International Journal For Technological Research In Engineering
Volume 4, Issue 11, July-2017 *ISSN (Online): 2347 - 4718*

PROPERTIES OF FIBER REINFORCED CONCRETE: COMPARATIVE STUDIES OF STEEL FIBERS & POLYPROPYLENE FIBERS

Sandeep Karwasra[1], Vikram[2]
[1]M. Tech Scholar, [2]Assistant Professor
Department of Civil Engineering, JCD Memorial College Of Engineering, SIRSA (Haryana)

Abstract: Many researches have been currently going to modify and improved the concrete properties by the addition of different types of materials. This paper represents the Optimum use of the fibres with the concrete mixture and will also help in achieving the desired results. This research work explores the effect of fibers i.e. steel and polypropylene with nominal concrete. For this purpose, 35 specimens tested for each investigation of their physical properties like compressive strength, flexural strength and split tensile strength respectively. During olden days, only plain concrete were used and after that reinforced of steel concrete was introduced. In this work, the effects of steel and polypropylene fibers were observed after 28 days of casting. For this purpose, we kept the main focus on aspect ratios of fibers, orientation of fibers as well as quantities of fibers. The experimental results show that the hybridization of fibers has slight effect on compressive strength values, while it causes increase in modulus of rupture (flexural strength), toughness (compressive strength) and impact resistance (tensile strength) values. The concrete with fibers reinforcement increased the strengths any all cases. At Some places the polypropylene fibers and somewhere steel fibers. But after observing by T-test techniques and statistical data, it is also showing the all values are beneficial for the grade M40 mix with fibers.
Keywords: Glass Fibres, Compressive Strength, Flexural Strength and Split Tensile Strength.

I. INTRODUCTION

One of the most consumed man-made materials in construction field is concrete. It is the combination of cementitious materials, water, aggregates and also different types of admixtures in a particular ratio. Fresh concrete has a property of plasticity, which means before casting it behaves like plastic but as time goes, it gets hard like rock. These hardening properties happens due to chemical reactions between cement and water, it gets stronger with long time period. Since last century, the concrete structures durability was based on ordinary Portland cement, round steel bars of mild steel, which was easily available in market. As time spent, these materials also changed with their physical appearance, properties and strength. For example, Pozzolana cement is used in place of Ordinary cement and TMT bars are in use in place of mild steel bars. Polypropylene fiber reinforced concrete has also a great use in thin shell domes; repair of surfaces and as a component in overlaying systems. Polypropylene fiber reinforced concrete is significantly in use over last two decades. Polypropylene fibers are unable to provide the primary reinforcement in a concrete work because of low modulus and strength when compared to steel fibers. These are also used to provide a support to make a desired material behavior such as decrease in plastic behavior, shrinkage and improved toughness. Polypropylene fibers have been used maximum in structural applications since 1950 and more recently in pavement formation of roads. The availability of polypropylene is in two forms that are monofilament fibers and film fibers. Production of monofilament fibers possible by an extrusion process through the orifices in a spinner jet and then cut them in desired length. This film may be stretchable into tapes axially. These tapes are stretched over carefully over design roller pin systems which generates longitudinal cutting and these can be cut or twisted to form various types of fibrillated fibers. The fibrillated fibers have a net-like structure. The tensile strength of fibers can be developed by the molecular orientation obtained during extrusion process. Polypropylene has a melting point of 165oC and can resist the temperatures up to 100oC for short time period before softening. This is chemically inert material and any chemical that can damage to polypropylene fibers, will be much more harmful to concrete mix. The polypropylene fibers are capable to resist the degradation by ultraviolet radiations or oxygen. However, in concrete after mixing with fibers, these remedies can be eliminated. That’s why the addition of fiber with concrete improved the concrete properties such as workability, brittleness, strength, corrosion resistance and ultimately increased life of the structure. Reinforcing capacity and proper functioning of fiber is based on length of fiber, diameter of fiber, the percentage of fiber and condition of mixing, orientation of fibers and aspect ratio. Aspect ratio is ratio of length of fiber to its diameter which plays an important role in the process of reinforcement.

II. LITERATURE REVIEW

As we know the properties of concrete gets improved due to the incorporation of fibre. Large no. of papers have being published which tells about the compressive strength, flexural strength and split tensile strength of concrete according to their opinion.

Bentur & Mindess [1], fibers are in use as reinforcement for quite some time now. Asbestos was first material widely used in the beginning of the 20th century. Manmade fibers produced from steel, glass, synthetics, asbestos and natural fibers such as cellulose, sisal and jute with high compressive strength. Before reinforcement of steel and materials which provides strength to resist the load, concrete always shows brittle nature with high compressive strength and low tensile strength

J. Turmo, N. Banthia R. Gettu and B. Barragan [2] studied that incorporation of fibers to the mixes increases the material toughness both tension or compression, as indicated by the toughness indexes of the JSCE and ASTM standards. The material toughness increase results in higher shear strength of the concrete and better deformability, i.e. the deflection at maximum load is significantly higher for FRC beams than plain concrete specimens.

Rashid Hameed et al. [3] made conclusions that On the basis of three-point bending tests performed on notched prismatic specimens constructed with mono- and hybrid fiber-reinforced concretes containing different fibers used in this study, the following conclusions can be drawn:

Adhering amorphous stainless metallic fiber, due to its high-bonding with the matrix, is very effective in controlling the micro-cracking mechanism, which results in an improved behavior in terms of smaller crack openings at peak resistance. On the other hand, high-modulus hook ended carbon steel fiber is effective in controlling macro-cracks over a wide range and at high stress level. As a result, the toughness of the material is significantly increased. It should also be noted that these fibers also have very different properties in terms of fiber geometry and tensile strength. These variables are also effective on flexural performance of beam samples at different loading levels.

Md Azree Othuman Mydin [4] summarizes three main properties of steel fiber reinforced high strength concrete which are mechanical, workability and durability properties. The investigation on the introduction of effect of steel fibers could be still promising as steel fiber reinforced concrete is used for sustainable and long-lasting concrete structures, and also the addition of steel fiber into concrete creates low workable or inadequate workability to the concrete.

S. O. Santos, J. P. C. Rodrigues, R. Toledo, R. V. Velasco [5] told that the effect of high temperatures on fiber reinforced concrete. It could be concluded that the inclusion of Polypropylene fibers in the concrete compositions prevented spalling. The specimens with steel and polypropylene fibers performed better than those with glass fibers. A small detachment of surface concrete was observed in the glass fiber specimens

Jaroslav Beno & Matouš Hilar [6] said about the use of steel fiber in tunnel linings. They said that SFRC is increasingly used as a structural material for precast segmental tunnel linings excavated by tunneling machines. In some cases SFRC is supplemented by steel bar reinforcement, while in other cases SFRC is used without steel cages. SFRC segments can bring many benefits during tunnel construction and operation

G. Velayutham and C.B. Cheah [7] concluded It has been found that steel fiber high strength concrete (SFHSC) is not suitable for hygro-thermal curing compared to normal strength concrete.

Khaled Abdelrahman and Raafat El-Hacha [8] told about cost and ductility effectiveness of concrete columns strengthened with CFRP and SFRP Sheets. A cost and ductility effectiveness study was conducted on concrete columns wrapped with CFRP and SFRP sheets experimentally tested under uni-axial compression loading.

Vikram Jothi Jayakumar and Sivakumar Anandan [9] concluded that Fiber addition consisting of polypropylene and steel showed considerable mechanical strength improvements with higher strain hardening properties of slag based concrete. The residual strength and residual toughness of the composite were found to be maximum for hybrid short steel-Polypropylene fiber combinations in the concrete composite.

K.Srinivasa Rao, S.Rakesh kumar, A.Laxmi Narayana [10] told about the temperature effects on high performed fiber reinforced concrete. An increase in compressive strength and tensile strength has been observed for both standard concrete and fiber reinforced standard concrete when exposed to a temperature of 500C. In the range of 50 to 800C the split tensile strength of both standard concrete and fiber reinforced standard concrete is same.

III. MATERIALS USED

These materials are described below-

CEMENT :- Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. There are different types of cement; out of that we have used two types i.e.

- Ordinary Portland cement
- Portland slag cement

Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. These are of three types, 33 grades, 43 grades, 53 grades. One of the important benefits is the faster rate of development of strength.

AGGREGATE:- Aggregate properties greatly influence the behavior of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as:

- Fine aggregate
- Coarse 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. Coarse aggregate form the main matrix of the concrete, where as 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. Also 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. In case of close reinforcement 10mm size also used. Since, aggregates occupy the volume of concrete, their size; shape and surface have significant impact on fresh and hardened properties of concrete.

FIBER MATERIALS:- According to terminology adopted by the American Concrete Institute (ACI) Committee 544, Fiber Reinforced Concrete, there are four categories of FRC based on fiber material type. These are Steel Fiber Reinforced Concrete, Glass Fiber Reinforced Concrete, Synthetic Fiber Reinforced Concrete, including carbon fibers; and Natural Fiber Reinforced Concrete. Different type of properties of different type of fibres are shown in Table No. 1.

Table No. 1 Properties of Fibers

Fiber	Diameter (μm)	Specific gravity	Modulus of elasticity (GPa)	Tensile strength (GPa)	Elongation at break (%)
Steel	5-500	7.84	200	0.5-2.0	0.5-3.5
Glass	9-15	2.60	70-80	2-4	2-3.5
Polypropylene:					
Aramid (Kevlar)	10	1.45	65-133	3.6	2.1-4.0
Carbon (high strength)	9	1.90	230	2.6	1.0
Cellulose	-	1.2	10	0.3-0.5	-
Acrylic	18	1.18	14-19.5	0.4-1.0	3
Polyethylene	-	0.95	0.3	0.7×10-3	10

ADMIXTURE:-According to ASTM C494, super plasticizer is an effective type of water-reducing admixture which improves the concrete workability. In present research, the admixture used was CICO which affects the cement particle separation leading to improvements in the concrete workability.

WATER: - Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkalis, salts and sugar, organic substances that may be deleterious to concrete. As per IS 456- 2000 Potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly, potable tap water was used for the preparation of all concrete specimens.

IV. EXPERIMENTAL PROGRAMME

In this section, GFRC based specimens has been tested for the compressive strength, flexural strength and split tensile strength.

COMPRESSIVE STRENGTH TEST: To examine the compressive strength of GFRC, cube of 150mm×150mm×150mm has been used in this experimental work 30-40 cubes has been casted to determine the compressive strength. firstly cement and sand are mixed uniformly in dry condition . Secondly coarse aggregates are added in this mixture. Now Glass fibres also added according to mix proportion to get the resultant mixture of M30 grade. Required dosage of water was added in the course of mixing. The cube moulds were demoulded after 24 hours then they were placed in water tank containing portable water and were left for curing. After that the specimen are tested at 7 days and 28 days at compression testing machine (CTM) as per IS 516-1959. Compressive strength of concrete mixtures was measured at the ages of 7 and 28 days and shown in Table No. 3. There was an increase in compressive strength of cube concrete specimens produced with Glass fibres.

Fig. 1 CUBE UNDER COMPRESSION TESTING MACHINE (CTM)

Table No. 2: Compressive Strength for Nominal Mix

Compressive Strength(N/mm^2) of 0% Fiber Grade M40		
	Observed C.S.	Avg. C.S.
Sample M1	36.4	38.34
Sample M2	36.2	
Sample M3	38.4	
Sample M4	40.1	
Sample M5	40.6	

Table No. 3: Compressive Strength for Steel Fiber Mix

Compressive strength(N/mm^2) of 1%, 2% and 3% Steel Fiber Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample CS1.1	51.2	52.74	53.1	54.34	55.6	55.66
	Sample CS1.2	53.2		54.8		55	
	Sample CS1.3	54.1		54		54	
	Sample CS1.4	54.4		55		57.5	
	Sample CS1.5	50.8		54.8		56.2	
60	Sample CS2.1	53.3	53.4	54.8	56.94	56	58.12
	Sample CS2.2	52.1		54.5		55.8	
	Sample CS2.3	54.4		58		58	
	Sample CS2.4	55.1		58		60.2	
	Sample CS2.5	52.1		59.4		60.6	

Table No. 4: Compressive Strength for Polypropylene fiber Mix

Compressive strength(N/mm^2) of 1%, 2% and 3% Polypropylene Fiber Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample CP1.1	38.8	41.32	48.8	47.02	49.4	49.2
	Sample CP1.2	40.4		44.4		50.8	
	Sample CP1.3	41.5		49.5		43.5	
	Sample CP1.4	42.4		44		57.8	
	Sample CP1.5	43.5		48.4		44.5	
60	Sample CP2.1	40.5	45.28	44.8	50.98	49.4	54.48
	Sample CP2.2	45.5		50.4		45.4	
	Sample CP2.3	48.9		53.6		60.1	
	Sample CP2.4	43.5		52.2		55.4	
	Sample CP2.5	48		53.9		62.1	

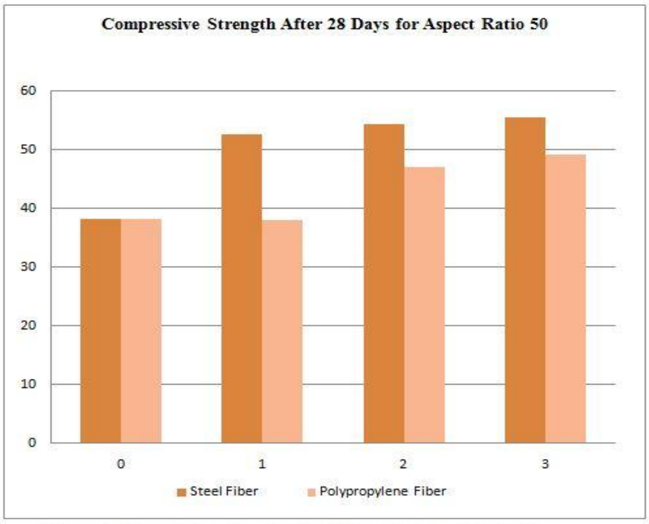

Figure 1: Compressive strength after 28 days for Aspect Ratio 50

Figure 1 is showing the compressive strength results after 28 days. After addition of steel fibers, compressive strength values increases as compared to polypropylene fibers. After addition of fibers with 1%, 2% and 3% small changes are coming in steel fiber whereas in case of polypropylene fiber, maximum changes are coming after 1% to 2%. In case of 2% and 3% polypropylene addition, a small change is there. If we compare between steel fiber and polypropylene fiber at 1%, 27% of total strength increased on addition of steel fiber.

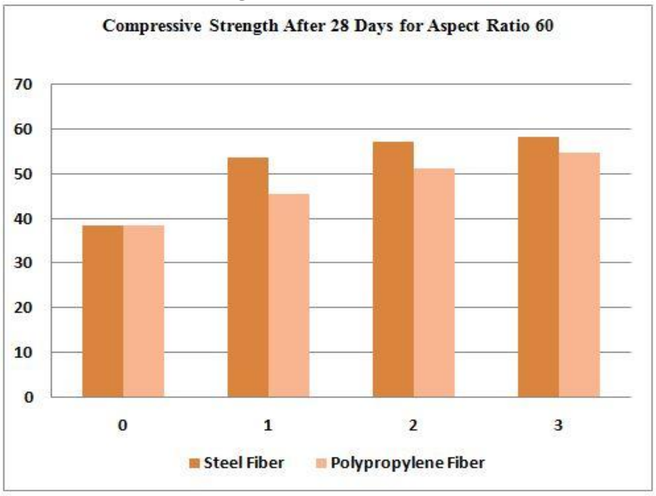

Figure 2: Compressive strength after 28 days for aspect ratio 60

Figure 2 is comparison between compressive strength results after 28 days for aspect ratio 60. For steel fibers, changes are very slow as compared to polypropylene fibers. On addition of 1% steel fiber, strength increased with 28% whereas in case of polypropylene fiber, strength increased 15% for same percentage. If we compare the changes in 1% to 2%, the strength gained approximately 6% for steel fibers and for polypropylene fiber, it is 11%.

FLEXURAL STRENGTH TEST:- To examine the flexural strength of GFRC, cylinder of size 150mm×150mm×70mm has been used in this experimental work. 30-40 beams has been casted to determine the tensile strength. The beams specimens of different proportions were demoulded after 24 hours and transferred to the curing tank for 28 days . After that, beams were placed to the two point loading machine on which we apply the load manually. Note down the load value at which cracks starts developing on the beam. Table no. 4 shows the values of flexural strength of GFRC beams at different mix proportions. Graph 2 shows the variations of flexural strength at 7 and 28 days.

Fig. 2 TEST SET UP FOR BEAM

Table No. 5: Flexural Strength for Nominal Mix

Flexural Strength(N/mm^2) of 0% Fiber Grade M40		
	Observed F.S.	Avg. F.S.
Sample MF1	7.4	7.62
Sample MF2	7.8	
Sample MF3	7	
Sample MF4	7.8	
Sample MF5	8.1	

Table No. 6: Flexural Strength for Steel fiber Mix

Flexural strength(N/mm^2) of 1%, 2% and 3% Steel Fiber Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample FS1.1	8.9	8.54	8.5	9.18	10.5	10.62
	Sample FS1.2	8.1		8.4		10.2	
	Sample FS1.3	9.1		9.4		11.2	
	Sample FS1.4	8.4		9.8		11.4	
	Sample FS1.5	8.2		9.8		9.8	
60	Sample FS2.1	8	8.58	8.9	9.622	11.5	11.54
	Sample FS2.2	8.2		9.5		9.4	
	Sample FS2.3	8.1		9.4		12	
	Sample FS2.4	9.2		10.2		12.4	
	Sample FS2.5	9.4		10.11		12.4	

Table No. 7: Flexural Strength for Polypropylene fiber Mix

Flexural strength(N/sqmm) of 1%, 2% and 3% Polypropylene Fiber Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample FP1.1	36.5	37.76	39.5	39.18	40.1	41.4
	Sample FP1.2	36.5		37.8		40.5	
	Sample FP1.3	40		38.4		42.7	
	Sample FP1.4	38.2		40		41.8	
	Sample FP1.5	37.6		40.2		41.9	
60	Sample FP2.1	40.5	40.14	39	42.18	32.8	44.26
	Sample FP2.2	42.5		45.5		34.9	
	Sample FP2.3	36.4		40		50.8	
	Sample FP2.4	40.2		43.2		51	
	Sample FP2.5	41.1		43.2		51.8	

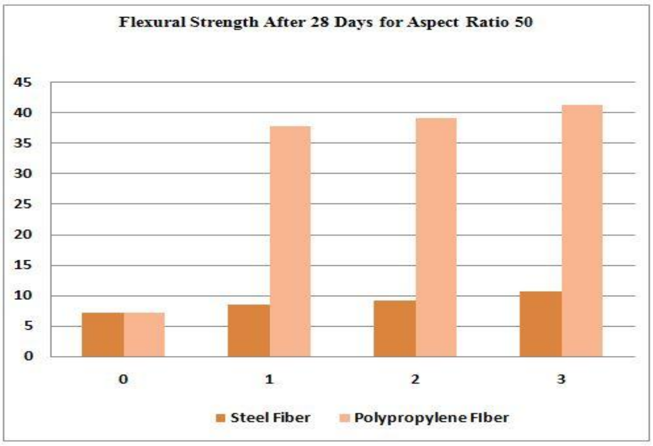

Figure 3: Flexural strength after 28 days for aspect ratio 50

Figure 3 is showing a big change in flexural strength in polypropylene fibers with respect to steel fibers. At 1% mixing of fibers, strength of steel fiber concrete was 15% whereas strength of polypropylene fibers was 80%. In case of 2% mixing of fibers, 21% gained for steel fibers, and 81% gained for polypropylene fibers. Similarly for 3% addition of fibers, steel fiber strength increased 32% whereas 83% strength increased for polypropylene fibers with respect to conventional concrete.

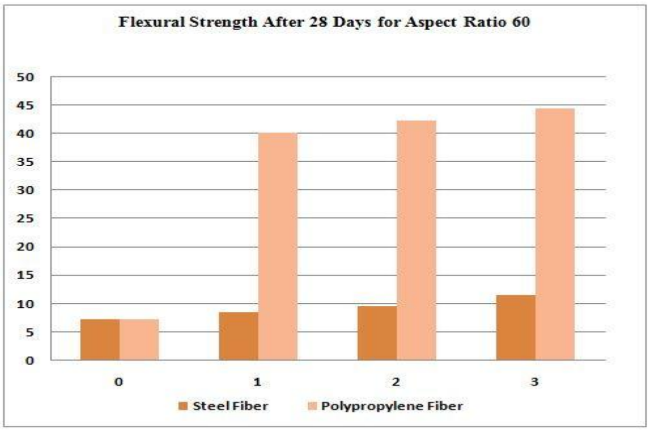

Figure 4: Flexural strength after 28 days for aspect ratio 60

From figure 4, the obtained results are very clear that after 3% addition of polypropylene fibers, the increased strength is 83.5% with respect to nominal concrete. Gained strength between 2% to 3% in polypropylene fibers is 4% whereas for steel fibers these changes are 16% for same. A comparison of steel and polypropylene fibers at 1% is 78.5%, at 2% is 77% and at 3% is 73%. The graphical presentation and analysis shows that a small change in strength is totally depend on percentages of fibers.

SPLIT TENSILE STRENGTH TEST:- To examine the tensile strength of GFRC, cylinder of size 150mm×300mm has been used in this experimental work . 30-40 cylinders has been casted. The cylinder moulds were demoulded after 24 hours and transferred to curing tank for 28 days. After that cylinders were tested horizontally under compression testing machine (CTM). The results shows that in general, there is an increase in splitting tensile strength of cylinder concrete specimens with the addition of fibres to the concrete at 28 days age.

Fig. 3 CYLINDER UNDER CTM

Table No. 8: Flexural Strength for Nominal Mix

Spit Tensile Strength(N/mm^2) of 0% Fiber Grade M40		
	Observed F.S.	Avg. F.S.
Sample MT1	2.9	3.56
Sample MT2	3.1	
Sample MT3	3.4	
Sample MT4	4.2	
Sample MT5	4.2	

Table No. 9: Flexural Strength for Steel fiber Mix

Split Tensile strength(N/mm^2) of 1%, 2% and 3% Steel Fiber Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample TS1.1	3.2	3.26	4.1	4.36	5.2	5.16
	Sample TS1.2	3		4.1		4.2	
	Sample TS1.3	2.9		4.3		5.4	
	Sample TS1.4	3.4		4.2		5.4	
	Sample TS1.5	3.8		5.1		5.6	
60	Sample TS2.1	2.9	3.36	6	4.76	4.5	5.28
	Sample TS2.2	3.2		3.5		5.6	
	Sample TS2.3	3.1		3.5		5.8	
	Sample TS2.4	3.4		5.2		5.9	
	Sample TS2.5	4.2		5.6		4.6	

Table No. 10: Flexural Strength for Polypropylene fiber Mix

Split Tensile strength(N/mm^2) of 1%, 2% and 3% Polypropylene Fiber Grade M40							
Aspect Ratio		1%	Avg.	2%	Avg.	3%	Avg.
50	Sample TP1.1	4.2	4.16	4.5	5.3	5.1	5.76
	Sample TP1.2	2.4		4.5		5.1	
	Sample TP1.3	4.5		5.6		5.2	
	Sample TP1.4	4.5		5.8		6.2	
	Sample TP1.5	5.2		6.1		7.2	
60	Sample TP2.1	4.8	5.5	4.8	5.98	4.6	6.58
	Sample TP2.2	5.1		5.2		8	
	Sample TP2.3	5.6		6.2		6.1	
	Sample TP2.4	5.8		6.4		6.8	
	Sample TP2.5	6.2		7.3		7.4	

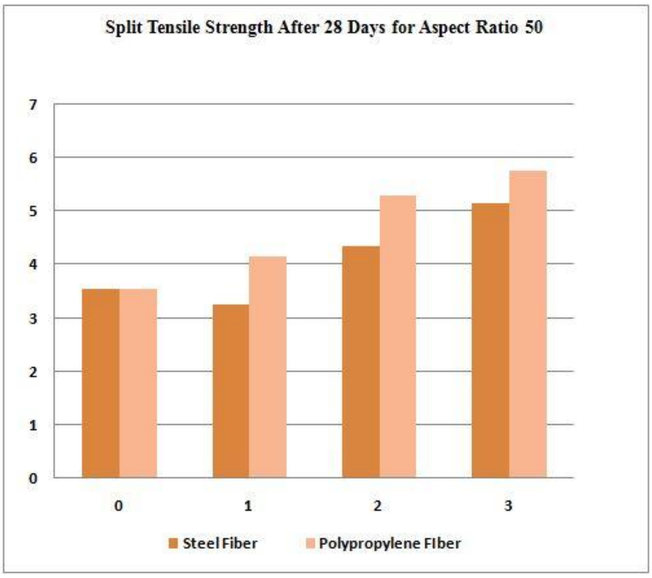

Figure 5: Split Tensile strength after 28 days for aspect ratio 50

Figure 5 is telling the strength of steel fibers at 1% with conventional concrete i.e. fiber free is decreased with 9% whereas for polypropylene fibers, strength increased with 14%. Split tensile strength comparison between 1% and 2% of steel fibers is showing 25% change whereas in polypropylene fibers 21%.

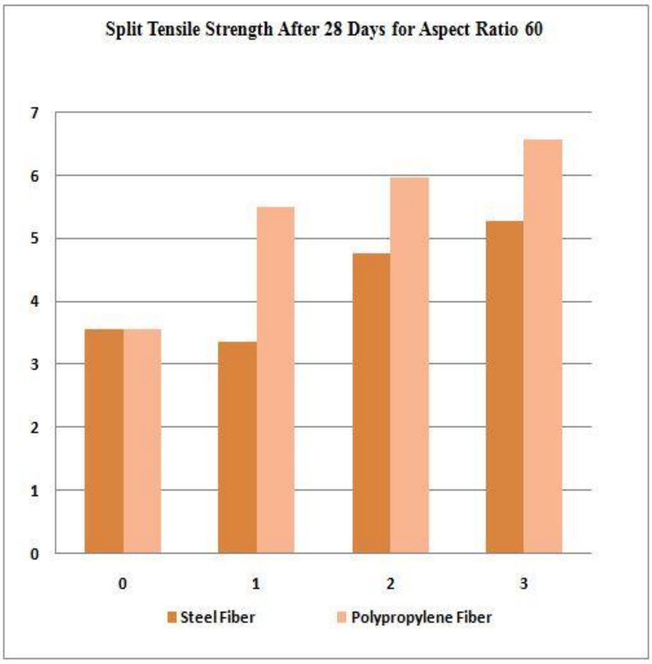

Figure 6: Split Tensile strength after 28 days for aspect ratio 60

Figure 6 is a comparison between split tensile strengths of steel and polypropylene fibers. At 1% of steel fiber addition, 6% strength decreased whereas at 2% addition of same, strength increased 25% with respect to conventional concrete. In polypropylene fiber mixing with conventional concrete, strength increased at 1% is 35% and at 2% is 40%. At 3% for both, polypropylene fibers are showing 13% more capable to check the strength as compared to steel.

V. CONCLUSION

In this present study with the stipulated time and laboratory set up afford has been taken to enlighten the use of so called fiber reinforced concrete in accordance to their proficiency. It was concluded that:

- With the use of superplasticizer, it is possible to get a mix with low water to cement ratio to get the desired strength.
- In case of ordinary portland cement with the use of steel fiber, the 28 days compressive strength at 3% fiber content the result obtained is maximum.
- When polypropylene fiber mixed with nominal concrete, it shows compressive strength is less than steel i.e. 11%.
- After mixing of fibers (i.e. steel & polypropylene) with by 1%,2% and 3%, the compressive strengths increases gradually. Which means slightly changes comes by increasing the percentage fibers for both aspect ratios.
- As shown in graphs for aspect ratios i.e. 50 and 60, compressive strength changes maximum limit in aspect ratio 60. This shows if the length of fibers is more, then compressive strengths will be more.
- The flexural strength for aspect ratio 60 and polypropylene fibers is showing a long gap between steel and polypropylene fibers.
- If we compare the split tensile strength, for the aspect ratio 50, it is 10% variation between steel and polypropylene. Whereas for aspect ratio 50, it is approximately 20% variation in same.
- Polypropylene fibers will be more effective in tensile zone because they have property of plasticity.
- The null hypothesis in T-Test for compressive strength with aspect ratios 50 and 60 for steel and polypropylene fibers shows that values 0.0011 and 0.020 which is showing the results obtained by tests is correct.
- The value 0.0009 for split tensile strength is there in T-Test, it is more effective to show that samples taken for these test are accurate.
- The statistical technique i.e. T-Test for steel and polypropylene fiber of aspect ratio 50 and 60 in case of compressive strength are 1.23x10-6 and 8.64x10-5. The result came from these are showing that assumed hypothesis is null hypothesis and the result is best i.e. 95% true.
- The approximated characteristic strength values for sample in split tensile strength for steel and polypropylene and aspect ratio 50 and 60 is 0.000479 and 9.68x10-5. It gives the result assurance is more than 95%.

VI. FUTURE SCOPE OF THE STUDY

The research work on pozzolanic materials and fiber along with pozzolanas is still limited. But it promises a great scope for further studies. Following aspects are considered for future study and investigation:

- Percentage and actual fineness of sand require as partial cement replacement for good strength development.
- Research on steel fiber and polypropylene fiber greater aspect ratios as a partial cement replacing material, by which we can minimize the cost and at the same time achieve the durability and strength for the production of high performance concrete.
- It requires a proper mixing proportions for the development of high strength, high performance concrete which may not be possible manually. So it needs some global optimization techniques to develop the desire result with greater accuracy and time saving.

REFERENCES

[1] Amit Rana, “some studies on steel fiber reinforced concrete” International Journal of Emerging Technology & Advanced Engineering, Vol. 3, Issue 1, Jan-2013
[2] A.L. Ardeshana, Dr. Atul K. Desai, “durability of fiber reinforced concrete of marine structures” International Journal of Engineering, Research and Applied Sciences, Vol. 2, Issue 4, pp 215-219, July-August 2015
[3] Amir M. Alami, Morteza Aboutalebi, “Mechanical properties of fiber reinforced concrete- A comparative experimental study” International Jounral of Civil, Environmental, Structural, Construction & Architectural Engineering, Vol. 7, No. 9, pp 310-216, 2013
[4] A.M. Vasumathi, K. Rajkumar & G.Ganesh Prabhu, “Compressive behavior of RC column with fiber reinforced concrete confined by CFRP sheets.” Volume 2014,
[5] Amit Rai & Dr. Y.P. Joshi, “Applications & Properties of fiber reinforced concrete” International Journal of Engineering Research & Applications, Vol. 4, Issue 5 (version 1), pp 123-131, 2014
[6] A. Ravichandran, K. Suguma & P.N. Raghunath, “Strength modeling of high strength concrete with hybrid fiber reinforcement” American Journal of applied sciences, 6(2), 219-223, 2009
[7] A. Saadun, Azrul A. Mutalib, R. Hamid & Mohd. H. Mussa, “behavior of polypropylene fiber reinforced concrete under dynamic impact load” Journal of Engineering, Science & Technology, Vol. 11, No. 5 (2016), 684-693
[8] Constantia Achilleos, Diofantos Hadjimitsis & Kyraceos Neocleous, Stelioes Kallis, “Proportioning of steel fiber reinforced concrete mixes for pavement construction and their impact on environment & cost”, 3, 968-983,pp,2011
[9] Dr. Abhijit P. Wadekar, Prof. Rahul D. Pandit, “ comparative evaluation for experimental and analytical mode for tensile behavior of high strength fiber reinforced concrete. American Journal of Engineering & Research, Vol. 03, Issue 11, pp 198-203, 2014
[10] Deepa A Sinha, “Strength characteristics of hybrid fiber reinforced concrete” Volume, Issue 5, oct-2012, pp,71-73
[11] Design considerations of steel fiber reinforced concrete, ACI 544.4R-88
[12] For Plain cement concrete-code practice, IS code 456: 2000
[13] Jaroslov Beno & Matuous Hilar, “Steel fiber reinforced concrete for tunnel lining- verification by extensive laboratory testing & numerical modeling, Acta Polytechnica, Vol. 53 No. 4,pp 329-337, 2013
[14] J. Turmo, N. Banthia, R. Gettu Y, B. Barrayan “Study of the shear behavior of fiber reinforced concrete beams” Materials of construction, Vol. 58, pp, 5-13, 2013
[15] K. Anbuvelan, “Experimental studies on impact characterstics of steel fiber reinforced concrete.” Research Journal of Applied Sciences, Engineering & Technology, 8(14):1625-1629, 2014
[16] Khaled Abdelrahman & Raafat El-Hacha, “Cost and ductility effectiveness of concrete columns strengthened with CRFP and SRFP sheets” by 2014, 6, 1381-1402
[17] K. Srinivasa Rao, S. Rakesh Kumar & A. Laxmi Narayana, “Comparison of performance of standard concrete & fiber reinforced standard concrete exposed to elevated temperatures” American Journal of Engineering Research, Vol. 02,Issue-03, pp 20-26
[18] Maniram Kumar & Er. Anush Khadewal, “strength of evaluation of steel-nylon hybrid fiber reinforced concrete” International journal of engineering Research & applications, Issue 7(version 6) pp 32-36, July 2014
[19] Measurement of properties of fiber reinforced concrete, ACI 544.2R-89
[20] Methods of testing for strength of concrete, IS code 516: 1969
[21] Md. Azree Othuman Mydin, “ Engineering performance of high strength concrete containing steel fiber reinforcement” ANALELE UNIVERSITATII, ‘EFTIMIE MURGU’ RESITA, ANULL XX, NR-31, 2013
[22] Milind V. Mohod, “Performance of steel fiber reinforced concrete” International Journal of Engineering & Science, Vol. 1, Issue 12, pp 01-04, Dec-2012
[23] N. Pannirselvam, P.N. Raghunath & K. Suguna, “strength of reinforced concrete beam with externally bonded fiber reinforced polymer reinforcement.” American Journal of applied sciences, 1(3), 192-199, 2008
[24] Ordinary Portland Cement, IS code 269: 1989
[25] Piero Colajanni, Marinella Fosseti, Maurizia Papia, “ An analytical step by step procedure to derive the flexural response of RC sections in compression” Hindawi Publishing Corporation, Advances in civil engineering, Volume 2013
[26] Portland Pozzolona Cement Specifications, IS 1489

(part-1): 1991
[27] Rashid Hameed, Anaclet Turatsinze, Fraderic Duprat & Alain Sellier "Study of the flexural properties of metallic hybrid fiber reinforced concrete, International Journel of Science and Technology, Vol. 4(02),pp 169-184, 2010

