transferred to curing tank where in they were allowed to cure for 28 days. The specimen was placed in the machine in such a manner that the load was applied to the uppermost surface as cast in mould, along two of the specimen spaced 133.3mm apart. The axis of the specimen was aligned with the axis of the loading device. The load was applied without shock and increasing continuously at a rate of 180Kg/min. Until the specimen failed.

Flexural strength = $\frac{PL}{B \times D \times D}$

Where P= Failure Load,

L= centre to centre distance between the support = 400mm,

B= width of specimen,

D= depth of specimen

Table 7: Flexural strength of FRC with 0% fibres M40 Grade

	Flexural Strength(N/mm²)	Avg. Flex. Strength(N/mm²)
Sample MF.1	7.4	7.4
Sample MF.2	7.8	
Sample MF.3	7.0	

Table 8: Flexural strength of SFRC with 1%, 2% and 3% fibres M40 Grade

Steel Fibres							
Different Aspect Ratios of Fibres		1%		2%		3%	
		Flexural Strength((N/mm²))					
			Avg.		Avg.		Avg.
50	Samples-FS1.1	8.9		8.5		10.5	
	Samples-FS2.1	8.1		8.4		10.2	
	Samples-FS3.1	9.1	8.7	9.4	8.7	11	10.5
60	Samples-FS1.2	8.0		8.9		11.5	
	Samples-FS2.2	8.1		9.5		9.4	
	Samples-FS3.2	8.2	8.1	9.4	9.2	12.0	10.9

Table 9: Flexural strength of PFRC with 1%, 2% and 3% fibres M40 Grade

Polypropylene Fibres							
Different Aspect Ratios of Fibres		1%		2%		3%	
		Flexural Strength(N/mm^2)					
			Avg.		Avg.		Avg.
120	Samples-FP1.1	36.5		39.5		40.1	
	Samples-FP2.1	36.5		37.8		40.5	
	Samples-FP3.1	40.0	37.6	38.4	38.5	42.7	41.1
239.6 (Approx. 240)	Samples-FP1.2	40.5		29.8		32.8	
	Samples-FP2.2	42.5		45.5		34.9	
	Samples-FP3.2	36.4	39.7	38.4	37.9	50.8	39.5

Split Tensile Strength Test: For split tensile strength test, cylinder of dimension 150mm diameter and 300mm length were cast. The specimens were de-moulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These were tested under Compression Testing Machine. In each category three cylinders were tested and their average value is reported.

$$\textbf{Split Tensile Strength} = \frac{2P}{\pi DL}$$

Where P= Failure Load
D= Diameter of cylinder
L= Length of cylinder

Table 10: Split Tensile strength of FRC with 0% fibres M40 Grade

	Split Tensile Strength(N/mm^2)	Avg. Split Tensile Strength(N/mm^2)
Sample MT.1	2.9	3.1
Sample MT.2	3.1	
Sample MT.3	3.4	

Table 11: Split Tensile strength of SFRC with 1%, 2% and 3% fibres M40 Grade

Steel Fibres							
Different Aspect Ratios of Fibres		1%		2%		3%	
		Split Tensile Strength(N/mm^2)					
			Avg.		Avg.		Avg.
50	Samples-TS1.1	3.2		4.1		5.2	
	Samples-TS2.1	3.0		4.1		4.2	
	Samples-TS3.1	2.9	3.0	4.3	4.16	5.4	4.9
60	Samples-TS1.2	2.9		6.0		4.5	
	Samples-TS2.2	3.2		3.5		5.6	
	Samples-TS3.2	3.1	3.09	3.5	4.3	5.8	5.3

Table 12: Split Tensile strength of PFRC with 1%, 2% and 3% fibres M40 Grade

Polypropylene Fibres							
Different Aspect Ratios of Fibres		1%		2%		3%	
		Flexural Strength(N/mm^2)					
			Avg.		Avg.		Avg.
120	Samples-TP1.1	4.2		4.5		5.1	
	Samples-TP2.1	2.4		4.5		5.1	
	Samples-TP3.1	4.5	3.7	5.6	4.8	5.2	5.1
239.6 (Approx. 240)	Samples-TP1.2	4.8		4.8		4.6	
	Samples-TP2.2	5.1		5.2		8.0	
	Samples-TP3.2	5.6	5.1	5.3	5.1	6.1	6.2

V. CONCLUSION

The following conclusions could be drawn from present investigation:

- It is observed that compressive strength, split tensile strength and flexural strength are on higher side of 3% fibres as compared to that produced from 0%, 1% and 2% fibres.
- All the strength properties are observed to be on higher side for aspect ratio of 50 as compared to those for aspect ratio 60 for steel.
- Compressive strength by using steel fibres increases 16% to 20% where as by using polypropylene fibres increases 0.05% to 1%.
- Flexural strength increases by 29% to 32% after mixing steel fibres where as almost 75% to 80% on addition of polypropylene fibres.
- Split tensile strength increases by 0.3% to 0.5% after mixing of steel fibres where as 40% to 50% on addition of polypropylene fibres.

VI. REFERENCE

[1] Kakooei,S., Akil, H.M., Jamshidi, M. and Rouhi, J., 2012. The effects of polypropylene fibers on the properties of reinforced concrete structures. Construction and Building Materials, Vol. 27, pp. 73-77.
[2] Woodward, R. and Duffy, N., 2011. Cement and concrete flow analysis in a rapidly expanding economy: Ireland as a case study. Resources, Conservation and Recycling, Vol. 55, pp. 448-455.
[3] Concrete Technology, M.S.Shetty, S. Chand & Company Pvt. Ltd. Page. 560
[4] Concrete Technology, M.S.Shetty, S. Chand & Company Pvt. Ltd. Page. 314
[5] Jackson, N. and Dhir, R. K. eds., 1996. Civil Engineering Materials. Fifth Edition. London: Palgrave Macmillan.
[6] Concrete Technology, M.S.Shetty, S. Chand & Company Pvt. Ltd. Page. 561-62
[7] Amit M. Alani, Morteza Aboutalebi, Mechanical properties of FRC ISSRI, Vol.7, No.9, 2013
[8] Wikipedia.com