AN EXPERIMENTAL STUDY ON SHEAR AND FLEXURAL BEHAVIOUROF POLYPROPYLENE AND CRIMPED STEEL FIBER CONCRETE BEAMS

GOKUL KIRUTHIKA.S
Department of Civil Engineering
Muthayammal College of Engineering
Kirthi.sgk@gmail.com

Abstract-----In this study, steel and polypropylene fibers are used to improve flexural and shear performance of reinforced concrete. The purpose of this work is to present the results of a study carried out to characterize the structural behavior of FRC beams under shear loading, considering fibers of different materials (steel and polymeric). Further, the study aims to evaluate the ability of predicting the ultimate shear capacity of concrete beams. At the same time, it is verified whether the design methods for SFRC can be extrapolated to polypropylene fiber reinforced concrete (PFRC). In order to improve its flexural strength and brittleness, a technique of mixing short fibers (similar to that used in conventional concrete) will be introduced to the concrete. In this work, the various literatures are learnt and various tests of cement, fine aggregate and coarse aggregate are handled. In phase-II, the polypropylene and steel fibers at the volume fractions of 0.4% added to the concrete and to find Flexural & shear performance of the FRSC is carried out according to Indian Standard Method.

I. INTRODUCTION

A. General

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of cracks in the concrete may also occur due to the drying shrinkage. So to increase the tensile strength of concrete a technique of introduction of fibers in concrete is being used. The initial researches combined with the large volume of follow up research have led to the development of a wide variety of material formulations that fit the definition of Fiber Reinforced Concrete.

II. METHADOLOGY & MATERIAL STUDY

A. General

The properties of the constituents used in this experimental investigation are given below.

B. Material Specification

1.Cement

Cement is the most important ingredient in concrete.One of the important criteria for the selection of cement is its ability to produce improved microstructure in concrete. Ordinary Portland Cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. For All specimens OPC 53 grade conforming to IS 12269:1987 was used. The properties of cement like Consistency, initial setting time, final setting time and specific gravity were studied and the obtained results were as shown in Table.

Fineness Test

This test is used for checking the proper grading of cement. For testing fineness of cement take 100gm of cement and this continuously passed through standard sieve No. 9 for 15 minutes. According to IS:269-1976 this weight should not be more than 10% of its original weight.

Table I Fineness Test of Cement

Sl.No.	Weight of cement (g)	Weight retained on sieve (g)	% weight of residue $(W_2/W_1) * 100$
1	100	4.8	4.8
2	100	4.3	4.3

Percentage weight of residue = (4.9 + 4.3) x 100 =4.55

This result satisfies the IS specification.

Specific Gravity

Weight of cement = 65

Initial reading =0.8ml

Final reading = 21.6mlVolume of cement = final reading – initial reading = 21.6 – 0.8 = 20.8ml

Specific gravity = weight of cement / volume of cement = $\frac{65}{20.8}$ = 3.13

Table II Test Results of Cement

S.No	Description	Result Obtained
1	Grade	OPC 53
2	Specific Gravity	3.13
3	Initial Setting Time	70 min
4	Final Setting Time	105 min
5	Standard Consistency	33%
6	Fineness	4.55

2. Fine 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. Locally available clean and dry Natural sand passing through IS 4.75 mm sieve is used for casting the specimens. The various tests were conducted for fine aggregates as per Indian Specifications IS 383-1970. The test results of Sieve analysis and specific gravity were listed in Table III

Sieve Analysis

The particle size distribution of fine aggregate was determined from sieve analysis and the experiments are carried out to find the properties of fine aggregates. IS sieve ranging from 10mm to 150micron were used to conduct the sieve analysis and fineness modulus was also found. The properties of fine aggregate satisfy the allowable limits of IS 383: 1970.

Table III Sieve Analysis of Fine Aggregate

IS sieve designation	Mass retained	Percentage retained	Percentage passing	Cumulative percentage Retained	Remarks
4.75mm	4	0.2	99.8	0.2	As per IS 383-1970 it is conformed to zone III
2.36mm	98	0.4	99.4	0.6	
1.18mm	249	9.8	89.6	10.4	
600µm	555	24.9	64.7	35.3	
300µm	81	55.5	9.2	90.8	
150µm	5	8.1	1.1	98.9	
75 µm	5	0.5	0.6	99.4	

Fineness modulus = sum of cumulative % weight retained/100
= (0.2+0.6+10.4+35.3+90.8+98.9) / 100
=2.4

Specific Gravity

Pycnometer was used for determining specific gravity. Take mass of empty Pycnometer (M_1). Then put 200 to 400gm of oven dried sample in the Pycnometer and take the mass (M_2). Pycnometer was then filled with water to the top and shaken well to remove entrapped air. Take its mass (M_3). Then empty the Pycnometer and fill with distilled water alone and take mass (M_4).

Specific gravity of fine aggregate test

Description Weight of sample

Weight of Pycnometer (W_1) = 616 g

Weight of Pycnometer + sample (W_2) = 1379 g

Weight of Pycnometer + sample + water (W_3) = 1936 g

Weight of Pycnometer + water (W_4) = 1467 g

Specific gravity= $(W_2-W_1) / ((W_2-W_1) – (W_3-W_4))$

= (1379 - 616) / ((1379 - 616) - (1936 – 1467)) = 2.61

Table IV Properties of Fine Aggregates

SI No	Description	Result Obtained
1	Specific Gravity	2.61
2	Fineness Modulus	2.4

3. Coarse Aggregate

Coarse aggregate are the crushed stone, which is used for making concrete. The size of coarse aggregate used for casting the specimen is 20mm.The particle size distribution experiment and Pycnometer experiment are carried out to find property of coarse aggregate. The properties of coarse aggregate satisfy the allowable limits of IS 383: 1970.

Particle Size Distribution: 2kg of coarse aggregate was taken. The sieves were in the order of 80mm, 40mm, 20mm, 10 mm and 4.75 mm with 80mm size at the top. Carry out sieving for 15 minutes and the weight of aggregate retained on each sieve was obtained.

Table V. Sieve Analysis of Coarse Aggregate

IS sieve designation	Mass Retained	Percentage retained	Percentage passing	Cumulative percentage retained	Remarks
80mm	0	0	100	0	As per IS 383-1970 it is Conformed to 20mm Size
40mm	870	43.5	43.5	56.5	
20mm	466	23.3	66.8	33.2	
10mm	534	53.4	0	100	
4.75mm	0	0	0	100	
Pan	0	0	0	100	

Fineness modulus = sum of cumulative % weight retained / 100
= (56.5+33.2+100+100+100+100+100+100) / 100 = 6.9

Specific Gravity

The container was filled with the given aggregate in three layers and then overfills with water. The weight of container with aggregate and water was noted. Empty the container and allow the aggregate to drain. Refill the container with water and take its weight. Place the aggregate on a dry cloth and gently surface dry with the cloth keeping it away from sun light. Take the weight of the surface dried aggregate. Place the aggregate in the oven in a

International Journal of Scientific & Engineering Research, Volume 7, Issue 4, April-2016
ISSN 2229-5518

shallow tray at a temperature of 100 to 110° C for 24± ½ hours. Cool the aggregates and note down the weight of oven dried aggregate

Specific gravity of Coarse aggregate Test

Description		Weight of sample
Weight of empty pycnometer (w_1)	=	625gm
Weight of pycnometer + coarse aggregate (w_2)	=	825gm
Weight of pycnometer + C.A + water(w_3)	=	1620gm
Weight of pycnometer + water (w_4)	=	1492gm

Specific gravity = (W2 - W1) / (W4-W1) – (W3-W2)
= (825-625) / (1492-625)-(1620-825)
= 200 / 72
= 2.77

Table VI. Properties of Coarse Aggregates

SI No	Description	Result Obtained
1	Specific Gravity	2.77
2	Fineness Modulus	6.9

4. Water

Water is an important ingredient of concrete as it actively participates in the chemical reactions with cement to form the hydration product, calcium-silicate-hydrate (C-S-H) gel. As per Neville (2000), the quantity of water added should be the minimum requirement for chemical reaction of unhydrated cement, as the excess water would end up only in the formation of undesirable voids in the hardened cement paste of concrete.

Portable tap water available in laboratory with pH value of 7.0±1 and confirming to the requirement of IS 456-2000 is used for mixing concrete and curing the specimen as well.

5. Fiber in Concrete

An unrestrained concrete member will shorten in all directions when it dries or cools. But because most concrete structural members are at least partially restrained, tensile stresses build up when the concrete dries or cools. The stresses are about the same as those that would occur if the concrete had been allowed to contract freely and had then been pulled back to its original length. When these stresses exceed the tensile strength of the concrete, the member cracks. Measures that can be taken to control this cracking include reducing the potential shrinkage of the concrete, providing joints to control crack location and adding nonstructural reinforcement. Even if joints are used to control crack location, cracks may still occur between joints. And in structural reinforced concrete, added measures may be needed to control shrinkage and temperature cracking. Goals for the engineer and contractor are to reduce the number of cracks and to keep ones that do form from opening up too wide. Adding polypropylene fibers to the concrete has been suggested as one way of achieving these goals.

Table VII. Details of fibers

Properties	Steel fiber	Polypropylene fiber
Length(mm)	30	15
Diameter(mm)	0.5	0.1
Shape	Crimped	Straight round
Aspect ratio	60	150
Density (g/cm^3)	7.8	0.9
Elongation at break	3.2	8.1
Tensile strength (MPa)	1500	800

III. MIX DESIGN

The mix design is done for M50 concrete as per IS 456- 2000 and IS 10262-2009.Mix design for M50 concrete is given below.

Mix Design for M50 Concrete
1) Target Mean Strength

Fck1 = fck + 1.65 x s (clause 3.2 of IS 10262-2009)
Fck1 = Target average compressive strength at 28days
fck = Characteristic compressive strength at 28days
s = Standard deviation (table1 / IS10262-2009)
Fck1 = 50+ (1.65 x 5) = 58.25 N/mm2

2) Determination of Free Water-Cement Ratio

In (Fig.1 of IS 10262-1982) using a curve the water-cement ratio corresponding to the target mean strength is determined.
The free water cement ratio for the required target mean compressive strength of 58.25 = 0.35 (Reference by clause 4.1 of IS 10262-2009).

3) Determination of Water Content

Maximum water content = 186 kg (for 25-50 mm slump value from table 2 of IS 10262-2009)
Estimated w/c for 100 mm slump value = 186 + (6/100*186)
= 197 kg/m3

4) Determination of Cement Content
The approximate free water cement content required for uncrushed coarse aggregate with maximum size of 20mm = 197 kg/m3
Cement content = water content / water-cement ratio
= 197 / 0.35 = 562.82 kg/m3 > 400 kg/m3
(Hence ok)

5) Proportion of volume of coarse aggregate & fine aggregate content

From table 3, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate of (zone I) for w/c ratio of 0.5 = 0.60.
In the present case w/c ratio is 0.35 Therefore the corresponding volume of coarse aggregate is increased to decrease the fine aggregate content.
Therefore the corrected volume of coarse aggregate for w/c ratio 0.35 = 0.63.
Volume of fine aggregate content = 1-0.63 = 0.37

Mix calculation
Volume of concrete = 1 m3
Volume of cement = (562.85x1)/(3.15x1000)
= 0.178 m3
Volume of water = (197x1)/(1x1000)
= 0.197 m3
Volume of all aggregate = 1- (0.178 + 0.197)
= 0.625 m3
Mass of coarse aggregate = 0.625x0.63x2.7x1000
= 1063.12 kg/m3
Mass of fine aggregate = 0.625x0.37x2.7x1000
= 624.375 kg/m3
Hence we have found out the required mix proportions:

Table VIII. Mix Proportion for M50 Grade of Concrete

	Cement(Kg)	Water	Fine aggregate(Kg)	Coarse aggregate(Kg)	Water-cement ratio
Quantity	562.23	197	624.4 kg	1063.2kg	0.35
proportions	1	0.35	1.11	1.89	

Table IX. Amount of Fiber Required

Amount of fiber required		
Percentage of fiber	For M50 grade of concrete (kg/m³)	1 mould of impact cylinder (gram)
0.4%	2.24	3.65
0.7%	3.93	7.31
1 %	5.628	10.97

IV. EXPERIMENTAL INSVESTIGATION

A. Introduction
In order to understand the shear and flexural properties of FRC, an extensive laboratory test was carried out at at the age of 7th and 28th days after casting and results obtained are as follows.

B. Compressive Strength

Table X Test Result of Compressive Strength

Sl.no	Design mix	Type of Fibers added	Percentage of fibers added	Avg. compressive strength @7 days	Avg. compressive strength @ 28 days
1.	M50	Nil	Nil	27.44	50.05
2.	M50	CSF	0.4	28.47	52.61
3.	M50	PF	0.4	28.16	52.50
4.	M50	CSF	0.7	30.84	53.72
5.	M50	PF	0.7	30.38	51..17
6.	M50	CSF	1.0	37.48	56.95
7.	M50	PF	1.0	36.90	5.43

C. Tensile Strength Test

Table XI Test Result of Tensile Strength

Sl.no	Design mix	Type of Fibers added	Percentage of fibers added	Avg. tensile strength @7 days	Avg. tensile strength @ 28 days
1.	M50	Nil	Nil	1.96	2.94
2.	M50	CSF	0.4	2.43	3.42
3.	M50	PF	0.4	2.21	3.08
4.	M50	CSF	0.7	2.54	3.59
5.	M50	PF	0.7	2.49	3.45
6.	M50	CSF	1.0	2.28	3.39
7.	M50	PF	1.0	2.16	3.26

D. Flexural Strength Test

Table XII Test Result of Compressive Strength

Sl.no	Design mix	Type of Fibers added	Percentage of fibers added	Avg. flexural strength @7 days	Avg. flexural strength @ 28 days
1.	M50	Nil	Nil	2.08	3.56
2.	M50	CSF	0.4	2.72	4.2
3.	M50	PF	0.4	2.16	3.71
4.	M50	CSF	0.7	2.96	4.91
5.	M50	PF	0.7	2.76	4.72
6.	M50	CSF	1.0	2.26	3.92
7.	M50	PF	1.0	2.00	3.64

The structural-scale beams were tested under shear loading through the two-point load configuration, with a shear span to depth ratio equal to 2.67. The shear ductility increase induced by fiber action is appreciable. In SFRC beams, the maximum load is higher by approximately 40% of that of RCC Beam with minimum stirrups, which increase the deflection at maximum load. An increase of ductility under shear loading can be clearly observed for all FRCs with respect to RCC Beam with minimum stirrups, indicated by the significant increase in the deformability of the elements at maximum load.

Load and Deflection for RCC Beam with minimum stirrups

The deflection was measured at three points using the dial gauge, one at the mid span and other two at one-third point from the support. The deflection increased according to the load increases. The maximum of 6.71 mm deflection was obtained for RCC Beam, which is for shear span to effective depth ratio of 2.67. The graph drawn for RCC Beam is shown below. Compared to all other beams, the shear load carrying capacity of RCC beam with minimum stirrups is low; up to the maximum load carrying capacity the Load Vs Displacement relationship is linear. After that the load, displacement is reducing gradually and then shear failure occur in the beam.

Table XIII Load and Displacement values for RC Beam with minimum stirrups.

	Load in KN	Displacement in mm (at point1)	Displacement in mm (at centre)	Displacement in mm (at point 2)
1.	8.24	0.43	0.43	0.35
2.	16.45	0.77	0.78	0.65
3.	24.67	1.20	1.26	1.06
4.	32.94	1.75	1.93	1.66
5.	41.00	2.70	3.05	2.60
6.	49.30	3.46	3.95	3.33
7.	48.2	4.25	4.75	4.10
8.	47.0	5.34	6.00	5.25
9.	45.5	5.90	6.71	6.08

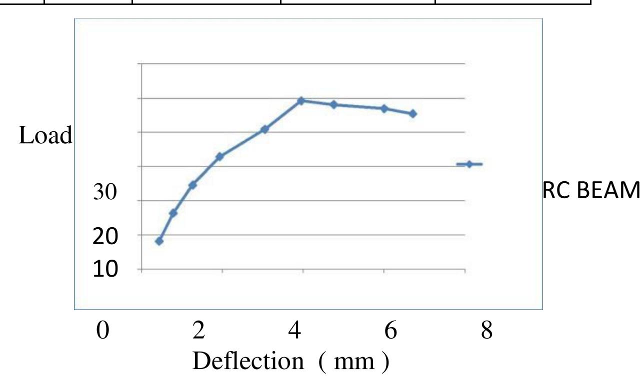


Fig. I load deflection plot for RCC beam

Load and Deflection for SFRC Beam

The deflection was measured at three points using the dial gauge, one at the mid span and other two at one-third point from the support. The deflection increased according to the load increases. The maximum of 10.25 mm deflection was obtained for SFRC, which is for shear span to effective depth ratio of 2.67. The test result of SFRC is presented in below Table. The graph drawn for SFRC is shown below. Compared to PFRC & RCC Beam the shear load carrying capacity of SFRC beam is maximum, up to the maximum load carrying capacity the Load Vs Displacement relationship is linear.

Table IVX Load and Displacement values for SFRC beam.

Sl. no.	Load in KN	Displacement in mm (at point1)	Displacement in mm (at centre)	Displacement in mm (at point 2)
1.	8.24	0.36	0.37	0.36
2.	16.45	0.82	0.84	0.78
3.	24.67	1.07	1.12	1.03
4.	32.94	1.75	1.90	1.70
5.	41.00	2.29	2.50	2.22
6.	49.30	2.94	3.20	2.85
7.	57.40	3.81	4.25	3.68
8.	65.15	4.55	5.07	4.39
9.	72.73	5.55	6.20	5.40
10.	70.00	6.28	7.10	6.25
11.	68.50	8.00	10.25	8.25

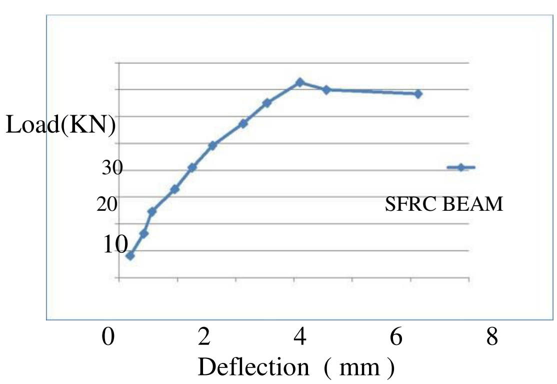


Fig.II load deflection plot for SFRC beam

Load and Deflection for PFRC Beam

The deflection was measured at three points using the dial gauge, one at the mid span and other two at one-third point from the support. The deflection increased according to the load increases. The maximum of 9.80 mm deflection was obtained for PFRC, which is for shear span to effective depth ratio of 2.67. The test result of PFRC is presented in Table 5.3. The graph drawn for SFRC is shown below.

Compared RCC Beam the shear load carrying capacity of PFRC beam is maximum; up to the maximum load carrying capacity the Load Vs Displacement relationship is linear.

Table XV Load and Displacement values for PFRC beam

Sl. no.	Load in KN	Displacement in mm (at point1)	Displacement in mm (at centre)	Displacement in mm (at point 2)
1.	8.24	0.45	0.54	0.39
2.	16.45	0.86	0.82	0.72
3.	24.67	1.09	1.09	1.04
4.	32.94	1.89	2.0	1.76
5.	41.00	2.23	2.43	2.11
6.	49.30	2.60	2.90	2.51
7.	57.40	3.60	4.04	3.51
8.	65.15	4.32	4.87	4.24
9.	63.00	5.20	6.70	5.60
10.	61.50	8.60	9.80	8.80

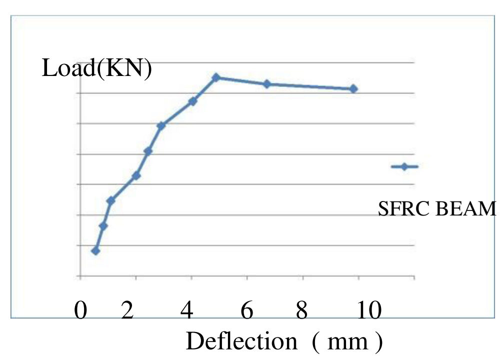
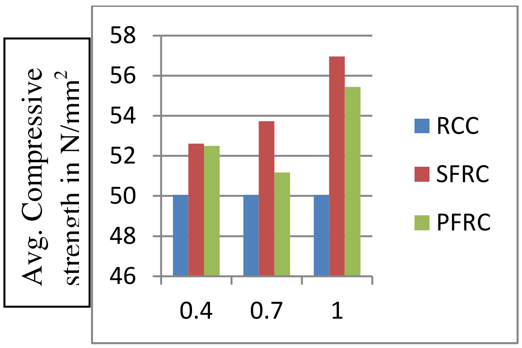


Fig.III load deflection plot for SFRC beam

V RESULTS & DISCUSSIONS

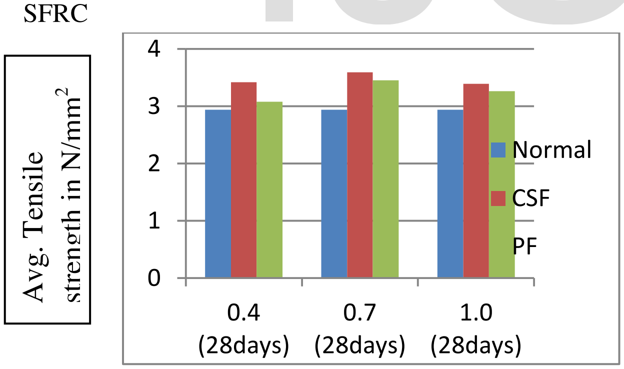
Compressive strength of the concrete is marginally improved due to the incorporation of fibers in the concrete. Compressive strength is maximum for SFRC than PFRC.



% of fibers added

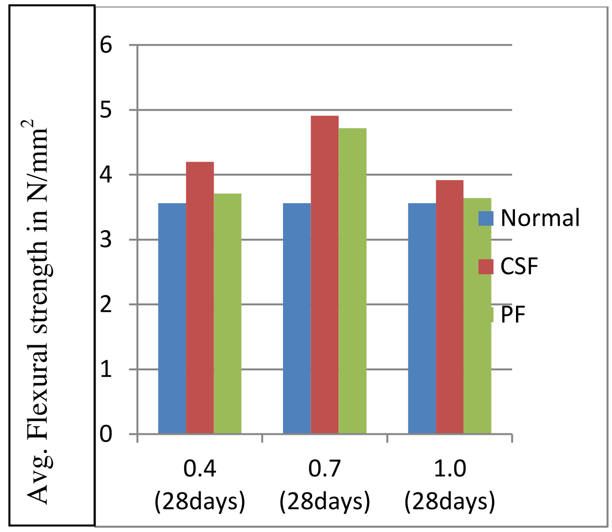
Fig. IV Compressive Strength of Concrete Cubes

Both flexural and split tensile strength is maximum for SFRC than compared to normal and PFRC. From the Fig V & VI we can clearly see that the flexural and tensile strength is maximum for SFRC



% of fibers added

Fig.V Split tensile strength of concrete



% of fibers added

Fig.VI Flexural strength of concrete

From the Fig. VII we can clearly note that the area under the curve is maximum for RCC Beam. Compared to RCC Beam with minimum stirrups, the area under the curve is maximum for both SFRC & PFRC beams. SFRC beam is having more shear carrying capacity than compared to PFRC beam.

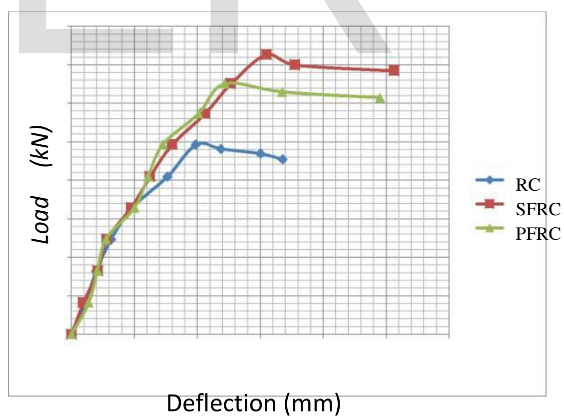


Fig.VII Load-Displacement Response under Shear Loading

VI. CONCLUSION

The following conclusions were drawn with in the limitations of experimental Investigation

It has been observed that the incorporation of fibers to the mix increases the material toughness both in tension and compression, as represented by the toughness indexes of the ASTM and JSCE standards.

COMPRESSIVE STRENGTH

Compressive strength concrete increased at 28days as compared with control mix. There is an increase of 17.5% using CSF (0.7%) with control mix and also there is an increase in 15.8% strength using PF (0.7%).

SPLIT TENSILE STRENGTH

Increase in the split tensile strength is observed up to 22% using CSF (0.7%) and 17.3% using PF (0.7%) compared to normal concrete.

FLEXURAL STRENGTH

The Flexural strength results for concretes is also increased as below

- 38% using CSF (0.7%)
- 32.5% using PF (0.7%)

First crack occurs earlier in PFRC when compared to SFRC. In SFRC beams, the maximum load increased by approximately 20% of the plain concrete. The length and width of the crack is reduced due to the incorporation of fibers in the concrete.

REFERENCES

- ***BensaidBoulekbache, MostefaHamrat ,MohamedChemrouk , SofianeAmziane,“Influence of yield stress and compressive strength on direct shear behavior of steel fiber-reinforced concrete”.***
- ***Cengiz, L. Turanli, “Comparative evaluation of steel mesh, steel fiber and high-performance polypropylene fiber reinforced shotcrete in panel test” Cement and Concrete Research (2004), Vol.34.***
- ***E.Cuenca, P. Serna, “Shear behavior of prestressed precast beams made of self-compacting fiber reinforced concrete” Construction and Building Materials (2013).***
- ***F. Bencardino, L. Rizzuti, G. Spadea, R.N. Swamy, “Experimental evaluation of fiber reinforced concrete fracture properties” Composites: Part B (2010).***
- ***G.M. Chen, Y.H. He, H. Yang, J.F. Chen, Y.C. Guo, “Compressive behavior of steel fiber reinforced recycled aggregate concrete after exposure to elevated temperatures” Construction and Building Materials (2014), Vol.71, pp. 1–15.***
- ***IS 456:2000, “Plain and Reinforced Concrete - Code of practice”, (Fourth revision), Bureau of Indian Standards - New Delhi.***
- ***IS 383: 1970, “Specification for Coarse and Fine Aggregates From Natural Sources For Concrete”,(Second Revisions) Bureau of Indian Standards - New Delhi.***
- ***IS 10262:2009 “The Indian Standard code of practice for Mix Design”(First Revision) Bureau of Indian Standards - New Delhi.***
- ***M.S.Shetty, “Concrete Technology”,S.Chand& Private Limited - New Delhi.***
- ***NemkumarBanthia, Cristina Zanotti, ManoteSappakittipakorn, “Sustainable fiber reinforced concrete for repair applications” Construction and Building Materials (2014) , Vol.67, pp. 405–412.***
- ***O. Plé, T.N.H. Lê, “Effect of polypropylene fiber-reinforcement on the mechanical behavior of silty clay” Geotextiles and Geo membranes (2012), Vol.32, pp. 111-116.***
- ***Peng Zhang, Qing-fu Li,“ Effect of polypropylene fiber on durability of concrete composite containing fly ash and silica fume” Composites: Part B (2013), Vol.45, pp. 1587–1594.***
- ***P.S. Song , S. Hwang , B.C. Sheu B, “ Strength properties of nylon- and polypropylene-fiber-reinforced concretes” Cement and Concrete Research (2005), Vol.35,pp.1546 – 1550.***
- ***SURINDER PAL SINGH “ Fatigue Strength of Hybrid Steel-Polypropylene Fibrous Concrete Beams in Flexure” Procedia Engineering (2011) , Vol.14, pp. 2446–2452.***