An Experimental Investigation on Flexible Concrete

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Abstract – Flexible concrete is composed of all the ingredients of a conventional concrete but the coarse aggregate is replaced and reinforced with polymer fibers. The flexibility of concrete is determined by ductile behavior of concrete. The scope of this study is to improve the ductility of conventional concrete by addition of polypropylene fiber (PP). Properties of polypropylene fiber reinforced concrete (PFRC) and flexible concrete (FC) were studied by casting samples using this fiber. Totally 178 specimens were cast. Preliminary test were carried out on 30 cubes of size 150x150x150 mm and beams of size 500x100x100 mm with two different mix proportions, replacing cement with fly ash and silica fume and fiber contents of 0,0.06,0.12,0.18,0.5,1.0% using Naphthalene based SP, which was found to be ineffective in achieving the workable concrete. From the preliminary test , 1:1.75:2.18:0.40 mix proportions with fiber contents of 0,0.05,0.10,0.15,0.20% and polymer based SP were chosen for casting 30 cubes , 30 disc, 30 beams. The properties of concrete vise ductility, flexural strength, load – deflection behavior, impact strength, stress – strain behavior and compressive strength were studied for all the five series. Also experimental work on FC was carried out on 16 slabs of size 500x110x15mm with fiber contents of 0, 0.5, 1.0, and 1.5% using CM 1:2 to study the flexural strength and load - deflection behavior. Addition of 0.1% PP fiber in PFRC increases the ductility index by 280%, ultimate mid span deflection by 341%, flexural strength by 16%, Modulus of Elasticity by 42%, impact strength by 163%, but decrease the compressive strength by 38% at 0.2%.Addition of 1.0% PP fiber in FC increases the flexural strength by 7.2%. Post crack deflection is 14 times at 1.5% but the workability decreases beyond 1.0%. Therefore addition of 1% PP fiber in CM 1:2 produced the flexible concrete.

Index Terms – Fiber Reinforced Concrete, Flexible Concrete, Polypropylene Fiber, Silica Fume.

1. INTRODUCTION

Concrete is considered to be very durable material that it requires little or no maintenance. In most structural applications concrete is employed primarily to resist compressive stresses. As a construction material, concrete has many advantages like ability to be cast, low cost, good durability, fire resistance, energy efficiency, on site fabrication and aesthetics. However concrete is considered a brittle material, primarily because of its low tensile capacity and poor fracture toughness. Concrete can be modified to perform in more ductile form by addition of fiber in the concrete. The principle role of fibers in brittle matrix composites is to increase their toughness. The behavior of fibers in a brittle matrix is dependent on their length and composition and on the quality of fiber – matrix bond. When a crack appears in the matrix, micro fibers are pulled out after progressive deboning. Longer fibers or fibers of low strength would break. In both cases, fibers serve as crack arrestors.

1.1FIBER REINFORCED CONCRETE

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lends varying properties to the concrete. In addition, the characters of fiber reinforced concrete changes with varying fiber materials, geometries, distribution, orientation and densities. Fibers are usually used in concrete to control cracking due to plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of composite (Concrete and fibers), termed “Volume Fraction” (V_f). The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d).

1.2FLEXIBLE CONCRETE

Flexible concrete (FC) also known as Engineers Cementitious Composites abbreviated as ECC is class of ultra – ductile Fiber Reinforced Cementitious Composites, characterized by high ductility and tight crack width control. This material is capable to exhibit considerably enhanced flexibility. An ECC has a strain capacity of more than 3% and thus acts more like a ductile metal rather than like a brittle glass. A flexible concrete is reinforced with micromechanically design polymer fibers.

1.2 POLYPROPYLENE FIBRE

Polypropylene fibers are found to be suitable to increase the impact strength. They possess very high tensile strength, elongation. Use of polypropylene fibers in concrete can improve mix cohesion when used in low dosage rate. It improves freeze – thaw resistance, impact resistance, resistance to plastic shrinkage during curing, resistance to explosive spalling in case of a severe fire.

2. METHODOLOGY

- Determination of properties of materials
- Design of mix proportion
- Preliminary studies on mix proportion and fiber content
- Study of workability of fresh concrete
- Casting of control concrete samples and flexible concrete samples for varying fiber content
- Obtaining the mechanical properties such as compressive strength, flexural strength and impact strength of the five series of fiber reinforced concrete and flexible concrete
- Study of the load – deflection behavior to obtain optimum fiber content for flexible concrete
- Comparisons the properties of flexible concrete with that of conventional concrete

3. MATERIALS USED

3.1 CEMENT

Locally produced 43 grade ordinary Portland cement was used in this study.

Specific gravity of cement = 3.14

Setting time of cement

Initial setting time = 55 mins

Final setting time = 180 mins

Compressive strength of

Cement =32.4 Mpa

3.2 FINE AGGREGATE

The fine aggregate used in this investigations is river sand passing through 4.75 mm sieve. Water absorption, fineness modulus and specific gravity of fine aggregate is determined.

Water absorption = 1.35%

Fineness modulus = 2.48

Specific gravity = 2.68

The sand used in the mix conforms to zone II

3.3 COARSE AGGREGATE

Hard broken granite of size 10 mm, angular aggregates was used, ware absorption, fineness modulus and specific gravity of coarse aggregate is determined.

Water absorption = 0.45%

Fineness modulus = 5.21

Specific gravity = 2.73

3.4 SUPERPLASTICIZER

1. Naphthalene based (Enfiiq Super Plasticizer 400)

2. Polymer based (Sika Latex Power)

The super plasticizer used for the preliminary test was Enfiiq Super Plasticizer 400, Naphthalene based super plasticizer, is the high range water reducing admixture to produce free flowing concrete. It contains SNFC especially to formulate to impart rheoplastic qualities to concrete. This effect was helpful in attaining increase in strength, to produce high workability of concrete with high range of water reduction. A dosage range of 100ml for per bag of cement. In this project, 0.16% by weight of cement was used.

To obtain more flexible, workable concrete, the super plasticizer used for the experimental work was Sika Latex Power, polymer based super plasticizer. This effect improves elasticity, flexibility and to produce high workability of concrete with high range of water reduction. It also inhibits cracking, improves surface hardening, limits wear and dust generation. A dosage range of 100 ml to 200 ml for per bag of cement. In this project, 0.35% by weight of cement was used.

3.5 WATER

The tap water in Government College of Engineering, Tirunelveli was used.

3.6 POLYPROPYLENE FIBRE

The properties of polypropylene fiber used in this experimental programme as supplied by the manufacturer are given below.

Fiber length = 12mm

Specific gravity = 0.91

Tensile strength = 560 – 780 Mpa

Youngs modulus = 3 – 15 Gpa

Elongation = 8%

Cost = Rs.560/Kg

Fig 3.6.1 polypropylene fiber

3.7 MIX DESIGN

Indian standard method of mix design is used for the design of concrete mix grade M30

S.No	Content	Trial 1	Trial 2	Trial 3
1	w/c	0.55	0.40	0.40
2	Cement (kg/m^3)	300	375	375
3	Fly ash (%)	30	5	-
4	Silica Fume (%)	-	15	-
5	FA (kg/m^3)	893	657	657
6	CA (kg/m^3)	1092	1092	1092
7	SP	Naphthalene	Naphthalene	polymer
	(%)	0.09	0.16	0.35
8	Fiber content (%)	0,0.06,0.12,0.18	0,0.50,0.10	0,0.05,0.10, 0.15,0.20
9	Mix Ratio	1:2.98:3.64	1:1.75:2.18	1:1.75:2.18

Table 3.7.1 Trial mix proportion

4. RESULTS AND DISCUSSIONS

4.1 RESULTS

The results of hardened properties of various combination of CC and PFRC are presented in this chapter

Sample	Days	Ultimate load (kN)	Flexural strength (Mpa)
CC	7th day	8	3.50
	28 th day	9	4.05
PFRC 0.05	7th day	8	3.60
	28 th day	9.5	4.28
PFRC 0.10	7th day	8.13	3.72
	28 th day	10.5	4.73
PFRC 0.15	7th day	7.2	3.03
	28 th day	9.05	4.07
PFRC 0.20	7th day	6.6	2.84
	28 th day	8.75	3.94

Table 4.1.1 Flexural Test On Beams

Sample	Fiber (%)	Mid span deflection (mm)		Ductility index
		Initial crack	Ultimate crack	
CC	-	1.25	1.78	1.42
PFRC 0.05	0.05	1.39	5.70	4.10
PFRC 0.10	0.10	1.45	7.85	5.40
PFRC 0.15	0.15	1.25	4.08	3.26
PFRC 0.20	0.20	1.28	2.98	2.34

Table 4.1.2 Ductility Index of Beams

Properties	Days	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
No of blows for ultimate collapse	7 th	7	12	19	13	11
	28 th	8	14	21	16	12
Energy absorbed (Nm)	7 th	140.28	240.48	380.76	260.52	220.44
	28 th	160.32	280.56	420.84	320.64	240.48

Table 4.1.3 Impact Strength of Discs

Properties	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
Density (kg/m^3)	2486	2468	2453	2433	2412
7 days compressive strength (Mpa)	28.13	26.45	22.96	20.49	19.48
28 days compressive strength (Mpa)	35.32	32.26	27.90	25.72	21.80

Table 4.1.4 Compressive Strength of Cubes

Sample	Days	Ultimate load (kN)	Maximum deflection	Flexural strength (Mpa)
CC	14 th	110	0.80	4.98
FC 0.5	14 th	115	4.90	5.21
FC 1.0	14 th	118	8.20	5.34
FC 1.5	14 th	116	11.95	5.25

Table 4.1.5 Flexure Test on Flexible Concrete

4.2 DISCUSSIONS

Contents	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
Flexural strength in (Mpa)	4.05	4.28	4.73	4.07	3.94
% change	-	+6	+16	+0.5	-3

Table 4.2.1 Flexural Strength Of Beams (28 Th Day)

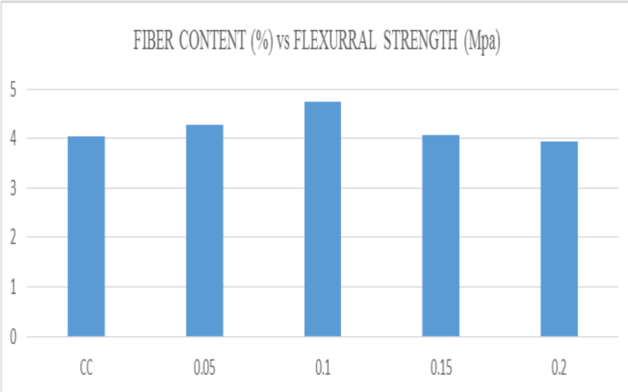

Fig 4.2.1.1 Fiber content Vs Flexural strength

From Fig 4.2.1.1, it is observed that the flexural strength increases up to 0.10% and it decreases beyond 0.10%

Contents	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
Ductility index	1.42	4.10	5.40	3.26	2.34
% Change	-	+189	+280	+130	+65

Table 4.2.2 Ductility Index (28 Th Day)

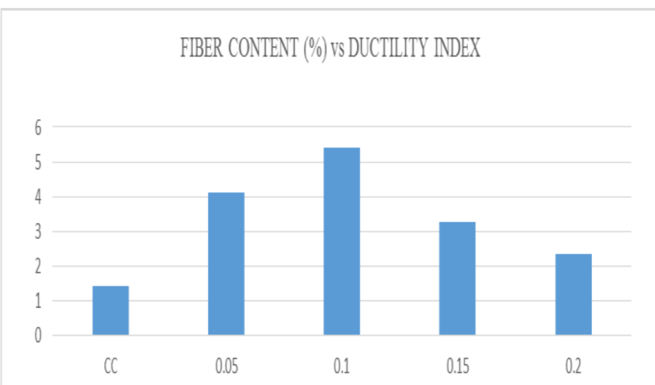

Fig 4.2.2.1 Fiber content Vs Ductility index

From fig 4.2.2.1, it is observed that the fiber content is increased from 0.05% to 0.2% and the ductility increases up to 0.10% and it decreases beyond 0.10%

Content	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
Impact strength in (Nm)	160.32	280.56	420.84	320.64	240.48
% change	-	+75	+163	+100	+50

Table 4.2.3 Impact Strength Of Discs (28 Th Day)

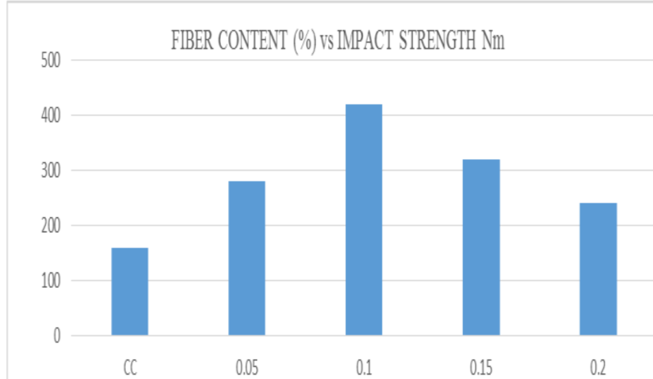

Fig 4.2.3.1 Fiber content Vs impact strength

From Fig 4.2.3.1, it is observed that the impact strength increases up to 0.10% and it decreases beyond 0.10%

Contents	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
Compressive Strength In (Mpa)	35.12	32.26	27.90	25.72	21.80
% Change	-	-9	-21	-27	-38

Table 4.2.4 Compressive Strength Of Cubes (28 Th Day)

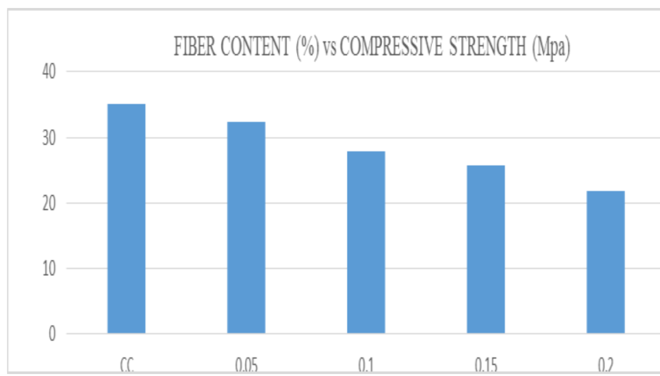

Fig 4.2.4.1 Fiber content Vs compressive strength

From fig 4.2.4.1, it is observed that the fiber content is increased from 0.05% to 0.2% and the compressive strength decreases

Contents	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
Density In Kg/M^3	2486	2468	2453	2433	2412
% Change	-	-0.7	-1.3	-2.1	-3

Table 4.2.5 Density Of Cubes (28 Th Day)

Contents	CC	PFRC 0.05	PFRC 0.10	PFRC 0.15	PFRC 0.20
Modulus Of Elasticity (Gpa)	32.70	41.24	46.30	34.33	29.07
% Change	-	+27	+42	+5	+12

Table 4.2.6 Modulus Of Elasticity (28 Th Day)

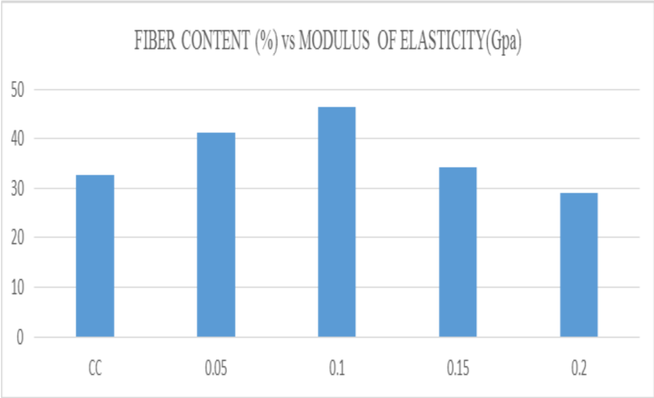

Fig 4.2.6.1 Fiber content Vs Modulus of elasticity

From Fig 4.2.6.1, it is observed that the modulus of elasticity increases up to 0.10% and it decreases beyond 0.10%

Contents	CC	FC 0.5	FC1.0	FC 1.5
Flexural Strength In (Mpa)	4.98	5.21	5.34	5.25
% Change	-	+4.60	+7.20	+5.40

Table 4.2.7 Flexural Strength Of Flexible Concrete (14th Day)

Contents	CC	FC 0.5	FC1.0	FC 1.5
Mid Span Deflection (Mm)	0.80	4.90	8.20	11.95
% Change	-	+512	+925	+1394

Table 4.2.8 Mid Span Deflection Of Flexible Concrete (14th Day)

5. CONCLUSION

The significant conclusions from the experimental study on polypropylene fiber reinforced concrete (PFRC) and flexible concrete (FC) are detailed below.

- Addition of 0.1% polypropylene fiber in PFRC increases the mid span deflection by 341%
- Addition of 0.1% polypropylene fiber in PFRC increases the Flexural strength by 16%
- Addition of 0.1% polypropylene fiber in PFRC increases the ductility index by 280%
- Addition of 0.1% polypropylene fiber in PFRC increases the impact strength by 163%
- Addition of 0.1% polypropylene fiber in PFRC increases the modulus of elasticity by 42%
- Addition of 0.2% polypropylene fiber in PFRC decreases the compressive strength by 38%
- Beyond 0.1% the above mechanical properties decreases hence the fiber can be used up to 0.1%
- Addition of 1.0% polypropylene fiber in FC increases the Flexural strength by 7.2%
- Addition of 1.5% polypropylene fiber in FC increases the post crack deflection by (14 times)
- Beyond 1.0% the flexural strength and workability decreases but the mid span deflection increases
- The failure mode indicates the efficiency of polypropylene fiber as crack arresters
- Addition of polypropylene fiber in PFRC and FC decreases the workability

REFERENCES

[1] Mr.Mehul J.Patel, Mrs.M.Kulkarni, " Effect of polypropylene fiber on the high strength concrete" in 2013
[2] K.Murahari,.Rama mohan Rao, " Effects of polypropylene fibers on the strength properties of fly ash based concrete" in 2013
[3] E.Ramya, etal, " Experimental investigation of polypropylene fiber in engineered cementitious composites" in 2014
[4] Mahendra Prasad," Experimental investigations on polypropylene fiber reinforced concrete" in 2014
[5] Peng Zhang and Li, "Experimental investigations on polypropylene fiber reinforced concrete" in 2014
[6] Faisal Wafa and Samir Ashour,"Mechanical properties of high dtrength flexible concrete" in 2015
[7] Milind V.Mohod, "Performance of polypropylene fiber reinforced concrete" in 2015
[8] Yu Zhu etal, "An experimental study on mechanical properties of flexible concrete" in 2016
[9] M.S.Shetty, "Concrete Technology – Theory and Practice"
[10] IOSR Journal of Mechanical and Civil Engineering
[11] Journals of advanced concrete technology
[12] Journal of information, knowledge and research in Civil Engineering
[13] www.iosrjournals.org/iosr-jmce/papers/vol11
[14] http://civilengineeringindaily.com/concrete-bendable-stronger/
[15] International Journal structure and civil engineering