



**EXPERIMENTAL STUDY ON RC BEAMS WITH AND WITHOUT
FERROUS & NON-FERROUS FIBERS**

A Project Report

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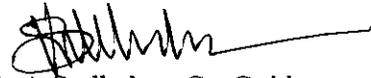
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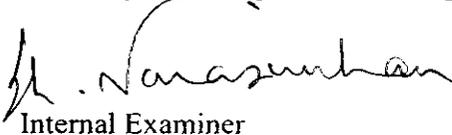


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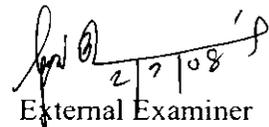


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SYNOPSIS

Concrete is a heterogeneous composite material made up of cement, fine aggregate, coarse aggregate and water mixed in a desired proportion based on strength requirement. Fiber reinforced concrete (FRC) is distinguished as a potential construction material over the ordinary reinforced cement concrete. It has superior properties like increased tensile strength, bending strength, improved ductility, resistance to cracking, high impact strength, toughness and spalling resistance. Fibers suitable for reinforcing concrete have been produced from steel, glass, and synthetic fibers.

In this experimental investigation, fiber reinforced concrete with and without ferrous and non-ferrous fibers was studied for M₂₅ and M₃₀ grade of concrete. The performance characteristics like workability, mechanical properties like stress-strain characteristics, compressive strength, split tensile strength, micro structural properties like water absorption and sorptivity for cube specimens. The toughness, toughness indices, flexural toughness factor of beams as per ASTM C1018 and JSCE SF 4 were studied and compared with plain concrete beams.

The tested result shows that maximum toughness of 43.1 N-m and flexural toughness factor of 2.3 was achieved in M₃₀ Steel (ferrous) fiber reinforced concrete. In case of FRC, there is marginal improvement in compressive strength than the tensile strength. Water absorption and Sorptivity values were less in Polypropylene (non-ferrous) fiber reinforced concrete.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM - American Standard for Testing Materials

CA - Coarse Aggregate

FA - Fine Aggregate

FRC - Fiber Reinforced Concrete

HFRC - Hybrid Fiber Reinforced Concrete

IS - Indian Standards

JSCE - The Japan Society of Civil Engineers

PFRC - Polypropylene Fiber Reinforced Concrete

SFRC - Steel Fiber Reinforced Concrete

SWA - Saturated Water Absorption

μ - Microns

δ - Deflection

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Fiber reinforced concrete (FRC) is a concrete made primarily of hydraulic cements, aggregates and discrete reinforcing fibers. Fibers suitable for reinforcing concrete have been produced from steel, glass and organic polymers (synthetic fibers). The concrete matrices may be mortars, normally proportioned mixes, or mixes specifically formulated for particular application. Generally the length and diameter of the fibers used for FRC do not exceed 76mm and 0.04mm respectively.

Introduction of fibers into the concrete results in post-elastic property changes that range from subtle to substantial depending upon number of factors, including matrix strength, fiber type, fiber modulus, fiber aspect ratio, fiber content and aggregate size effects. For many practical applications, the first crack strength is not increased. In these cases, the most significant enhancement from the fibers is the post-cracking composite response. This is most commonly evaluated and controlled through toughness testing (such as measurement of area under the load-deformation curve).

1.2 FIBER REINFORCED Vs CONVENTIONAL CONCRETE

Unreinforced concrete has a low tensile strength and a low strain capacity at fracture. Adding reinforcing bars or prestressing steel traditionally overcomes these shortcomings. Reinforcing steel is continuous and is specifically located in the structure to optimize performance. Fibers are discontinuous and are generally distributed randomly throughout the concrete matrix. Although not currently addressed by ACI Committee 318, fibers are being used in structural applications with conventional reinforcement. Because of flexibility in methods of fabrication, fiber reinforced concrete can be an economic and useful construction material.

1.3 ADVANTAGES OF FIBERS

- Improved long-term serviceability of the structure or product
- Prevents the occurrence of large crack widths
- Increases matrix tensile strength at high volume percentages of fibers
- Results in saving of expensive mortar, cement and sand
- Reduces crack during plastic and hardening stage
- Reduces water seepages and protects steel in concrete from corroding and walls from dampening
- Protects corners in precast slabs and concrete flooring
- Increases abrasion resistance by over 40% thereby increasing life of roads, walkways, and floors.
- Reduces pitting of floor

1.4 APPLICATIONS OF FIBERS

- Rock slope stabilization and support of excavated foundations in conjunction with rock and soil anchor systems
- Industrial floorings, road pavements, warehouses, channel linings
- Protect bridge abutments
- Rehabilitation of deteriorated marine structures such as light stations, bulk heads, piers, sea walls and dry docks
- Slip-formed cast-in-place tunnel linings
- RCC & PCC like lintel, beam, column, flooring and plastering walls
- Hollow blocks and precast
- Manhole cover, tanks and tiles

CHAPTER 2

MAIN THEME OF THE PROJECT

2.1 LITERATURE REVIEW

Anbuvelan et al (2007) studied the properties of concretes containing polypropylene, steel and re-engineered plastic shred fiber in three grades of concrete with and without addition of fibers. In their research attempt has been made to study the influence of these fibers with 0.1%, 0.5% and 0.75% by volume of concrete mix, with the same aspect ratio of 80, on properties such as compressive strength, flexural strength, abrasion strength, impact strength and plastic shrinkage. It was found that re-engineered plastic shred fibers in concrete improves the performance of highway pavements and also solving the solid waste disposal of plastics.

Appa Rao and Raghu Prasad (2000) conducted a study on the fracture toughness behaviour of steel fiber reinforced high-strength concrete. Straight steel fibers are distributed randomly at three different volume fractions of 0.31, 0.47 and 0.62 percent (24, 36 and 48 Kg/m³ of concrete respectively). It has been observed that the influence of volume fraction and reinforcement index on strength of concrete was negligible. The fracture energy and toughness of high strength concrete was increased as the volume fraction of fibers increased. It was found that relatively large amount of fracture energy was needed for fracturing the fiber reinforced high-strength concrete.

Balaguru and Najm (2004) investigated the high-performance fiber-reinforced concrete mixture proportions with high fiber volume fractions. They tested six mortar mixture proportions and one lightweight concrete mixture and three fiber types. The flexural toughness of mixtures achieved in this study was two to three times higher than those of conventional FRC. FRC with volume fractions up to 3.75% was achieved using mortar matrix and up to 3% using lightweight concrete matrix. It was concluded that FRC with hooked steel fibers had the highest toughness compared with straight fibers and polypropylene macro fibers.

Nataraja et al (1998) studied the behaviour of steel fiber reinforced concrete under compression for cylinder compressive strength ranging from 30 N/mm² to 50 N/mm². Round crimped fibers with three volume fractions of 0.5, 0.75 and 1 percent (39, 59 and 78 Kg/m³) and for two aspect ratios of 55 and 82 are considered. Also the effect of fiber addition to concrete on compressive strength was studied. It was noted that addition of fibers to concrete significantly increases its toughness and makes it more ductile as observed from the modes of failure of the test specimens.

Nemkumar Bantia and Sayed Mohamad Soleimani (2005) studied the flexural response of hybrid fiber-reinforced cementitious composites. They investigated the flexural toughness properties of hybrid fiber-reinforced concrete and identified the synergistic effects between fibers. It was noted that some hybrid composites demonstrated some synergy between fibers. They concluded that isotropic pitch-based carbon fiber with its greater strain capacity work better in hybrids than the low strain capacity mesophase pitch-based carbon fiber.

Piti Sukontasukkul (2004) evaluated the toughness of steel and polypropylene fiber reinforced concrete beams under bending. Two different methods (ASTM C1018 and JSCE SF-4) are used to measure the toughness of steel and polypropylene fiber reinforced concrete subjected to bending. It was indicated that in the JSCE method, the information obtained by only one specified deflection toughness seemed to be insufficient in reflecting the characteristics of the load-deflection curves of both FRCs but in the ASTM method, the obtained information using the four toughness values at different deflections appeared to better clarify the characteristics of both FRCs.

Rashid and Mansur (2005) investigated the reinforced high-strength concrete beams in flexure. They used 16 reinforced concrete beams flexural results to evaluate the implications of using high-strength concrete. Test parameters considered include concrete compressive strength, ratios of tensile and compressive reinforcements and spacing of lateral ties. It was noticed that some detailing requirements for compression

reinforcement need to be assessed so as to utilize its full strength potential and ensure adequate ductile response of the beam when high strength concrete is involved.

Raul Zerbino et al (2006) analyzed the pseudo-ductile behaviour of steel fiber reinforced high-strength concretes, with emphasis on toughness parameters determined through the ASTM C1018 procedure. The effects of matrix strength level, fiber type and dosage are studied and the geometry of the specimens and loading configuration varied. They also analyzed the failure mechanism under compressive loading using critical stress concept. It was observed that toughness indices tend to increase with a decrease in the beam height and are lower for center-point loading than for third-point loading.

Yurtseven et al (2006) characterized and quantified the mechanical properties of hybrid fiber reinforced concrete. They prepared nine mixes, one plain control mix and eight fiber reinforced mixes. Six of the mixes were reinforced in a hybrid form. Volume percentage of fiber inclusion was kept constant at 1.5% and in hybrid reinforced mixes; volume percentage of macro fibers was 1% whereas the remaining fiber inclusion was composed of micro fibers. It was observed that micro steel fibers contributed to the strength and toughness whereas polypropylene fibers are effective in providing ductility.

Zongcai Deng and Jianhui Li (2006) studied the mechanical behaviors of concrete combined with steel and synthetic macro-fibers, which includes high elastic modulus steel fiber and low elastic modulus synthetic macro-fiber as two elements were used as reinforcement materials in concrete. Flexural impact strength was analyzed with statistic analyses method based on ASTM and JSCE method, an improved flexural toughness evaluating method suitable for concrete with synthetic macro-fiber was proposed. It was noticed that the flexural toughness of concrete combined with hybrid fibers were better than that of the concrete only with single type of fibers and the relative residual strength of the concrete combined with 0.5% volume fraction steel fibers and 1% HPP fibers was about 80%.

2.2 OBJECTIVES AND SCOPE OF INVESTIGATION

The objective of the present investigation is to study the following aspects of fiber reinforced concrete with and without ferrous & non-ferrous fibers.

- To study the performance characteristics of the materials used in FRC
- To study the strength characteristics like Compressive strength and Split tensile strength of FRC
- To study the Stress-Strain characteristics of FRC
- To study the first crack load, ultimate failure strain, toughness indices as per ASTM C1018 method and toughness factor by JSCE- SF 4 method
- Micro structural properties like Water absorption and Sorptivity using ASTM standards

2.3 MATERIALS USED

- Portland Pozzolana Cement (PPC) as per IS 1489-1991 with specific gravity of 3.15 was used in this research
- Locally available river sand confirmed to zone II (as per IS 383-1970) of fineness modulus of 2.7 was used as fine aggregate
- Crushed blue granite as per IS 383-1970 passing through 20mm sieve and retained on 12.5mm sieve was used as coarse aggregate
- Potable water as per IS 456-2000 was used for the concrete preparation
- Steel fibers of hooked type with length of 60mm and diameter of 0.5mm was used as ferrous fiber
- Polypropylene fibers of virgin type with length of 12mm was used as non-ferrous fiber
- Hybrid fibers (combination of steel fiber and polypropylene fiber) were used

2.4 PERFORMANCE CHARACTERISTICS OF MATERIAL

2.4.1 Test on cement

Cement used in this research were PPC whose properties like consistency, initial setting time, final setting time and specific gravity were studied and results are shown in Table 3.1

2.4.2 Tests on aggregate

2.4.2.1 Fine aggregates

Fine aggregate used for concrete was well graded, locally available river sand passing through 4.75mm sieve and retained on 150 micron sieve to achieve minimum void ratio. The properties of fine aggregates like fineness modulus, specific gravity and bulk density were studied as per IS 383-1970 and the test results are shown in Table 3.2

2.4.2.2 Coarse aggregates

Locally available crushed blue granite stones of size passing through 20mm sieve and retained on 12.5mm sieve as per IS 383-1970 was used as Coarse aggregate for experimental purposes. Tests such as fineness modulus, specific gravity and bulk density were performed as per IS 2386-1963 and the results are shown in Table 3.3

2.4.3 Tests on FRC

2.4.3.1 Fresh Concrete

Slump test was conducted on fresh concrete as per IS 1199-1959 to know the workability of concrete and the obtained values are shown in Table 3.5

2.4.3.2 Hardened Concrete

The hardened properties of concrete like Compressive strength test, Split tensile strength test and the micro structural properties like saturated water absorption, Sorptivity, Stress- Strain characteristics for the concrete mixes were conducted as per IS 516-1959, IS 5816-1999 and ASTM standards respectively and the test results were shown in Table 3.6, 3.7, 3.8, 3.9 and 3.10.

2.5 EXPERIMENTAL PROGRAMME

Mixture proportioning of M₂₅ and M₃₀ grades as per IS 10262-1982 followed for concrete with and without ferrous and non-ferrous fibers. Volume of concrete mix was calculated to arrive the weight of individual materials necessary for the particular mix. Three types of locally available aggregates, i.e. 20mm coarse aggregate, 12.5mm coarse aggregate and fine aggregates were used together.

The aggregates and cement were mixed dry in a pan mixer for 2 minutes for concrete without fibers and water was added gradually. For concrete with fibers are

added in small quantity after 80% of water was added to the mix and mixed for another 2 minutes. The concrete cubes, cylinders and prisms were casted and are vibrated as per IS standards. Needle vibrator was used for compaction of concrete beams.

The concrete mix was placed in beams in three layers and vibration was done using needle vibrator, as the depth of the beam was high in which manual strokes are not suitable. The cubes, cylinders, prisms and beams were left in moulds for a period of 24 hours in accordance with the test variables selected. After 24 hours, specimens were de-moulded and placed in curing tank for 28 days. The loading rate and other test procedures used were in accordance with the details specified in the relevant Indian standards, ASTM C1018 and JSCE SF-4.

The size of 150 mm x 150 mm x 150 mm cube specimens was casted for Compressive strength test and micro structural property studies. 150 mm x 300 mm cylinder specimens were used for Split tensile strength test and Stress-Strain characteristics of concrete. 100 mm x 100 mm x 500 mm prism specimens were used for flexural strength test from which optimum dosage of fibers was obtained. 150 mm x 250 mm x 2150 mm beam specimens with two numbers of 10mm dia bars were used for evaluating first crack load, toughness indices and toughness factor.

Details of casted specimens

Number of Cubes (150 x 150 x 150mm)	= 30
Number of Cylinders (150mm dia & 300mm height)	= 30
Number of Prisms (100 x 100 x 500 mm)	= 24
Number of Beams (150 x 250 x 2150 mm)	= 24

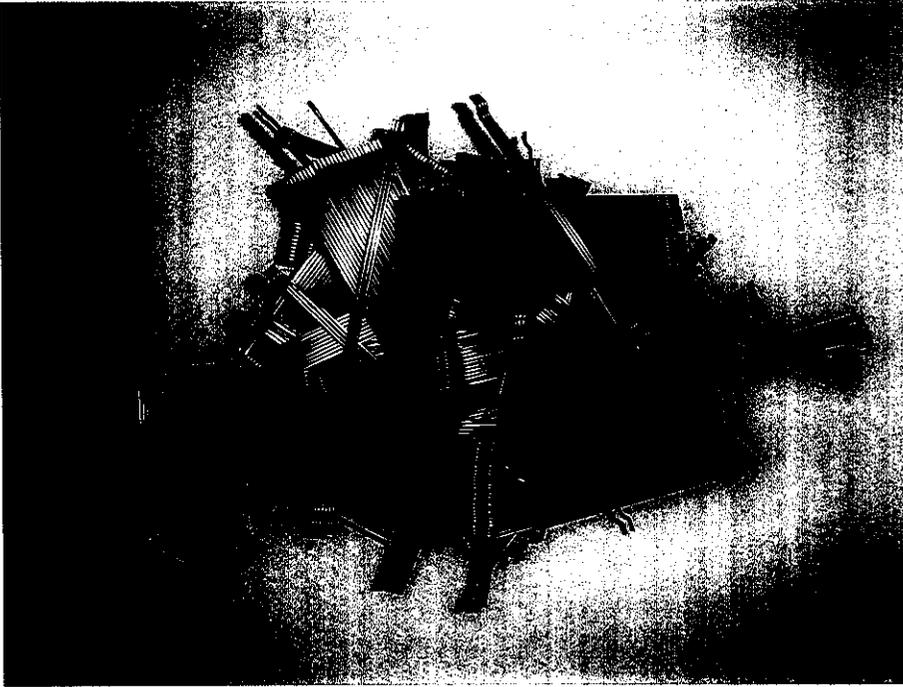


Fig 2.1 Glued Dramix Steel (ferrous) fiber



Fig 2.2 Polypropylene (non-ferrous) fiber

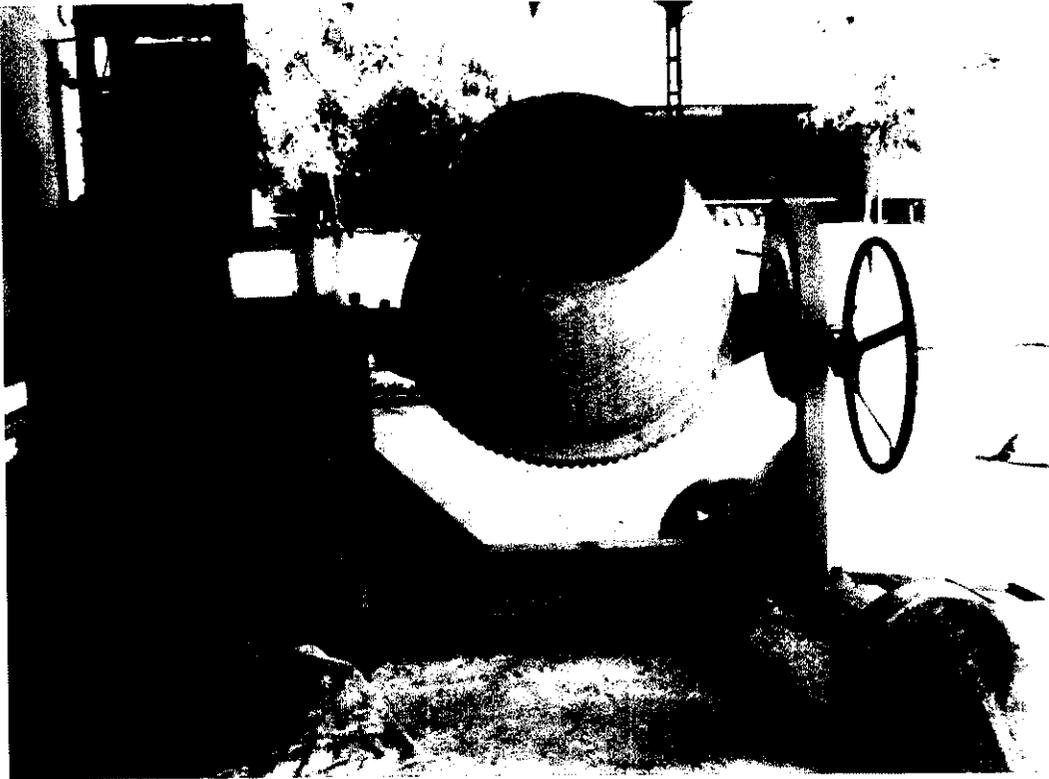


Fig 2.3 Concrete Mixer Machine

Fig 2.4 Beam Mould of Size 150mmx250mmx2150mm

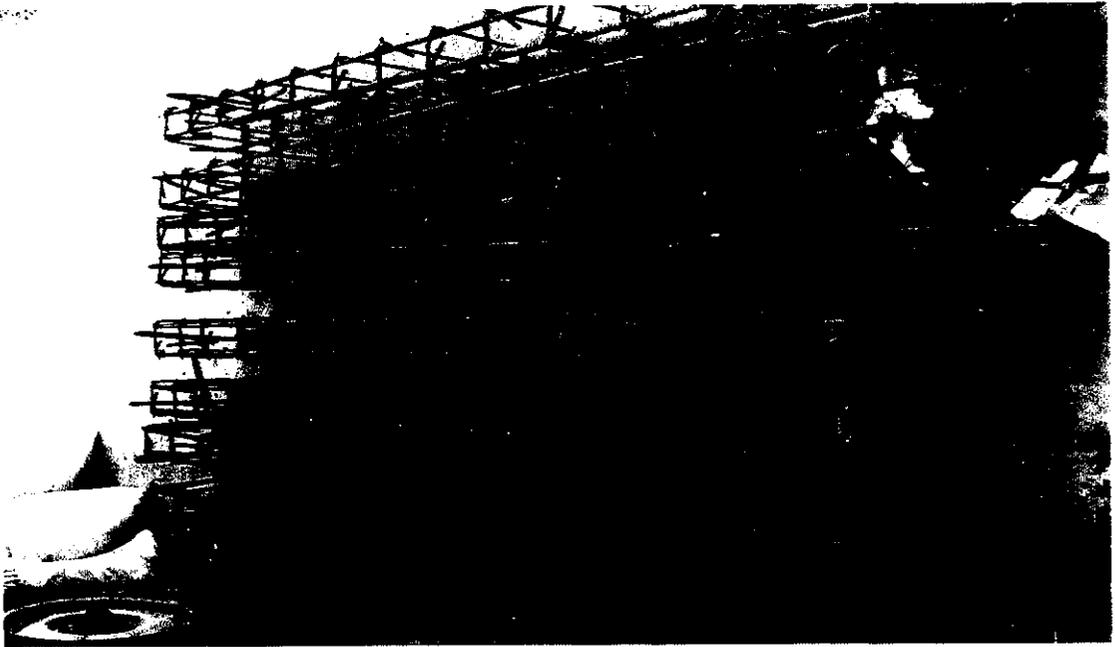


Fig 2.5 Reinforcement

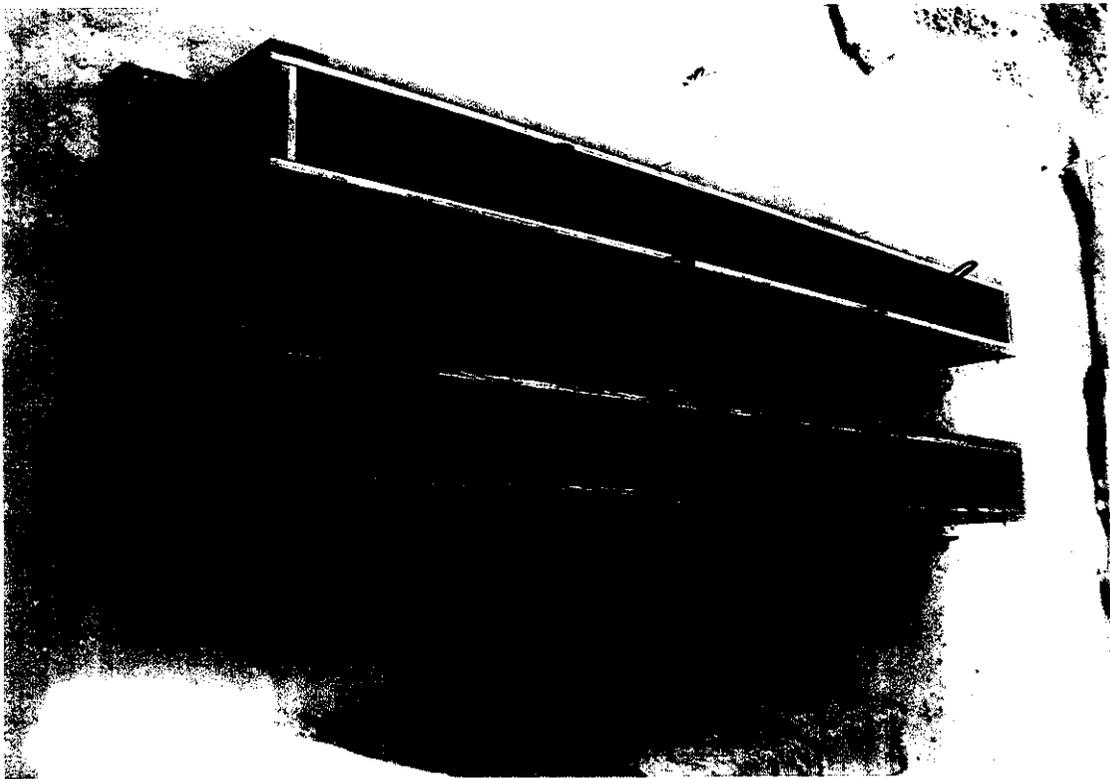


Fig 2.6 Beams with Reinforcement

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Fig 2.7 Compaction with Needle Vibrator

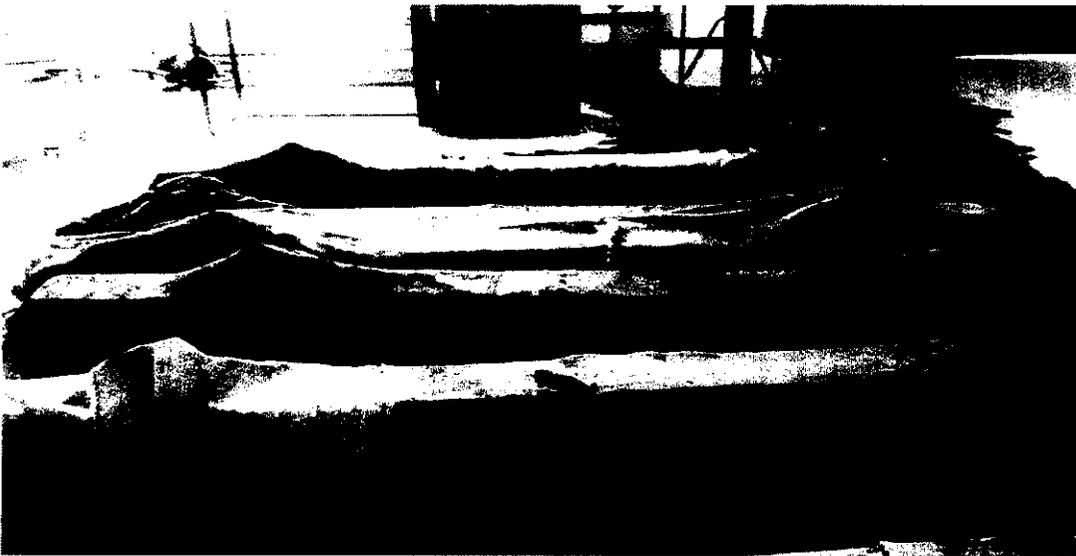


Fig 2.8 Curing of beams with Gunny bags

CHAPTER 3

RESULTS, DISCUSSIONS AND CONCLUSIONS

3.1 TEST RESULTS ON CEMENT

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 3.1

Table 3.1 Properties of PPC

Properties	Result obtained	As per IS 4031-1998
Consistency	33%	-
Initial setting time	90 minutes	Not less than 30minutes
Final setting time	300 minutes	Not more than 600minutes
Specific gravity	3.15	-

3.2 RESULTS ON AGGREGATES

3.2.1 Fine aggregate

The physical properties like fineness modulus, specific gravity and bulk density were studied as per IS 383-1970 and the obtained results were as shown in Table 3.2

Table 3.2 Properties of Fine aggregate

Properties	Result obtained	As per IS 383-1970
Fineness modulus	2.7	Medium sand
Specific gravity	2.6	2.55 minimum
Bulk density (Kg/m ³)	1607	-

3.2.2 Coarse aggregate

The physical properties like fineness modulus, specific gravity and bulk density were performed as per IS 383-1970 and the test results obtained were shown in Table 3.3

Table 3.3 Properties of Coarse aggregate

Properties	Result obtained	As per IS 383-1970
Fineness modulus	5	5 to 7
Specific gravity	2.64	2.6 minimum
Bulk density (Kg/m ³)	1580	-

The aggregates were found to be good sounding and angular in shape. It is well fit to be used in concrete.

3.3 MIX DESIGN OF FIBER REINFORCED CONCRETE

In this experimental investigation, a different percentage of fiber volume fractions 0.25%, 0.5% and 0.75% are used in M₂₅ and M₃₀ mix and optimum fiber dosage was obtained from testing the prisms, for which beam specimens of size 150mm x 250mm x 2150mm were casted.

3.3.1 Fiber Reinforced Concrete Mixture

Concrete mix design is vast and generally based on performance criteria. Based on the criteria, some simple guidelines for the design of fiber reinforced concrete are followed.

The wet mixture used was prepared first without the fibers. The slump of the concrete before fiber addition should be (50 to 76 mm) greater than the final slump desired. Normally, the mixture would be prepared using the water-cement ratio found to give the best results and meeting the specifications of the research. The use of high-range water-reducing admixture can be advantageous, but was not essential.

With the mixes operating at normal charging speed, add the individual fibers ball-free to the mixer. After all the required fibers were introduced into the mixer, the mixer should be slowed to the rated mixing speed and mixed for approximately 10 to 15 revolutions to obtain the uniform concrete mix.

3.3.2 Mixture Proportion

Mixture proportions of fiber reinforced concrete with and without ferrous and non-ferrous fibers with the design compressive strength of M1 mix as 25Mpa and M2

mix as 30Mpa were used in this investigation. PPC conforming to IS 1489-1991 was used. The bulk density of cement was taken as 1450 Kg/m³. No industrial by-product was incorporated. The combined aggregate was selected to match the standard grading curves used in the design of Portland cement concrete mixtures. For instance, the aggregate may comprise 713 Kg/m³ (60%) of 20mm aggregates, 475 Kg/m³ (40%) of 12.5mm aggregates and 576 Kg/m³ of fine aggregate to meet the requirement of standard grading curves. The water-cement ratio was 0.5 and 0.44 respectively.

Initially different percentage of fiber volume fractions (0.25%, 0.5% & 0.75%) was incorporated in cubes, cylinders and prisms. After obtaining the optimum dosage of fiber content, the percentage of fiber volume fractions was kept constant to 0.5% throughout this research. In hybrid fibers, both the ferrous and non-ferrous fibers were kept constant to 0.5%. The FRC mix details with and without ferrous and non-ferrous fiber mixtures were shown in Table 3.4

Table 3.4 FRC (with and without ferrous & non-ferrous fibers) Mixture proportions

Mix designation	Cement content Kg/m ³	F.A content Kg/m ³	Total C.A content Kg/m ³	60% of 20mm C.A content Kg/m ³	40% of 12.5mm C.A content Kg/m ³	Water content Kg/m ³	Steel fiber content Kg/m ³	Polypropylene Fiber content Kg/m ³	W/C ratio
M1	377	576	1187	712	475	188	0	0	0.5
M1 SFRC	377	576	1187	712	475	188	39.3	-	0.5
M1 PFRC	377	576	1187	712	475	188	-	0.9	0.5
M1 HFRC	377	576	1187	712	475	188	39.3	0.9	0.5
M2	420	547	1181	708	472	184	0	0	0.44
M2 SFRC	420	547	1181	708	472	184	39.3	-	0.44
M2 PFRC	420	547	1181	708	472	184	-	0.9	0.44
M2 HFRC	420	547	1181	708.5	472.5	184	39.3	0.9	0.44

3.4 TEST RESULTS ON FRESH CONCRETE

Slump test is the most commonly used method for measuring workability of concrete, which can be employed either in laboratory or at site of work. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

The slump cone mould is placed on a smooth, horizontal, rigid and non-absorbent surface in which concrete is poured in three layers and tamped 25 times by tamping rod taking care to distribute the strokes evenly over the cross section. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subsidence is referred as Slump of concrete.

The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm is taken as Slump of concrete. The results obtained from the slump test for all the mixes of FRC with and without ferrous and non-ferrous fibers were shown in Table 3.5

Table 3.5 Results of Slump test

Mix designation	Slump in mm*
M1	65
M1 SFRC	60
M1 PFRC	50
M1 HFRC	55
M2	60
M2 SFRC	57
M2 PFRC	55
M2 HFRC	54

* Results shown is average of three trials

3.5 TEST RESULTS ON HARDENED CONCRETE

3.5.1 Compressive Strength

The compressive strength of concrete with and without ferrous and non-ferrous fiber was conducted on the cubes of size 150mm were tested as per IS 516-1959 specifications and the experimental set up as shown in Fig 3.1. The unit weight of the specimens was also determined at the same time. The cubes were tested for compressive

strength at the age of 28 days of curing. Three specimens were tested from each of the mix and the average values of the test results are shown in Table 3.6.

Fig 3.1 Experimental set up of Compressive Strength Test

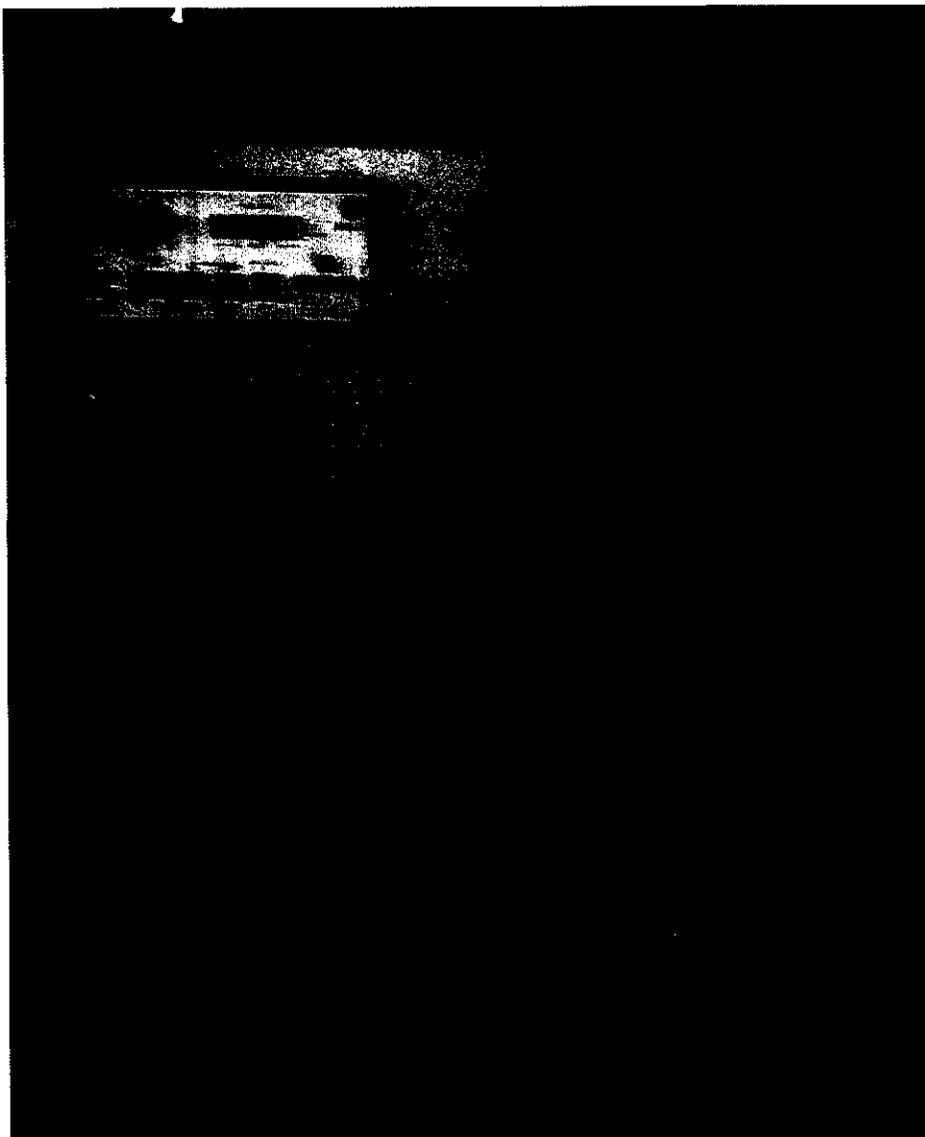


Table 3.6 Test Result of Compressive Strength

Mix designation	Specimen details	Ultimate Load (KN)	Compressive strength (N/mm²)	Average Compressive strength (N/mm²)
M1	C1	595	26.4	26.7
	C2	606	27	
	C3	597	26.5	
M1 SFRC	C1	679	30.2	30.5
	C2	672	29.8	
	C3	686	30.5	
M1 PFRC	C1	564	25.1	25.5
	C2	572	25.4	
	C3	566	25.2	
M1 HFRC	C1	721	32.1	31.5
	C2	695	30.8	
	C3	703	31.2	
M2	C1	734	32.6	33.5
	C2	757	33.6	
	C3	763	34	
M2 SFRC	C1	816	36.3	37.0
	C2	824	36.6	
	C3	833	37.1	
M2 PFRC	C1	652	28.9	29.0
	C2	664	29.5	
	C3	650	28.8	
M2 HFRC	C1	824	36.6	37.0
	C2	818	36.4	
	C3	826	36.7	

3.5.2 Split Tensile Strength

Split tensile strength is an indirect method of finding the tensile strength of concrete. It is easy to perform and gives more uniform strength than the tension test. The specimen is loaded horizontally between the loading surface of the compression testing machine and is loaded until the failure of the cylinder and the experimental setup is as shown in Fig 3.2

Split tensile test was conducted for 28 day cured specimens. Three specimens from each mix were tested and the average values of the test result are shown in Table 3.7.

Fig 3.2 Experimental set up of Split Tensile Strength Test

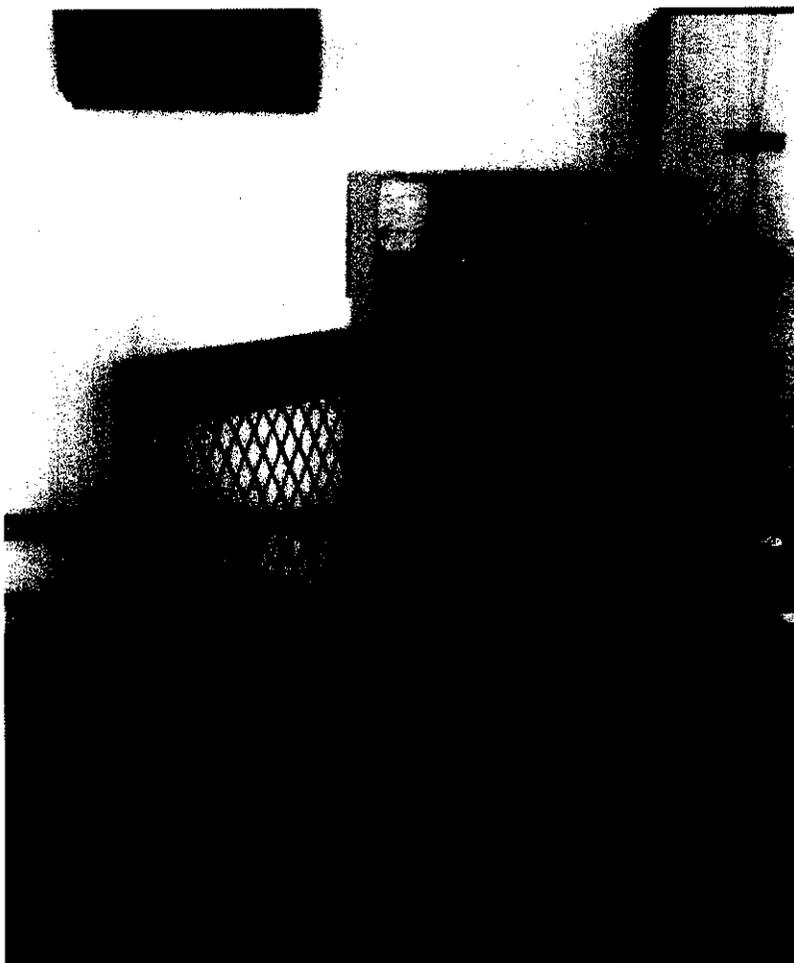


Table 3.7 Test Result of Split Tensile Strength

Mix designation	Specimen details	Tensile Strength (N/mm ²)	Avg Tensile strength (N/mm ²)
M1	C1	3.4	3.6
	C2	3.8	
	C3	3.6	
M1 SFRC	C1	4.7	4.7
	C2	4.5	
	C3	4.8	
M1 PFRC	C1	4.3	4.1
	C2	4.1	
	C3	3.9	
M1 HFRC	C1	5.6	5.3
	C2	5.2	
	C3	4.9	
M2	C1	3.6	3.7
	C2	3.9	
	C3	3.7	
M2 SFRC	C1	4.7	4.9
	C2	4.9	
	C3	5.2	
M2 PFRC	C1	3.9	4.3
	C2	4.3	
	C3	4.6	
M2 HFRC	C1	4.8	5.3
	C2	5.4	
	C3	5.8	

3.5.3 Stress-Strain Characteristics

The test for Stress-Strain characteristics of the specimen were studied for the age of 28 days. The test specimens were prepared in accordance with the procedure laid for

compressive strength testing and the test was carried out as per ASTM C 469-94 designation. Three cylinder of 150mm diameter and 300mm height were used for the test and the specimen for testing to obtain the stress-strain curve are as shown in Fig 3.3.

First the test specimens for the compressive strength were tested and the average compressive strength was recorded. When the specimens are still in the wet condition, parallel the axis of the specimen in such a way that the gauge point are symmetric about than a distance equal to half the width of the specimen. The extensometer was fixed with the recording points at the same ends and then the specimen was placed in the testing machine and accurately centered as shown in Fig 3.4.

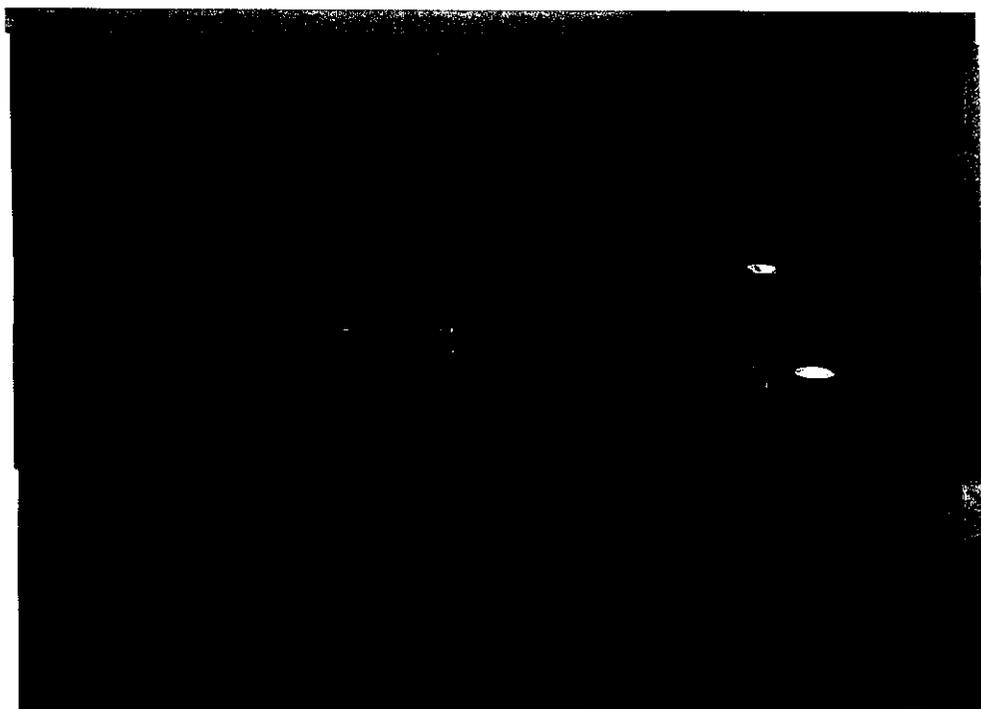
Fig 3.3 Specimen for testing Stress-Strain Characteristics



Mix Designation	Peak Stress (40% of Ultimate Load) Mpa	Strain μ mm/mm	Modulus of Elasticity(E) Mpa x 10³
M1	1.5	97.5	15.38
M1 SFRC	2.1	100.5	20.89

M1 PFRC	1.9	137.4	13.83
M1 HFRC	2.8	178.9	15.65
M2	1.8	98.5	18.27
M2 SFRC	2.5	110.8	22.56
M2 PFRC	2.1	147.4	14.25
M2 HFRC	3.2	196.2	16.31

Fig 3.4 Experimental set up of Stress-strain characteristics



3.5.4 Micro Structural properties

3.5.4.1 Saturated Water Absorption Test (SWA)

The saturated water absorption of concrete is a measure of the pore volume of porosity of concrete, which is occupied by water in the saturated condition. The saturated water absorption was determined on 150mm concrete cubes as per ASTM C 642-90 by drying the specimen in the hot air oven at a temperature of 100°C to constant mass.

The dried specimen from the hot air oven is then immersed in water after cooling to room temperature as shown in Fig 3.5 and the saturated water absorption is calculated as follows.

$$\text{SWA} = \frac{\text{Wt of saturated specimen} - \text{Wt of oven dried specimen}}{\text{Wt of oven dried specimen}} \times 100$$

The values of saturated water absorption of the specimen at 120 hours are obtained and are tabulated as shown in Table 3.9.

Fig 3.5 Saturated Water Absorption



Table 3.9 Test Result of Saturated Water Absorption

Mix designation	Water absorption in %*
M1	2.7
M1 SFRC	2.1
M1 PFRC	1.4
M1 HFRC	1.9
M2	2.8
M2 SFRC	2.2
M2 PFRC	1.1
M3 HFRC	1.7

*According to concrete society UK, water absorption less than or equal to 3% is Good Concrete

3.5.4.2 Sorptivity Test

Sorptivity is a measure of the rate of penetration of water into the pores in concrete by capillary suction. The test of Sorptivity was conducted on 150mm cubes by immersing them in water as shown in Fig 3.6 and measuring the gain in mass at different intervals of time. A graph is plotted with an increase in mass versus the square root of time and a straight line is fitted. The Sorptivity was computed by considering the slope of the line of the test results. The test result obtained was as shown in Table 3.10.

Fig 3.6 Sorptivity Test

Table 3.10 Test Result of Sorptivity

Mix designation	Sorptivity * $10^{-6} \text{ m/s}^{0.5}$
M1	8.86
M1 SFRC	8.63
M1 PFRC	8.32
M1 HFRC	8.54
M2	8.72
M2 SFRC	8.42
M2 PFRC	8.39
M2 HFRC	8.43

*According to Allen, Sorptivity less than $12 \times 10^{-6} \text{ m/s}^{0.5}$ is Good Concrete

3.5.5 Toughness Test on Beams

3.5.5.1 Experimental procedure

The beams to be tested were placed in the loading frame of capacity 30 tonne under third point loading. The end condition of the beam was kept as simply supported. Before placing the beams in loading frame, the beam was divided into number of grids for the observation of crack pattern. The load cell was placed in loading jack at the center of the beam from which, load imparted to the beam can be observed.

The Deflectometer were placed at one-third loading for finding deflections at that point and LVDT was placed in the center of the beam to measure the mid-deflection. The strain gauges were fixed in top and bottom fiber of beams, from which the strains can be obtained. The load cell, LVDT and Strain gauges were connected to 20 Channel Data Logger, where the results can be viewed. The experimental set up was shown in Fig 3.7.

Fig 3.7 Experimental set up of Beam in Loading Frame



3.5.5.1.1 ASTM C1018 method

The most common method of evaluating the flexural toughness of FRC is ASTM standards. This method evaluates the flexural performance of toughness parameters derived from fiber reinforced concrete in terms of areas under the load-deflection curve obtained by testing a simply supported beam under third-point loading. Toughness determined in terms of areas under the load deflection curve is an indication of the energy absorption capability of the particular test specimen. Fig 3.8 illustrates the evaluation of toughness by this method.

This test method involves the determination of a number of parameters called toughness indices that identify the magnitude of energy imparted to the specimen up to the selected deflection criteria. In principle the energy absorbed up to a certain specified deflection is normalized by the energy absorbed up to the point of first cracking. The test results were shown in Table 3.11.

Fig 3.8 Evaluation of Toughness by ASTM C1018 Method

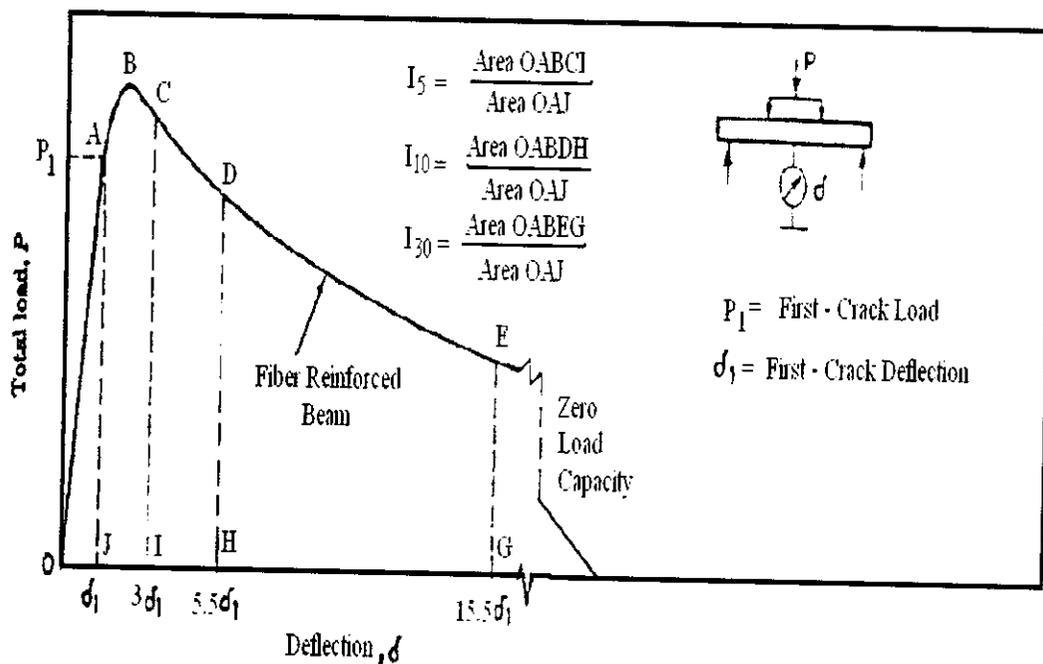


Table 3.11 Test Results of FRC beams (using ASTM C1018 Method)

Mix designation	M1	M1 SFRC	M1 PFRC	M1 HFRC	M2	M2 SFRC	M2 PFRC	M2 HFRC
First crack load (KN)	9.5	10.5	8.5	12.5	11	8.5	9.1	10.5
Ultimate load (KN)	25.4	31.6	29.3	33.8	27.3	32	29.8	35.7
Toughness* (N-m)								
δ	1.1	3.2	2.1	2.5	1.2	4.1	2.5	3.3

3 δ	3.4	9.7	6.5	7.7	3.8	12.8	7.8	10.9
5.5 δ	-	19.4	13.6	15.7	-	25.6	14.8	20.2
10.5 δ	-	33.8	24.1	26.3	-	43.1	27.5	36.7
Toughness indices**								
I ₅	3.1	3.1	3.1	3.3	3.1	3.2	3.1	3.4
I ₁₀	-	6.1	6.5	6.3	-	6.4	6.1	6.2
I ₂₀	-	11.3	11.6	10.5	-	10.7	11	11.2

* Area under the load-deflection Curve

$$** I_5 = 3.4/1.1 = 3.1$$

$$I_{10} = 19.4/3.2 = 6.1$$

$$I_{20} = 33.8/3.2 = 11.3$$

3.5.5.1.2 JSCE-SF 4 method

According to JSCE code, the toughness index is defined as the area under the load deflection curve up to a deflection of span length/150. Fig 3.9 illustrates the evaluation of toughness by JSCE-SF4 method. Flexural toughness factor depends upon specimen geometry. The span length for smaller and larger toughness index is designed as absolute toughness. The test results were shown in Table 3.12.

Fig 3.9 Evaluation of Toughness by JSCE-SF 4 Method

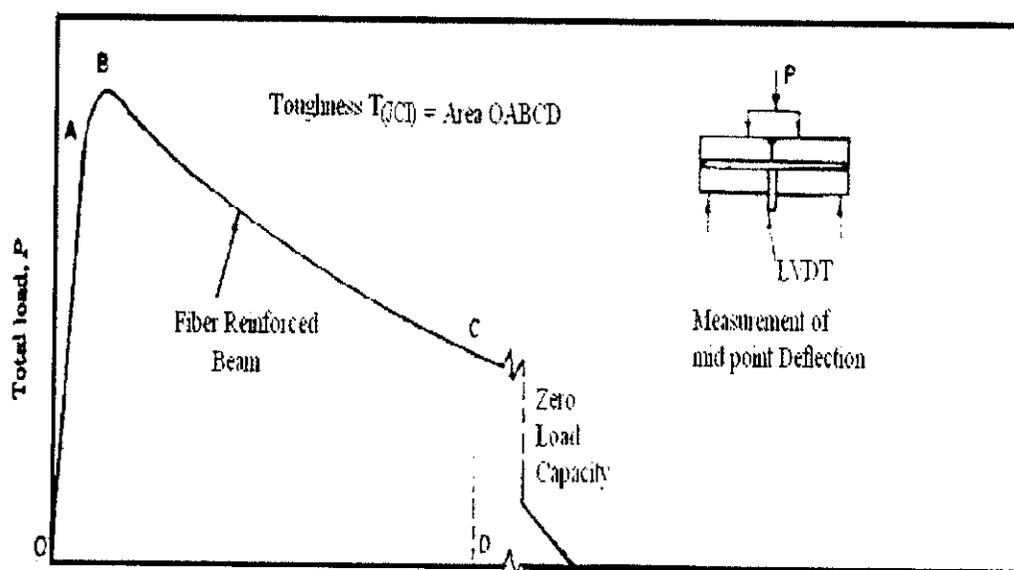


Table 3.12 Test Results of FRC beams (using JSCE-SF 4 Method)

Mix designation	Toughness (N-m)	Toughness factor*
M1	4.2	1.1
M1 SFRC	7.4	1.68
M1 PFRC	4.7	1.07
M1 HFRC	5.3	1.21
M2	5.5	1.24
M2 SFRC	9.8	2.23
M2 PFRC	6.7	1.52
M2 HFRC	6.9	1.56

* Toughness factor = Area OABCD x L / (L/150) wd²

Where, w- width, L- length, d- depth

$$\begin{aligned} \text{Toughness factor} &= 74000 \times 1800 / (1800/150) \times 150 \times 210^2 \\ &= 1.68 \end{aligned}$$

Crack Pattern of Beams

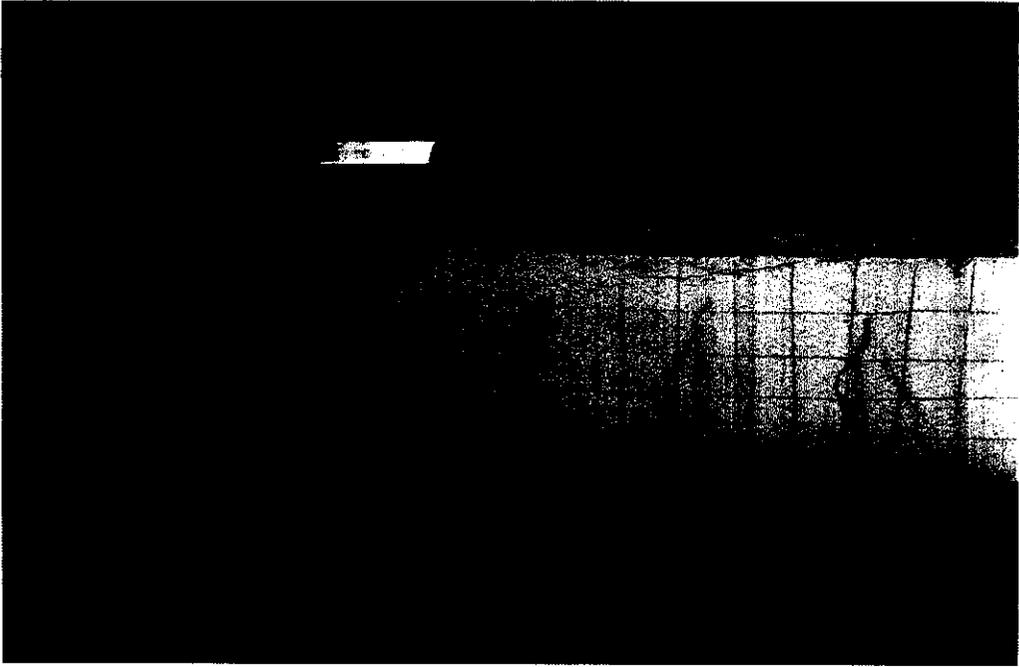


Fig 3.10 M25

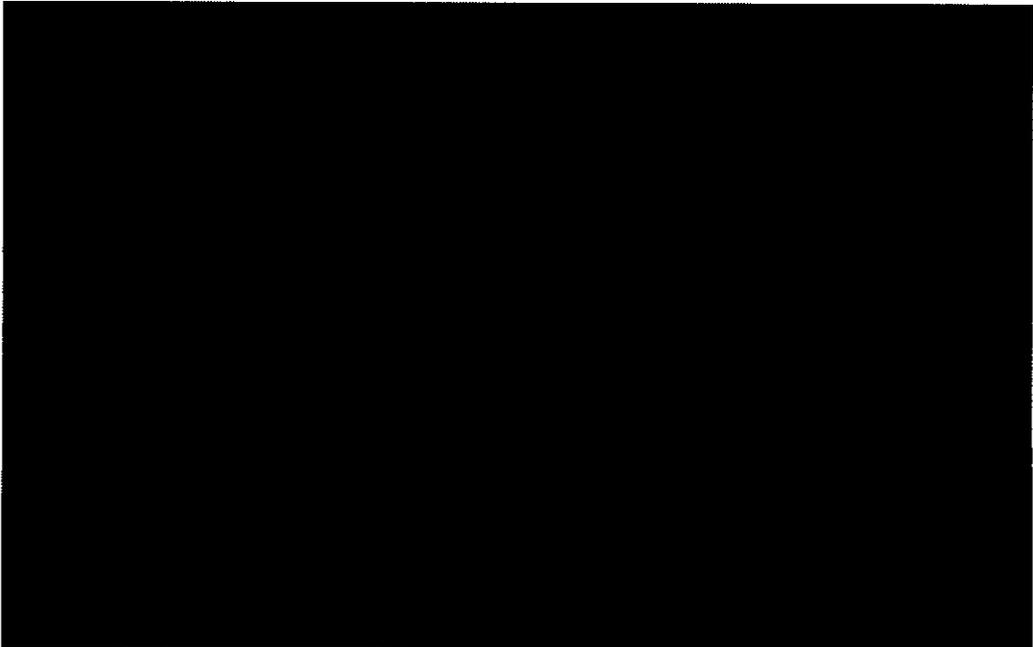


Fig 3.11 M25 SFRC

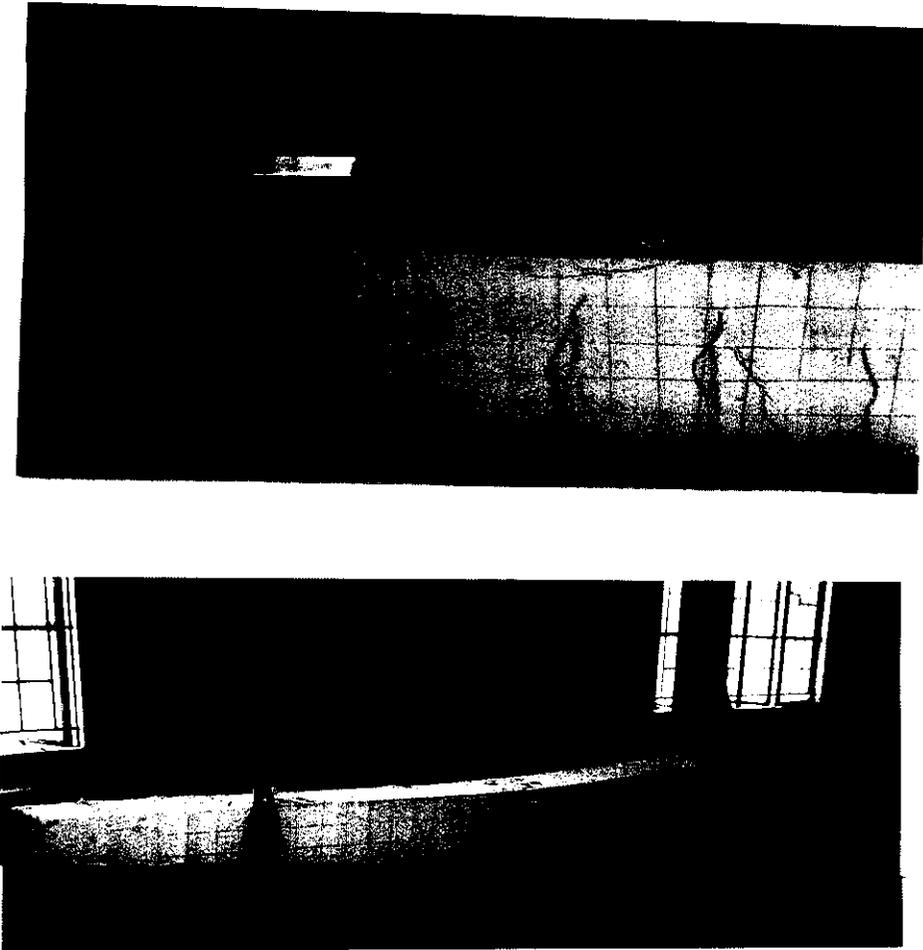


Fig 3.13 M25 HFRC

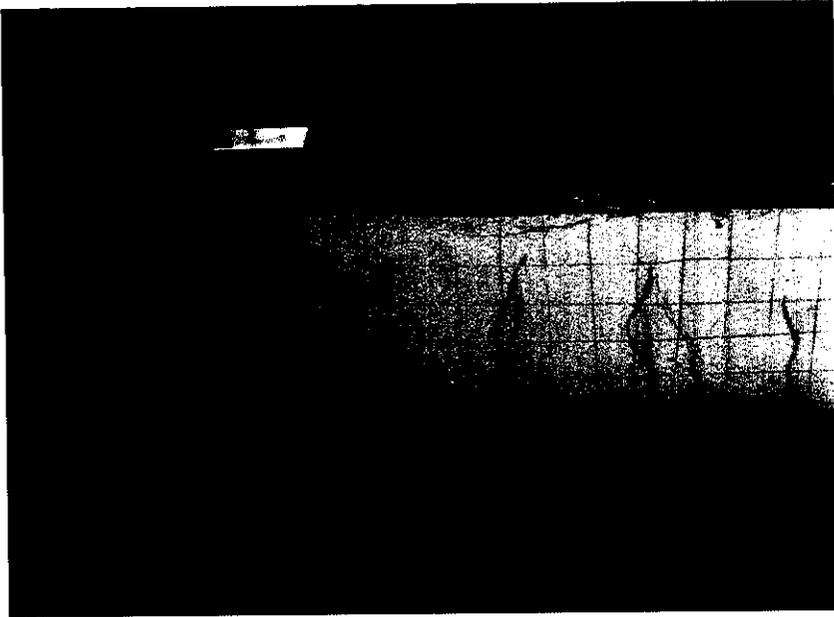


Fig 3.14 M30

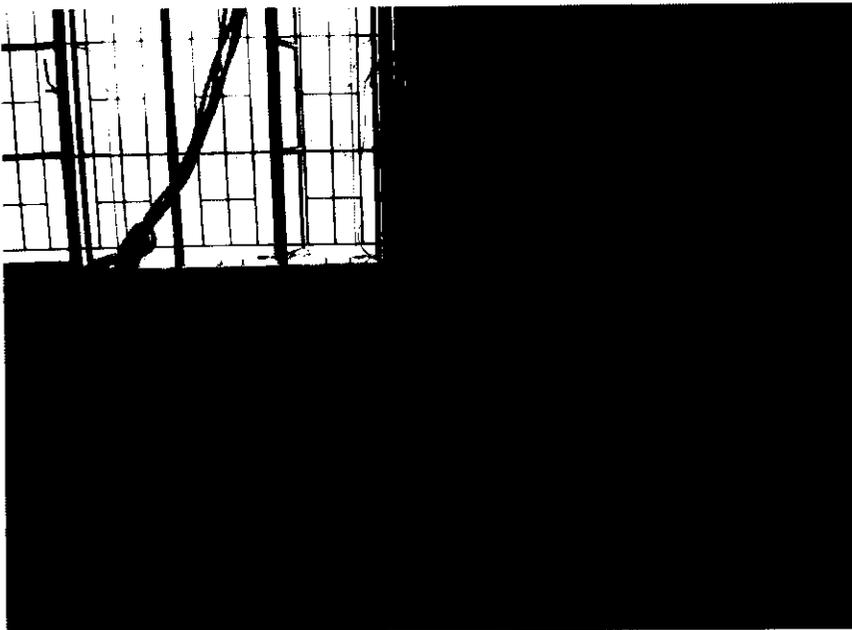


Fig 3.15 M30 SFRC

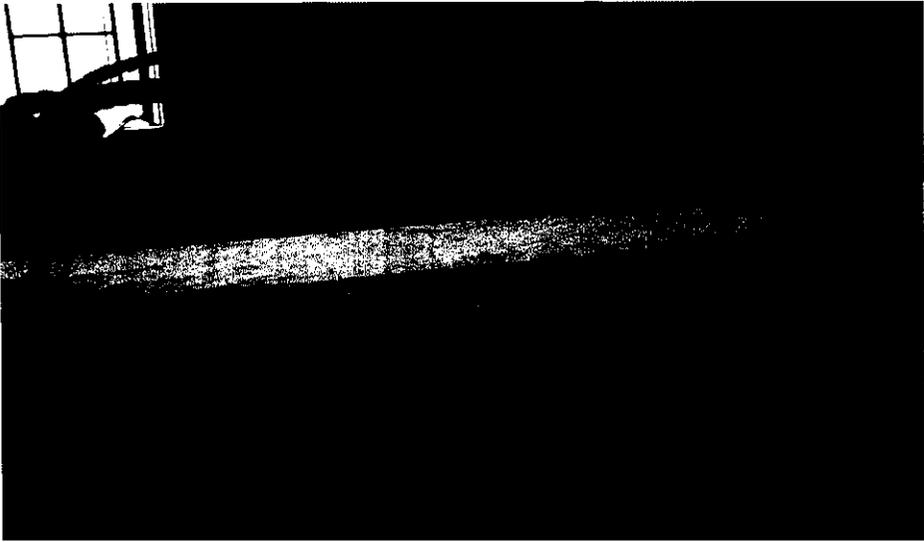


Fig 3.16 M30 PFRC

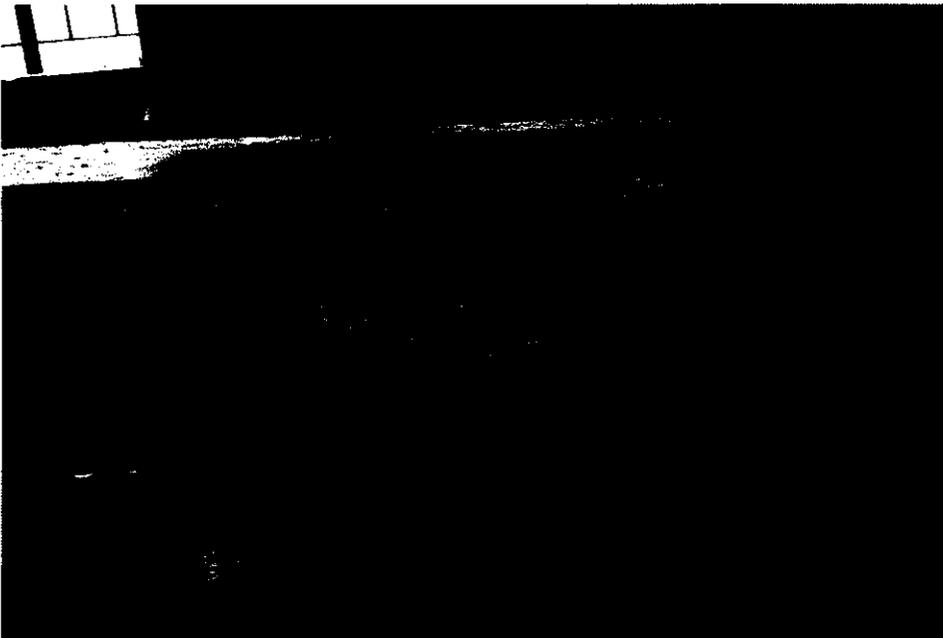


Fig 3.17 M30 HFRC

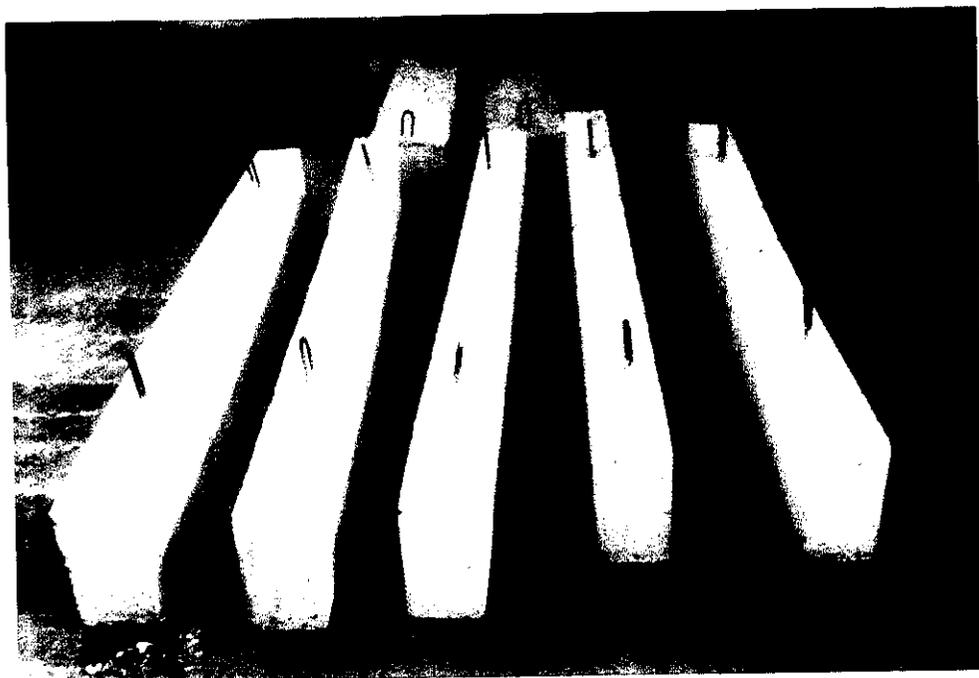


Fig 3.18 Beams before Testing



Fig 3.19 Beams after Testing

3.6 CONCLUSIONS

The following conclusions were drawn within the limitation of experimental investigation

General Conclusion

From the limited study carried out it was concluded that FRC has shown improvement in the strength and toughness characteristics.

- The Compressive Strength increases marginally in fiber reinforced concrete than concrete without fibers
- As the fiber dosage increases, the tensile strength increases accordingly. The hybrid fibers shows increase in tensile strength than plain concrete
- Modulus of elasticity obtained from Stress-Strain characteristics is high for SFRC
- Water absorption and Sorptivity is less incase of PFRC when compared to SFRC and plain concrete
- First crack load occurs earlier in PFRC when subjected to toughness testing
- Toughness, toughness indices, flexural toughness factor increases extensively in SFRC

Specific Conclusion

Compressive Strength Test

M2 HFRC shows the maximum compressive strength of 37 MPa at 28 days test. It was found that only 3.5% increase in strength when compared to plain concrete. So there was no much influence of fibers incase of compressive strength.

Split Tensile Strength Test

The tensile strength studies showed that there was drastic improvement in split tensile strength. M1 and M2 HFRC shows maximum split tensile strength of 5.3 MPa. It was found that 17% increase in strength was achieved.

Stress strain characteristics

From the experiments, it was observed that increase in stress leads to increase in strain in the ascending branch and renders a drop in the remaining part of the curve. It was found that M2 SFRC shows high modulus of elasticity of 22.56×10^3 MPa when compared to PFRC, HFRC and plain concrete.

Micro Structural Studies

Saturated Water Absorption Test of FRC

Good concrete according to BS 1881-part 5 has absorption values of less than 3%. The water absorption phenomenon of concrete with and without ferrous and non-ferrous fibers was found to be less than the recommended value due to the improved micro structural properties of FRC. The lowest value of 1.1% water absorption was obtained for M2 PFRC and the highest value of 2.8% was obtained for M2 plain concrete mix.

Sorptivity Test of FRC

According to Allen, Sorptivity less than $12 \times 10^{-6} \text{ m/s}^{0.5}$ is good concrete. It was found that M2 PFRC has lowest sorptivity value of $8.39 \times 10^{-6} \text{ m/s}^{0.5}$ and M1 plain concrete has highest sorptivity value of $8.86 \times 10^{-6} \text{ m/s}^{0.5}$. From the test results, it was inferred that Sorptivity values for the concrete with and without ferrous and non-ferrous fibers lies within the permissible limits.

3.7 SCOPE FOR FUTURE WORK

- Fiber dosage can be varied and studied for toughness test
- Acid resistance test can be studied
- Structural behaviour of FRC columns with and without ferrous and non-ferrous fibers can be studied for various mixes
- Wear and tear mechanism of concrete with fibers can be studied
- Shrinkage and creep study
- Orientation of fibers can be studied

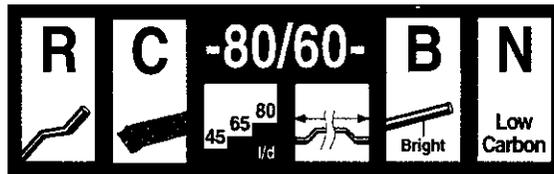
REFERENCES

- ACI 544.1R-96, "Report on Fiber Reinforced Concrete", Manual of concrete practice.
- Anbuvelan, K., Khadar, M.M., Lakshmipathy, M & Sathyanarayanan, K.S. (2007) "Studies on properties of concretes containing polypropylene, steel and reengineered plastic shred fiber", The Indian concrete journal, pp 38-44.
- Appa Rao, G and Raghu Prasad, B.K., (2000) "Fracture toughness of fiber reinforced high-strength concrete", Sri Venkateswara University, pp 40-45.
- ASTM C 642-1990, "Standard test method for specific gravity, absorption and voids in hardened concrete", Annual book of ASTM standards.
- ASTM C 1018-97, "Standard test method for flexural toughness and first-crack strength of fiber reinforced concrete (Using beam with third-point loading)", Annual book of ASTM standards.
- Balaguru, P and Najm, H., (2004) "High- performance fiber reinforced concrete mixture proportions with high fiber volume fractions", ACI materials journal, pp 281-286.
- Hall, C (1989) "Water Sorptivity of mortars and concrete; a review", Magazine of Concrete research, Vol.41, No.147, pp 51-61
- IS 383-1970 (R-1997), "Indian standard for Specification for coarse and fine aggregate from natural sources for concrete", Bureau of Indian Standards, New Delhi.
- IS 456-2000, "Plain and Reinforced Concrete Code of Practice", Bureau of Indian Standards, New Delhi.
- IS 5816-1970, Indian standard "Methods of test for splitting tensile strength of concrete cylinder", Bureau of Indian Standards, New Delhi.
- IS 516-1959, "Indian Standard Method of test for strength of concrete", Bureau of Indian Standards, New Delhi.
- Nataraja, M.C., Dhang, N., Gupta A.P.(1998) "Steel fiber reinforced concrete under compression", The Indian concrete journal, pp 353-356.

- Nemkumar Banthia and Sayed Mohamad Soleimani (2005) “Flexural response of hybrid fiber-reinforced cementitious composites”, *ACI materials journal*, pp 382-387.
- Piti Sukontasukkul (2004) “Toughness evaluation of steel and polypropylene fiber reinforced concrete beams under bending”, *Thammasat Int.J.Sc.Tech.*, Vol.9, pp 35-41.
- Rashid, M.A and Mansur, M.A (2005) “Reinforced high strength concrete beams in flexure”, *ACI structural journal*, pp 462-471.
- Raul Zerbino, L., Graciela Giaccio and Ravindra Gettu (2006) “Pseudo-ductile behaviour of steel fiber reinforced high-strength concrete”, *The Indian concrete journal*, pp 37-43.
- Yurtseven, A.E., Yaman, I.O and Tokyay, M (2006) “Mechanical properties of hybrid fiber reinforced concrete”, *Springer*, pp 207-214.
- Zongcai Deng and Jianhui Li (2006) “Mechanical behaviors of concrete combined with steel and synthetic macro-fibers”, *International journal of physical sciences*, Vol.1 (2), pp 57-66



Dramix®

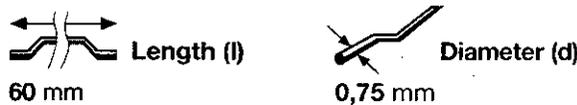


Description: Dramix® fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. Dramix® RC-80/60-BN is a cold drawn wire fibre, with hooked ends, and glued in bundles.

Applications:

- jointless floors
- suspended ground slabs
- jointless floors on vibrocompacted piles
- industrial floors
- slabs on vibro-compacted piles
- liquid tight floors
- overlays
- pavements
- segmental linings
- compression layers
- cellar walls
- precast

Geometry:



80 Performance class: 80
 Aspect ratio (= l/d): 80
 4600 fibres/kg

Approvals:

Conforms to **ASTM A820**

Quality System in Belgium, Brasilian, Czech, Turkish and Chinese plants

Product **Belgium**
ATG 04/1857

Product **Poland**
AT-15-2117/2001

The Netherlands

22702

Romania
007-01/068-2003

Turkey

Germany

Tensile strength:

- on the wire: minimum 1050 N/mm²
- low carbon conforms to EN 10016-2 - C9D

Coating: None

Technical data:

For industrial floors, floors on vibrocompacted piles, jointless floors... ask for specialized documentation.

1 Equivalent flexural strength

- $f_{ctm,eq,300}$, $f_{ctk,eq,300}$ = average and characteristic equivalent flexural strength to a deflection of 1,5 mm according to NBN B 15-238, 239, JSCE-SF4 and CUR35.

- $f_{ctm,eq,150}$, $f_{ctk,eq,150}$ = average and characteristic equivalent flexural strength to a deflection of 3 mm according to NBN B 15-238, 239, JSCE-SF4 and CUR35.

Dramix® RC-80/60-BN

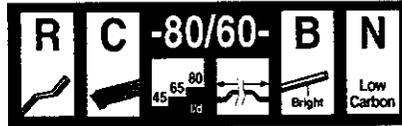
$f_{ctm,ft}$ (1) ▶	3,7 (C20/25) (2)		4,3 (C25/30)		4,8 (C30/37)		5,3 (C35/45)		5,8 (C40/50)	
Dosage ▼	$f_{ctm,eq,300}$	$f_{ctm,eq,150}$								
20	2,1	1,9	2,4	2,3	2,8	2,6	3,0	2,8	3,2	3,0
25	2,5	2,3	2,9	2,7	3,2	3,0	3,5	3,2	3,7	3,3
30	2,8	2,7	3,3	3,1	3,6	3,3	3,9	3,5	4,1	3,6
35	3,2	3,0	3,6	3,3	3,9	3,6	4,2	3,8	4,4	3,9
40	3,5	3,3	3,8	3,5	4,2	3,9	4,4	4,1	4,6	4,2
45	3,7	3,4	4,0	3,6	4,3	4,0	4,6	4,2	4,8	4,3
50	3,9	3,5	4,2	3,7	4,4	4,1	4,8	4,3	5,0	4,4

(1) $f_{ctm,ft}$ = mean flexural tensile strength of plain concrete (N/mm²).
 (2) Concrete class corresponding with $f_{ctm,ft}$ according to ENV 1992-1-1. Boxed value [0.5] is replaced by the value 0,6 in formula (3.1).

$f_{ctk,eq,300} = 0,7 \times f_{ctm,eq,300}$
 $f_{ctk,eq,150} = 0,7 \times f_{ctm,eq,150}$ } According to Dramix® guideline unless more specific data available.

2 Equivalent axial tensile strength

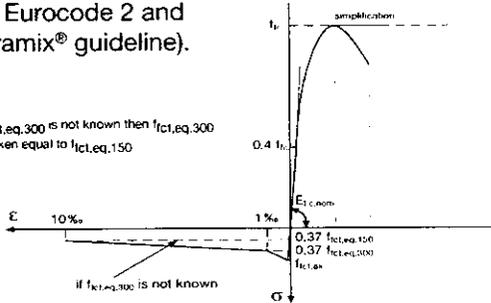
Dramix®



Stress-strain diagram

For steel fibre reinforced concrete, the following stress-strain diagram applies (symbols conform to Eurocode 2 and Dramix® guideline).

If $f_{ct,eq,300}$ is not known then $f_{ct,eq,300}$ is taken equal to $f_{ct,eq,150}$



Equivalent shear strength

The design value of the increase in shear strength due to steelwire fibres:

τ_{fd} (N/mm²) - (material safety factor included).

The contribution of concrete and stirrups must be added to this contribution of the wire fibres.

Dramix® RC-80/60-BN

$f_{ctm,fl}$	3,7 (C20/25) (2)	4,3 (C25/30)	4,8 (C30/37)	5,3 (C35/45)	5,8 (C40/50)
dosage ▼	τ_{fd}	τ_{fd}	τ_{fd}	τ_{fd}	τ_{fd}
20	0,18	0,22	0,24	0,27	0,30
25	0,21	0,25	0,28	0,31	0,35
30	0,24	0,29	0,32	0,35	0,40
35	0,26	0,31	0,35	0,38	0,43
40	0,28	0,34	0,37	0,41	0,47
45	0,30	0,36	0,40	0,44	0,50
50	0,31	0,38	0,42	0,46	0,52

$f_{ctm,fl}$ = mean flexural tensile strength of plain concrete (N/mm²).
Concrete class corresponding with $f_{ctm,fl}$ according to ENV 1992-1-1.
Rounded value [0,5] is replaced by the value 0,6 in formula (3.1).

See also consult the Dramix® guideline

Toughness values

Dramix® RC-80/60-BN

dosage ▼	Re1,5 (%)	Re3 (%)
5	45	42
10	56	52
15	65	60
20	74	68
25	80	75
30	86	80
35	90	86
40	94	90

Values based on concrete $f_{ctm,fl} = 4,8$ N/mm². To be used up to C40/50.

Recommendations - mixing

1. General

- ✓ preferably use a central batching plant mixer
- ✓ recommended maximum dosage:

Max. aggregate size (mm)	Dosage (kg/m ³)	
	pour	pump
8	60	45
16	50	35
32	35	30

- ✓ a continuous grading is preferred
- ✓ mix until all glued fibres are separated into individual fibres. Fibres don't increase mixing time significantly.
- ✓ if special cements or admixtures are used, a preliminary test is recommended

2. Fibre addition

- ✗ Bags are non-degradable and may not be thrown into the concrete.



2.1. In batching plant mixer

- ✓ never add fibres as first component in the mixer
- ✓ fibres can be introduced together with sand and aggregates, or can be added in freshly mixed concrete

2.2. Truckmixer

- ✓ run mixer at drum speed: 12-18 rpm
- ✓ adjust slump to a min. of 12 cm (preferably with water reducing agents or high water reducing agents)
- ✓ add fibres with maximum speed of 40 kg/min
- ✓ optional equipment: belt-hoist elevator
- ✓ after adding the fibres, continue mixing at highest speed for 4-5 min. (± 70 rotations)

2.3. Automatic dosing

- ✓ Fibres can be dosed from bulk at rates from 0 up to 3,5 kg/sec with a specially developed dosing equipment

Recommendations - storage

Delivered in

