"Study on Strength Behaviour of Partial Fibre Reinforced Concrete in Slabs"

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ABSTRACT: *In plain concrete, micro-cracks develop even before loading, particularly due to drying shrinkage or other causes of volume changes. These internal micro-cracks are inherently present in the concrete, and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. When loaded, the micro-cracks propagate and open up, and owing to the effect of stress concentration, additional cracks form in places of minor defects. Thus the need for multidirectional and closely spaced reinforcement for concrete arises.*

It has been recognized that the addition of small, closely spaced and uniformly distributed fibres to concrete would act as crack arrester and would significantly improve its static and dynamic properties. This type of concrete is called Fibre Reinforced Concrete.

Partial Fibre Reinforced Concrete (PFRC) is the method of limiting the addition of Fibres in FRC, only to the area subjected to maximum Compressive or Tensile strength when subjected to loading. PFRC will have very similar strength compared to the FRC and have the advantage of lesser fibre quantity which reduces the cost of fibre required. PFRC also have better workability compared to normal FRC.

In this project Concrete slabs were selected as the element for the study of strength behavior of Partial Fibre Reinforced Concrete. M20 Concrete with Mix design carried out based on IS 10262-2009 was used to cast the specimen. Steel fibre of 1mm diameter and coconut fibre of 0.45mm diameter were selected to fibre reinforce the concrete. An aspect ratio of 80 is maintained in both the fibres.

Various tests like Compressive strength, Split tensile strength, Rebound Hammer, Ultrasonic Pulse Velocity, Ball Impact and Load frame test are done in order to study the strength behavior of Partial Fibre Reinforced Concrete Slabs. Based on the final results obtained from the study, it is concluded that both FRC and PFRC behaves similarly under loading conditions and more than 98% of strength of FRC can be achieved by PFRC with up to 50% reduction of fibre volume and cost.

Key words: *Partial Fibre Reinforced Concrete (PFRC),* Steel Fiber, coconut Fiber, *Compressive strength, Split tensile strength, Rebound Hammer, Ultrasonic Pulse Velocity, Ball Impact, Load frame test.*

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Concrete is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. This weakness had been adjusted over many decades by using a system of reinforcing bars (rebar) to create reinforced concrete; so that concrete primarily resists compressive stresses and rebar resist tensile and shear stresses.

In plain concrete and similar brittle materials, micro-cracks develop even before loading, particularly due to drying shrinkage or other causes of volume changes. These internal micro-cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such microcracks, eventually leading to brittle fracture of the concrete. When loaded, the micro-cracks propagate and open up, and owing to the effect of stress concentration, additional cracks form in places of minor defects. Thus the need for multidirectional and closely spaced reinforcement for concrete arises.

It has been recognized that the addition of small, closely spaced and uniformly distributed fibres to concrete would act as crack arrester and would significantly improve its static and dynamic properties. This type of concrete is called Fibre Reinforced Concrete.

Fibre reinforced concrete can be defined as composite material consisting of mixture of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. The use of randomly oriented, short fibres to improve the physical properties of a matrix is an ancient concept. For example, fibres made of straw or jute has been used to improve the properties of bricks for thousands of years.

1.2 TYPES OF FIBRES AND APPLICATIONS

Natural fibres are made from plant, animal and mineral sources. The most used natural fibres are cotton, bamboo and coconut. Metallic fibres are made of either steel or stainless steel. Polymer fibres are a subset of man-made fibres, which are based on synthetic chemicals (often from petrochemical sources) rather than arising from natural materials by a purely physical process. The polymeric fibres include acrylic, aramid, carbon, nylon, polyester, polyethylene and polypropylene fibres. Glass fibre is the predominantly used mineral fibre. Mineral fibres can be particular strong because they are formed with a low number of surface defects. Various kinds of organic and inorganic fibres such as cellulose are also being used to reinforce the cement matrix.

Fibre reinforced concrete is increasingly used because of the advantage of increased static and dynamic tensile strength, energy absorbing characteristics and enhanced fatigue strength. The uniformly dispersal of fibres through the concrete provides isotropic properties not common to traditional reinforced concrete. Fibre reinforced concrete has been tried on overlays of air-field, road pavements, industrial floorings, bridge decks, channel lining, explosive resistant structures, refractory linings etc. The fibre reinforced concrete can be also used for the production of precast products like pipes, boats, beams, flight of steps, wall panels, manhole cover etc.

1.3 FACTORS AFFECTING PROPERTIES OF FRC

The properties of FRC would obviously depend upon the efficient transfer of stress between matrix and fibres, which is largely dependent on the

- Type of fibre used
- Orientation of fibre
- Fibre geometry
- Distribution of the fibre
- Fibre content
- Mixing and compaction techniques of concrete
- Shape and size of the aggregate

1.4. PARTIAL FIBRE REINFORCED CONCRETE

Partial Fibre Reinforced Concrete (PFRC) is the method of limiting the addition of Fibres in FRC, only to the area subjected to maximum Compressive or Tensile strength when subjected to loading. PFRC will have very similar strength compared to the FRC and have the advantage of lesser fibre quantity which reduces the cost of fibre required. PFRC also have better workability compared to normal FRC.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Many researchers have analysed the benefits of Fibre Reinforced Concrete and the fibre properties. The following throw some light on these advantages.

S.K. Al-Oraimi and A.C.Seibi (1979) conducted an experimental using glass and palm tree fibres on high strength concrete. Mechanical strength properties such as compressive, split tensile, flexural strengths and post cracking toughness were studied. It was concluded that natural fibres are comparable with glass fibres.

M.B.Kanchi and O.P.Jain (1980) conducted some experiments and reported that based on the results of three methods such as split tensile test, direct tensile test and flexural test, split tensile strength test was recommended for fibrous concrete. Here also increase in tensile strength and post cracking strength, toughness were reported.

Balaguru and Shah (1992) have reported that the fibres that are long and at higher volume fractions were found to ball up during the mixing process. The process called 'balling' occurs and causes the concrete to become stiff and a reduction in workability with increase volume dosage of fibres. This has a tendency to influence the quality of concrete and strength.

According to Vandewalle 2000; Mindess et al 2003 fine steel fibres mixed in concrete improve the tensile performance of concrete. Fibre reinforced concrete can resist larger tensile stress than normal concrete can. Moreover, fibre reinforced concrete sustains a reasonable proportion of the peak tensile stress (i.e. cracking stress) in the post-cracking phase due mainly to the crack-bridging phenomena.

Buyle-Bodin and Madhkhan (2002) compared the behaviour of SFRC structures with similar structures made of conventional reinforced concrete (RC) and to investigate if the addition of fibres contributed to significant improvement in the overall structural performance.

Vinish John (2011) has reported that more than 98% of compressive strength and flexural strength of FRC is attained by PFRC cubes and beams with 2% fibre volume.

2.2 NEED FOR THE PRESENT WORK

Based on tests results, performed by Vinish John (2011) on PFRC elements it was concluded that more than 98% of compressive strength and flexural strength of FRC is attained by PFRC cubes and beams with 2% fibre volume in both Partial Steel Fibre Reinforced Concrete and Partial Coconut Fibre Reinforced Concrete.

Even though PFRC is highly economical for common use, a comparative study on strength property of PFRC and FRC slabs has to be done for further advancements in their reliability.

2.3 RESEARCH SIGNIFICANCE

A highly cost effective method for the usage of fibre reinforced concrete in slab design can be developed without compromising the strength and durability, specifically in mass concreting.

2.4 OBJECTIVE OF THE WORK

- ✓ To evaluate the optimized fibre quantity of coconut fibre and steel fibre for FRC by split tensile strength test.
- ✓ To investigate and compare the strength behaviour of PCC, FRC, and PFRC slabs.

2.5 SCOPE OF THE WORK

Fibres mixed in concrete improve the tensile performance of concrete. Fibre reinforced concrete can resist larger tensile stress than normal concrete can. Even with this wide variety of applications, there are limitations on the use of PFRC in buildings and bridges because of the lack of convincing evidences generated by quality research.

2.6 SCHEME OF WORK

Behaviour of structural elements made by PCC, FRC and Partial FRC are to be evaluated experimentally using various tests. Scheme of work is given in Figure 2.1,

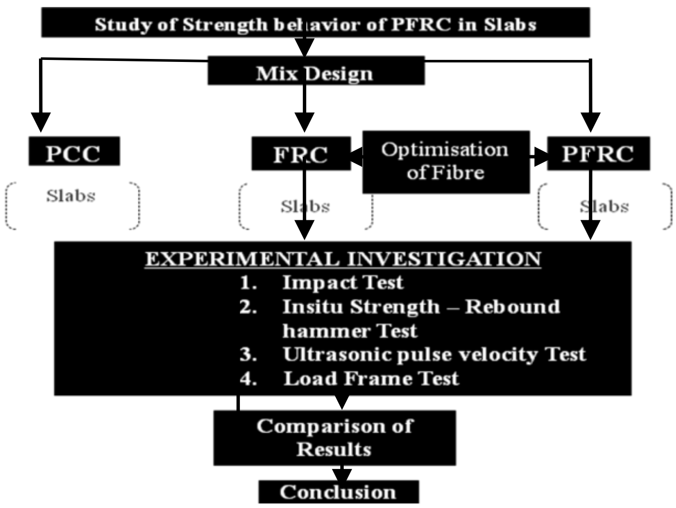

Figure 2.1 – Scheme of work

CHAPTER 3

EXPERIMENTAL INVESTIGATION

3.1 METHODOLOGY

M20 Concrete is considered for the entire experiment. Steel Fibre (artificial fibre) and Coconut Fibre (natural fibre) of 1mm and 0.45mm diameter respectively with an aspect ratio of 80 are used for fibre reinforcing the specimens. The fibres used steel fibre and coconut fibre used for Fibre reinforcing us shown in Figure 3.1,

Figure 3.1 Steel fibre and coconut fibre

The standard specimen chosen for the experiment are Slabs. Further details of the specimen are shown in Figure 3.2.

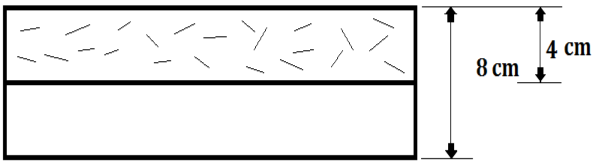

Figure 3.2 FFRC slab

3.2 CASTING AND CURING OF SPECIMENS

The Fine aggregate and cement are mixed in hand until the mixture is thoroughly blended. Coarse aggregate is added to the blend and is mixed until the coarse aggregate is uniformly distributed throughout the batch. Adequate quantity of water is added to get a homogenous mix with desired normal consistency.

Oil is applied thoroughly in order to avoid concrete from sticking at the inner walls of the moulds and the concrete is filled in layers approximately of 5cm thickness. Each layer is compacted with not less than 20-25 strokes per layer using a tamping rod.

The test specimens are stored in moist air for 24hours and after this period, the specimens are removed from the moulds and kept submerged in clear fresh water until taken out to test. The picture taken after fabrication of specimens is given from Fig 3.3

Figure 3.3 Completed cubes

Figure 3.4 Completed cylinders

3.3 TYPES OF TESTS

1 Tests for Determining Mix Design
- Sieve Analysis
- Specific gravity of cement
- Specific gravity of fine aggregate
- Specific gravity of coarse aggregate
- Initial Setting time of cement
- Final Setting time of cement
- Cube Compressive Strength Test

2 Strength Behaviour Studies
- Split tensile strength test
- Rebound hammer test
- Ultrasonic pulse velocity test
- Impact test (Drop ball)
- Load frame test

The following tests were adopted for the study of strength behaviour of the specimens.

a. Cube Compressive Strength Test

The cube test is carried out by placing the cube centrally in between the flat pads on top and bottom of the cube Compression-Testing Machine and applying load. The test is carried out on cube of 150mmx150mmx150mm dimension. The crushing load of the specimen is noted and the compressive strength of the concrete is calculated by dividing Crushing Load with Crushing Area. The compressive strength is the average of the strength of the three cubes for each period of curing.

b. Split Tensile Strength Test

Split tensile test is carried out by applying load on cylinder placed horizontally in between the flat pads of the Compression-Testing Machine. Plywood strips are provided on above and below the specimen, where it is in contact with the plate to assure uniform load distribution. The load is applied continuously without shock and the ultimate splitting load of cylinder is noted. The splitting tensile strength of concrete is calculated using the Equation,

$$f'_{st} = \frac{2P}{\pi\, ld}$$

where *P* is the maximum load at failure in N, and *l* and *d* are the length and diameter of the cylindrical specimen, respectively, in mm.

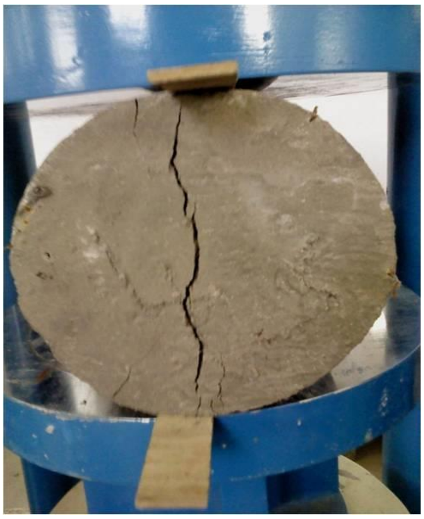

Figure 3.5 Split tensile strength test

c. Rebound Hammer Test

Rebound hammer test is done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992. The underlying principle of the rebound hammer test is the rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the pring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete.

The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Figure 3.6 Rebound hammer

d. Ultra Sonic Pulse Velocity Test

This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS: 13311 (Part 1) – 1992. The underlying principle of this test is -
The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc.

Pulse velocity= (Path length/Travel time)

Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

Figure 3.7 UPV test result interpretations

e. Impact Test (Drop Ball)

To determine the impact strength of the concrete by using this drop ball (Schroeger's impact machine) gives the most accurate results. Initially the dimensions of the concrete specimen should be measured and recorded. Then the specimen is kept at the centre of the machine and application of load is done by using hammer. (Drop ball) The energy per blow is 20 J. Here number of blows to form the initial crack and final crack should be noted. The drop height of the ball is 1m.

f. Load Frame Test

This test is used to plot a relation between load and its corresponding deflection. The apparatus required are loading frame, hydraulic jacks, proving ring, reading line etc. The given concrete specimen is centralized in the loading frame and levelled by using a spirit level.

The initial reading in the dial gauge and deflection gauge are noted. Then the load is incremented by a sequence of 500 Kg and the corresponding deflections are noted. The graph will be plotted between load(X axis) and its corresponding Deflection(Y axis).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 GENERAL

91 specimens of PCC, FRC and PFRC comprising of 9 cubes, 52 cylinders and 30 beams are cast and about to be experimentally tested. The properties of materials used and the results attained by testing of specimens are presented in this section.

4.2 PROPERTIES OF MATERIALS USED FOR THEE SPECIMEN

4.2.1 Cement

Ordinary Portland cement conforming to IS 8112-1989 is used throughout the investigation. Cement used in this study is tested as per IS 4031-1989 and the various results are listed in Table 4.1

Table 4.1 Properties of cement

S. No	Materials	Properties	Experimental Results	Normal Value
1.	Cement (53 grade-OPC)	Specific Gravity ➢ Initial Setting Time ➢ Final Setting Time	3.10 50mins 550mins	>30mins <600mins

4.2.2 Fine aggregate

The clean river sand passing through 4.75mm sieve with specific gravity of 2.605 is used for this investigation. Table 4.2 shows particle size distribution of sand,which confirms to Zone II as per IS383-1970.

Table 4.2 Particle size distribution of sand

Particle Size (mm)	Percentage of Passing	As per IS 383-1970 for Zone II
10	100	100
4.75	97	90-100
2.36	82	75-100
1.18	65	55-90
0.6	42	35-59
0.3	18	8-30
0.15	4	0-10

4.2.3 Coarse aggregate

Machine crushed hard blue granite broken stone angular in shape having a specific gravity value of 2.878 is used as a coarse aggregate. Maximum size of aggregate is limited to 20mm.

4.2.4 Water

Portable water of good quality and free from suspended particles, chemical substances etc., is used both for mixing of concrete and curing of specimens.

4.3 MIX PROPORTION

A mix proportion of 1:1.5:2.8 by weight of cement sand and coarse aggregate is adopted with water cement ratio 0.45 for casting all specimens. The mix design is carried out of M20 concrete using Indian Standard method. The details of mix design are given below.

Mix design (As per IS 10262-2009)

Step 1: Characteristic compressive strength f_{ck} = 20 N/mm^2

Step 2: Target mean strength f_m = $f_{ck} + k \times s$

Where

K = 1.65

S = standard deviation

= 4.0 N/mm^2 (As per IS code 456 – 2000)

Mean size of the aggregate = 20mm (angular)

Degree of workability = 0.8 (compacting factor)

Degree of quality control = good

Type of exposure condition = moderate (assumed)

Step 3: Test data of materials

a) Ordinary Portland Cement(OPC) = 53 grade

b) Specific Gravity of cement = 3.10

c) Specific Gravity of coarse aggregate = 2.878

d) Specific Gravity of fine aggregate = 2.605

e) Fineness of cement = 9%

f) Free moisture present in fine aggregate = 0%

g) Fine aggregate confirming to zone II grading (As per IS 383- 1970 Table 2)

h) Coarse aggregate confirms to IS 383-1970

Target mean strength of concrete at the end of 28 days

f_m = $f_{ck} + k \times s$

= 20 + 1.65 x 4.0

= 26.6 N/mm^2

Step 4:

Maximum water cement ratio = 0.50(from Fig.2 IS 10262- 2009)
Minimum cement content = 260 kg/m^3 (IS 456-2000, Table 5)

Step 5: Determination of water content and sand content per m^3 of concrete
Water content = 186 kg/m^3
Sand content = 40% (As per IS 10262-1982, Table 3)
Step 6: Adjust / correction in water content and sand % due to variations

Volume of coarse aggregate = 0.60
Since w/c ratio is reduced 0.05
Corrected volume of coarse aggregate = 0.62 x .01 + 0.62 = 0.63

Volume of fine aggregate = 1 - 0.67 = 0.37

Step 7: Calculation for Cement content

W/C = 0.45

Cement content = water content / W/c

Cement content = 186 / 0.48 = 387.5 kg/m^3
The minimum cement content for mild exposure condition = 250 kg/m^3

Determination of coarse and fine aggregate

W_{ca} = V_{fa} x D_{fa} (sp.gr x density)
= 0.6 x 0.63 x 2.878 x 1000
= 1088 kg/m^3

W_{fa} = V_{ca} x D_{ca} (sp.gr x density)
= 0.6 x 0.37 x 2.605 x 1000
= 578 kg/m^3

Ratio
Cement : Sand : Coarse aggregate

387.5 : 578 : 1088

1 : 1.5 : 2.8

W/c = 0.45

RESULT 1: 1.5: 2.8 ; W/c = 0.45

4.4 TEST RESULTS FOR P.C.C SPECIMENS

The Compressive Strength Test results for P.C.C Cubes, results are shown in Table No 4.3

Table 4.3 Test results for compressive strength test

Specimen	Compressive Strength (N/mm^2) in Days		
	7	14	28
P.C.C	17.20	22.54	25.83

4.5 TEST RESULTS FOR SPLIT TENSILE STRENGTH

The steel and coconut fibre are mixed with the PCC with different fibre volume to cast cylinders, and the fibre volume showing highest Split Tensile Strength is selected. The test results are given in Table 4.4.

Figure 4.1 Splitting of cylinder

Table 4.4 Test results of split tensile strength (7 and 14 days)

Type of Fibre	No. of Days	Split Tensile Strength N/mm^2					
		Fibre Percentage					
		1.5	2.0	2.5	3.0	3.5	4.0
Coconut Fibre	**7 Days**	2.65	2.72	2.90	**3.08**	2.60	2.44
	14 Days	3.45	3.62	3.76	**4.28**	3.43	3.26
Steel Fibre	**7 Days**	2.43	2.51	**2.62**	2.51	2.39	2.28
	14 Days	3.03	3.21	**3.81**	3.21	3.14	2.96
P.C.C	**7 Days**	2.36					
	14 Days	3.16					

The FRC cylinders with fibre volume of 3% and 2.5% achieved maximum Split Tensile Strength for Coconut fibre and Steel fibre respectively. Henceforth, for the further studies in Strength behaviour of slabs, 3% and 2.5% fibre volume will be used.

4.6 TEST RESULTS FOR REBOUND HAMMER TEST

The plunger of the rebound hammer is pressed against the surface of the slab which gives the compressive strength without destructing the member. The rebound hammer test results for PCC, PFRC and FRC slabs by using steel fibre and coconut fibre are given in table 4.5

Table 4.5 Test results of rebound hammer test

Specimen	Rebound Number		Compressive Strength (14 days) in N/mm^2	
	SFRC	CFRC		
PCC	24		16	
PFRC	27	31	17	20
FRC	28	35	18	22

4.7 TEST RESULTS FOR ULTRASONIC PULSE VELOCITY METHOD

The ultra sonic pulse velocity test results for PCC, PFRC and FRC slabs by using steel fibre are given in Table 4.6

Table 4.6 Test results of upv method for SFRC

Specimen	SFRC		Compressive Strength (28 days) in Nmm²
	Time (in sec)	Velocity (in m/s)	
P.C.C	23.5	3200	25-30 (Good)
PFRC	25.1	3400	25-30 (Good)
FRC	25.4	3450	30-35 (Excellent)

The ultra sonic pulse velocity test results for PCC, PFRC and FRC slabs by using coconut fibre are given in table 4.7

Table 4.7 Test results of UPV method for CFRC

Specimen	CFRC		Compressive Strength (28 days) in Nmm²
	Time (in sec)	Velocity (in m/s)	
P.C.C	24	3200	25-30 (Good)
PFRC	26.2	3800	30-35 (Excellent)
FRC	26.1	3950	30-35 (Excellent)

4.8 TEST RESULTS FOR IMPACT TEST (DROP BALL)

To determine the impact strength of the concrete by using this drop ball (Schroeger's impact machine). Here number of blows to form the initial crack and final crack should be noted. The drop height of the ball is 1m.

The impact test results for PCC, PFRC and FRC slabs by using steel fibre and coconut fibre coconut fibre are given in table 4.8

Table 4.8 Test results of drop ball impact test

Specimen	Average Number of Times Ball Dropped			
	SFRC		CFRC	
	Initial Cracking	Final Cracking	Initial Cracking	Final Cracking
PCC	14	55	14	55
PFRC	18	68	24	81
FRC	20	74	25	89

4.9 TEST RESULTS FOR LOAD-FRAME TEST

Load Vs Deflection readings for P.C.C. slab is presented in Table 4.9 and the Load Vs Deflection Graph for the P.C.C. slab is plotted and presented in Figure 4.2

Table 4.9 Test results of load-frame test for P.C.C

Load(in kg)	P.C.C Deflection (in mm)
0	0
500	0.19
1000	0.45
1500	0.61
2000	0.72
2500	0.80

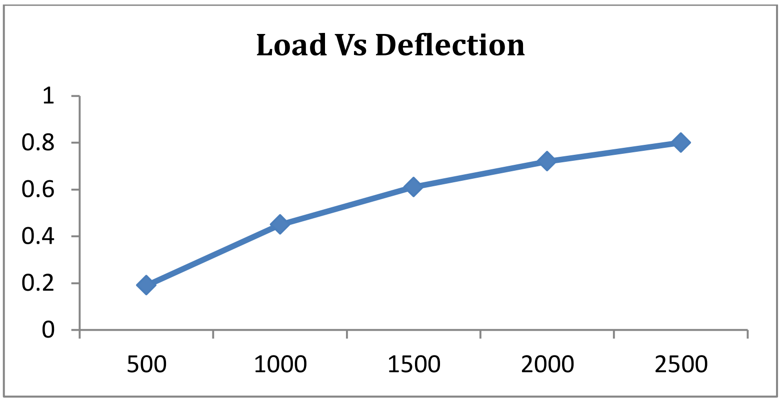

Figure 4.2 Load vs deflection for P.C.C

Load Vs Deflection readings for PFRC beam with Steel Fibre and Coconut Fibre is presented in table 4.10 and the Load Vs Deflection Graph for PFRC beam with Steel Fibre and Coconut Fibre is plotted and presented in fig 4.3 and fig 4.4

Table 4.10 Test results of load-frame test for PFRC

Load (in Kg)	PFRC Deflection (in mm)	
	SFRC	CFRC
0	0	0
500	0.16	0.12
1000	0.35	0.28
1500	0.56	0.37
2000	0.63	0.48
2500	Fail	0.52

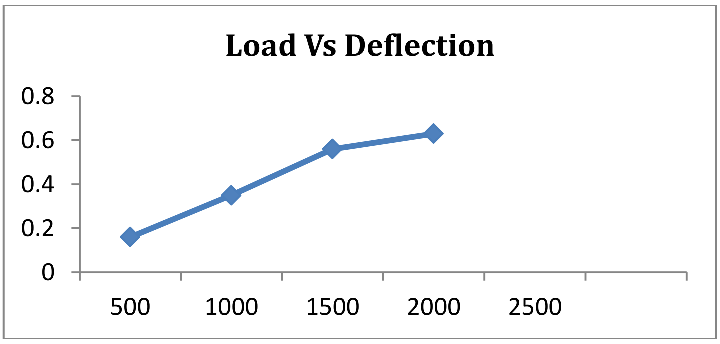

Figure 4.3 Load vs deflection for PFRC (SFRC)

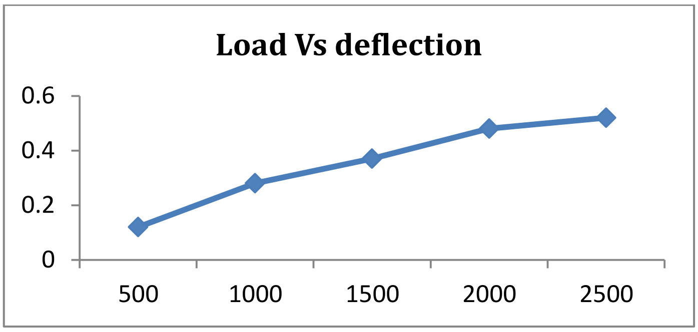

Figure 4.4 Load vs deflection for PFRC (CFRC)

Load Vs Deflection readings for FRC beam with Steel Fibre and Coconut Fibre is presented in table 4.11 and the Load Vs Deflection Graph for FRC beam with Steel Fibre and Coconut Fibre is plotted and presented in fig 4.5 and fig 4.6

Table 4.11 Test results of load-frame test for FRC

Load (in Kg)	FRC Deflection (in mm)	
	SFRC	CFRC
0	0	0
500	0.14	0.10
1000	0.31	0.25
1500	0.50	0.34
2000	0.58	0.45
2500	Fail	0.49

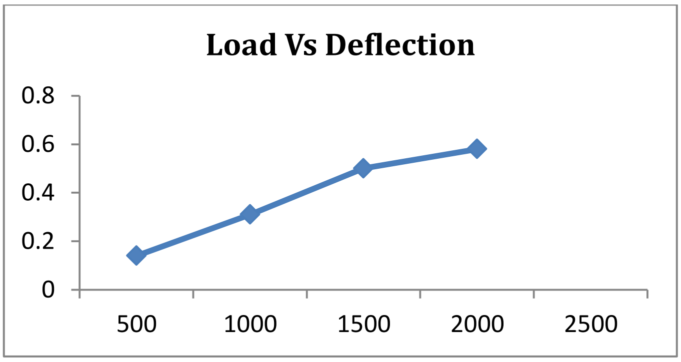

Figure 4.5 Load vs deflection for FRC (SFRC)

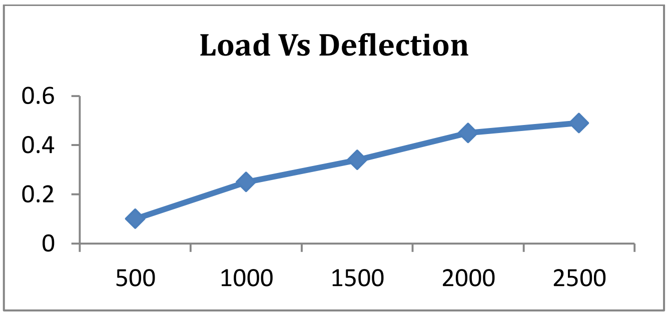

Figure 4.6 Load vs deflection for FRC (CFRC)

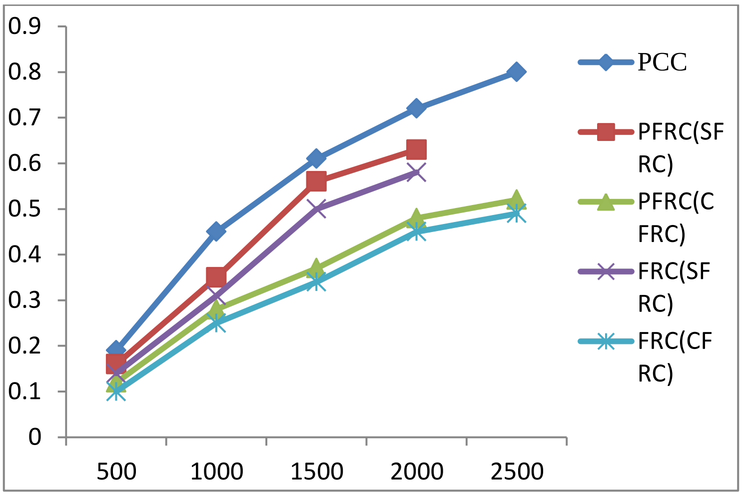

Figure 4.7 Load vs deflection for PCC, PFRC, FRC

Figure 4.8 SFRC Mix

Figure 4.9 CFRC Mix

Figure 4.10 Laying of slabs

Figure 4.11 Failure of PFRC slab

CHAPTER 5

CONCLUSION

5.1 GENERAL

The addition of fibres in Fibre Reinforced Concrete, without considering the actual depth, is practiced so far. In this study, an effort has been made to look into the behaviour of Partial Fibre Reinforcement instead of fibre reinforcing the complete structure. The standard specimens of Cubes, Cylinders and Slabs are chosen for studying the strength behaviour of the PFRC.

The properties of PFRC are investigated by the comparison of Compressive Strength, Split Tensile Strength, Rebound Hammer, Ultra Sonic Pulse Velocity, Ball Impact and Load Frame test of PCC, FRC and PFRC specimens. The results and the conclusion is presented in the following sections.[It is concluded that the similar strength behaviour of FRC can be achieved by PFRC with up to 50% reduction of fibre volume and cost.]

5.2 CONCLUSION

Based on the results obtained in the present study and the discussion of results the following conclusions are made:

- Split Tensile Strength Test carried on FRC cylinders with varying fibre quantity confirms that the maximum Tensile Strength is attained, when the fibre quantity is 2.5% for Steel and 3% for Coconut Fibre.

- Addition of Steel Fibres and Coconut Fibres into PCC increased the Split Tensile Strength of concrete upto 1.36 times and 1.55 times respectively.

- FRC with Coconut Fibres shows better Compressive Strength, Split Tensile Strength and Impact Strength compared to the FRC with Steel Fibres.

- PFRC with Steel Fibres attained 99.92% of Compressive Strength of FRC, by providing a layer of FRC.

- Similarly PFRC with Coconut Fibres attained 98.81% of Compressive Strength of FRC, by providing a layer of FRC

- Both FRC and PFRC with steel fibres show a similar load vs. deflection graph, which confirms that both the FRC and PFRC slabs with steel fibres behaved in a similar manner under load.

- Similarly FRC and PFRC with coconut fibres show a similar load vs. deflection graph, which confirms that both the FRC and PFRC slabs with coconut fibres behaved in a similar manner under load.

5.3 SCOPE FOR FUTURE RESEARCH

- Other specimens like columns, trusses and frames can be considered for testing.
- A detailed investigation on the resilience and workability of PFRC can be carried out.
- Further investigation for the optimisation of FRC layer thickness in PFRC can be carried out.

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