EXPERIMENTAL STUDY ON FRC SLABS WITH AND WITHOUT FERROUS AND NON- FERROUS FIBERS

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

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During this period, his work and conduct was found to be very good.

We wish him success in all his future endeavors.

For ACC Ltd.

A.Sudhahar,
Assistant Manager,
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BONAFIDE CERTIFICATE

Certified that this project report titled **"EXPERIMENTAL STUDY ON FRC SLABS WITH AND WITHOUT FERROUS & NON-FERROUS FIBERS"** is the bonafide work of **Mr.S.BOOPATHYRAJA, Reg No: 71206413005,** who carried out the research work under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

It is now well established fact that one of the important properties of fibre reinforced concrete is its superior in resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fiber composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibers are able to hold the matrix together even after extensive cracking.

In this project, experimental investigation has been carried out to study the performance of FRC Slabs with varying percentage replacement of 0, 0.25, 0.50, and 0.75 Steel, Polypropylene. The Hybrid fibers are combination of both SFRC and PFRC of 0.5% are also used. The compressive Strength of concrete with fibers increases marginally, but the tensile strength of concrete increased considerably. The Young's modulus of elasticity was found more for SFRC than PFRC.

This aim of the project is to quantify the extent to which fiber improves the resistance against impact loading by drop weight test were conducted on FRC slabs (1000 mm x 1000mm x 25mm) to study their energy absorption under impact loading. Conventional reinforced concrete slabs are also tested to identify the advantages of using FRC slabs in this application. The impact resistance of slabs with different materials is evaluated in terms of the extent of damage, Energy absorption capacity. The drop weight impact test results showed that the hybrid fiber exhibit lesser damage, significantly improved impact resistance against multiple impacts and improved ductility and energy absorption capacity compared to both Steel and Polypropylene Fiber.

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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

PFRC - Polypropylene Fiber Reinforced Concrete

SFRC - Steel Fiber Reinforced Concrete

SWA - Saturated Water Absorption

Chapter 1

Introduction

CHAPTER 1
INTRODUCTION

1.1 GENERAL

Concrete structures are often subjected to short duration (dynamic) loads. Such loads originate from sources such as impact from missiles and projectiles, wind gusts, earthquakes and machine vibrations. Due to a relatively low tensile strength and fracture energy, impact resistance of concrete is poor. Hence, much research has been directed towards developing concrete that exhibits improved impact resistance than conventional concrete. Fiber reinforced concrete (FRC) has emerged as a viable structural material for use in such applications[1].

One method to improve the fracture resistance and the resistance of concrete when subjected to impact and/or impulsive loading is by incorporating randomly distributed the short fibers. Concrete so termed as fiber reinforced concrete (FRC).

Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres.. 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. Adding fibers greatly improves the fracture and impact resistance of concrete.

1.2 IMPORTANCE OF IMPACT IN STRUCTURES

Impact loading is generally an extremely server loading condition characterized by great intensity and short duration. The behaviour of structural members under impact loading may consist of two responses; one is the local transient response mainly due to the stress wave that occurs at the loading point during a very short period after impact and the other is the overall response with vibration effects due to the elastic-plastic deformation that occurs in the whole structural member over a long period after impact. The overall response strongly depends on the quasi-static behavior with loading rate effect of the structural member [**fujikake et al, 2006**]. It is well know that rapid loading test is the best way to examine the quasi-static behaviour of a structural member under constant high deformation velocity.

When an impulsive loading acts on a structure, it produces an instantaneous velocity change; momentum is acquired and the structure gains kinetic energy which is converted to strain energy as the structure deforms. The most important feature of structures required to resist impact loading is that structural components must possess adequate deformation capacity under extreme overload to dissipate large amounts of energy prior to failure; that is, to permit significant localized damage and simultaneously preventing catastrophic collapse. Therefore, the material must have both adequate ductility and strength. Besides the energy absorption capacity, the other crucial factors influencing the performance of protective materials include scabbing and spalling resistance, multiple-impact resistance, and sensitivity to strain rate. Plain concrete is a brittle material. Under impact loading, plain concrete exhibits extensive cracking and undergoes brittle failure. The inclusion of fibres in concrete, mortar and cement paste can enhance many of the engineering properties of these materials, such as fracture toughness, flexural strength, resistance to fatigue, impact, thermal shock and spalling.

Impact loading is often encountered in case of machine foundations, as in case of forge hammers and rotating machinery with eccentric mass distribution, explosive storage cubicles. Recent terrorist attacks have clearly highlighted the need for structures of military and strategic importance to withstand severe impact and explosive loads.

1.3 ADVANTAGES OF FIBERS

- Improved long-term serviceability of the structure or product
- High ductility
- 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

1.5 USAGE IN INDIAN PROJECTS

- KRCL-MSRDC tunnels
- Naftha Jakari hydro electric project
- KOL hydro electric project
- Baglihar hydro electric project
- Chamera hydro electric project
- Uri dam
- Sirsisilam project
- Tehri Dam project
- Salal Hydroelectric project
- Ranganadi Hydroelectric project, etc.,

Chapter 2

Main Theme of the Project

CHAPTER 2

MAIN THEME OF THE PROJECT

2.1 LITERATURE REVIEW

Impact testing

Improved impact resistance (dynamic energy absorption as well as strength) is one of the important attributes of FRC. Several types of tests have been used to measure the impact resistance of FRC. These can be classified broadly, depending upon the impacting mechanism and parameters monitored during impact, into the following types of tests: (a) weighted pendulum Charpy-type impact test; (b) drop-weight test (single or repeated impact); (c) constant strain-rate test; (d) projectile impact test; (e) split-Hopkinson bar test; (f) explosive test; and (g) instrumented pendulum impact test [ACI Committee 544.2R-1989].

Conventionally, impact resistance of concrete has been characterized by using one of the following measures viz., (a) the energy consumed to fracture a notched beam specimen (computed from the residual energy stored in the pendulum after impact); (b) the number of blows in a "repeated impact" test to achieve a prescribed level of distress; and (c) the size of the damage (crater/perforation/scab) or the size and velocity of the fall after the specimen is struck with a projectile or after the specimen is subjected to a surface blast loading.

Results from such tests are useful for ascertaining the relative merits of the different mixtures as well as for providing answers to specific practical problems. However, they depend on the specimen geometry, test system compliance, loading configuration, loading rate, and the prescribed failure criterion. The simplest of the conventional tests, which is more often adopted for concrete, is the "repeated impact," drop weight test.

More recently, instrumented impact tests have been developed that provide reliable and continuous time histories of the various parameters of interest during the impact viz., load, deflection, and strain. These provide basic material properties at the various strain rates for the computation of flexural/tensile strength, energy absorption capacity, stiffness, and load-deformation characteristics, fracture toughness and ultimate strength. While retaining the conventional mechanisms to apply impact loads, instrumented impact tests permit the monitoring of several parameters during the impact event, manifested by a single blow fracture.

Instrumented impact testing has been applied successfully to fiber reinforced concrete also. Two types of systems are commonly used: a drop-weight-type system and a pendulum-type system (Charpy impact system). Instrumentation of these systems is quite complex and implies instrumentation of the striker as well as the anvil supports that act as load cells. In the instrumented drop weight system [**Fig.2.1**], a weight equipped with a striker is dropped by gravity on the specimen while guided by two columns. The Charpy system [**Fig.2.2**] uses a free-falling pendulum weight equipped with a striker as the impacting mechanism. The weight of the impacter and the drop height in both systems provide a range of impact velocities and energy capacities for the impact test. The electronic instrumentation is the same for both systems even though the mechanical configurations of the drop weight and the Charpy systems are different.

Instrumentation for instrumented impact testing includes dynamic load cells, foil-type resistance gages for strain measurements, and associated signal conditioning amplifiers and storage oscilloscope (preferably digital). All electronic equipment must have adequate high-frequency response to monitor and record all transducer outputs without distortions during the short impact event (< 1 millisecond).

Fig.2.1 Block Diagram of the General Layout of the Instrumented Drop Weight System

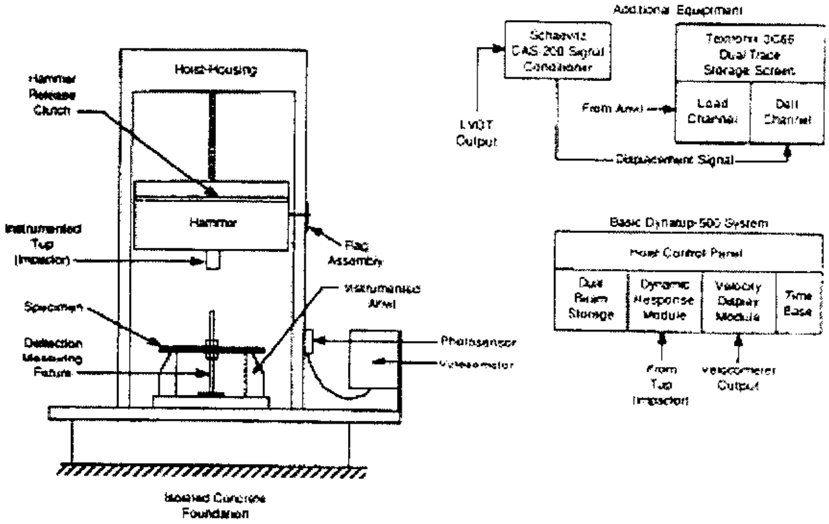
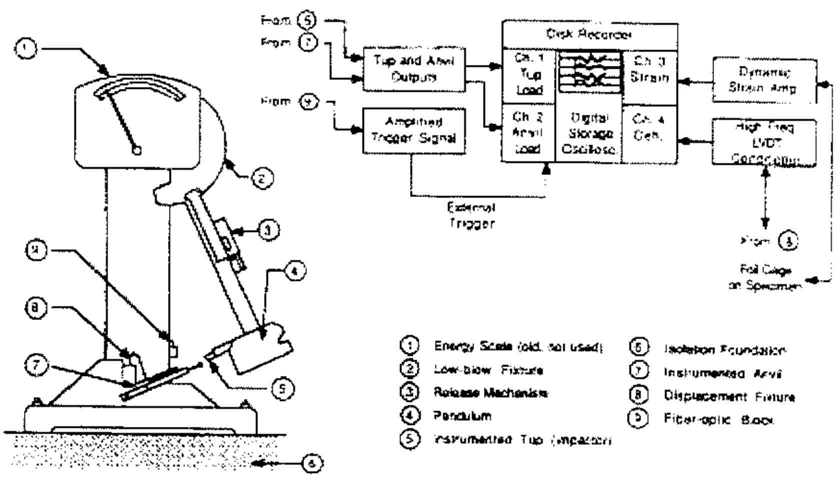


Fig.2.2 Block Diagram Of The General Layout Of The Modified Instrumented Charpy System



Simultaneous electronic recording of the anvil and striker loads is essential for the proper interpretation of inertial loads and to assess the influence on the results of parameters such as test system compliance, specimen size, and impact velocity. The anvils and the striker should be designed to serve as dynamic load cells and to ensure elastic behavior even under high loads. They should be sufficiently rounded at the specimen contact points to avoid local compression damage to the specimen on impact and to facilitate specimen rotation during bending. The load cells are instrumented using semiconductor strain gages mounted in full bridge configuration within protective recesses provided on either side of each cell (anvil and striker). The full bridge configuration is recommended for high signal to noise ratio and to allow for temperature compensation. Output signals from the two anvils should be connected in series to monitor the total load at the supports.

Problems of parasitic inertial loads in the responses recorded from instrumented impact tests often arise and recommendations have been made by some researchers to overcome them. As a general guideline, the test parameters should be selected so that the difference between the striker and anvil loads recorded during the test does not exceed 5 percent.

Ali R. Khaloo and Majid Afshari (2004) are studied the Influence of length and volumetric percentage of steel fibres on energy absorption of concrete slabs with various concrete strengths is investigated by testing 28 small steel fibre reinforced concrete (SFRC) slabs under flexure. Variables included; fibre length, volumetric percentage of fibres and concrete strength. Test results indicated that generally longer fibres and higher fibre content provide higher energy absorption. The results are compared with a theoretical prediction based on random distribution of fibres. The theoretical method resulted in higher energy absorption than that obtained in experiment. A design method according to allowable deflection is proposed for SFRC slabs within the range of fibre volumetric percentages used in that study.

P.S.Song et al (2004) are investigate the impact resistance of the high-strength steel fiber-reinforced concrete improved satisfactorily over that of the high-strength concrete, the failure strength improved most, followed by first-crack strength and percentage increase in the number of postfirst- crack blows. The two concretes resembled each other on the coefficient of variation values, respectively, on the two strengths, whereas the high-strength concrete was much higher in the value on the percentage increase. The

Kolmogorov–Smirnov test indicates that the high strength concrete was approximately normally distributed in first-crack and failure strengths, high-strength steel fiber-reinforced concrete was poorly normally distributed in the two strengths, and both concretes were hardly normally distributed in the percentage increase. Finally, for both concretes, failure strength regression models were developed, and then, the accompanying 95% prediction intervals for the strength were established.

Kiang-Hwee Tan and P. Paramasivam (1991) are studied the punching shear behavior of steel fiber reinforced concrete slabs. Each of 14 square slabs was simply supported along four edges and loaded to failure under a concentrated load over a square area at the center. The test parameters were the effective span to depth *a/d* ratio, volume fraction of steel fibers pf, slab thickness h, concrete strength f'c, and size of load-bearing plate r. Test results indicate that the load-deflection curve of slabs exhibits four distinct regions that may be characterized by first cracking, steel yielding, and ultimate load. Within the scope of the test program, an increase in the values of Pr, h, or r was found to lead to an increase in both the punching shear strength and the ductility of the slab. The ultimate punching shear strength of the slabs was compared with the predictions of equations available in the literature and code equations for reinforced concrete. The British Standard CPl10's equation was found to estimate the punching shear strength of the test specimens reasonably

Jing Zhang et al (2007) are investigated of quantify the extent to which hybrid-fiber ECC improves the resistance of blast panels against impact loading. Drop weight tests were conducted on full-scale hybrid-fiber ECC blast/shelter panels 2 m x 1 m x 0.05–0.1 m to study their response and performance under impact loading. Conventional steel reinforced concrete RC and steel fiber-reinforced concrete FRC blast panels were also tested to identify the advantages of using ECC in this application. Both the drop weight projectile with a hemispherical head and the panel specimen were instrumented to facilitate evaluation of the global and local response. The impact resistance of blast panels of different materials is evaluated in terms of the extent of damage, energy absorption capacity and residual resistance against multiple impacts. The drop weight impact test results showed that the hybrid-fiber ECC panels exhibit lesser damage, significantly improved impact resistance against multiple impacts and improved ductility and energy absorption capacity compared to both RC and FRC counterparts. A single degree of freedom model was adopted to analyze the global flexural behavior of RC and ECC panels.

Kazunori Fujikake et al (2006) are studied the impact response of a RPC (Reactive Powder Concrete) beam and develop an analytical model to represent its impact response. The drop hammer impact test was performed to investigate the influence of drop height of the hammer on the impact response of the RPC beam. Subsequently, a static flexural loading test was conducted to find out the residual load carrying capacity of the RPC beam after impact loading. In the impact analysis, the two degrees of freedom mass-spring-damper system model was used. The analytical results were in good agreement with the experimental results when high damping for the local response at the contact point was assumed.

T. S. Lok et al (2004) are studied the uniaxial compressive response of steel fiber-reinforced concrete Subjected to high strain rate loading is presented. Details of an experimental investigation using a 75-mm-diameter split Hopkinson pressure bar (SHPB) are outlined. The investigation focuses on recorded data and results in distinguishing the strain rate that mobilizes ductility of steel fiber reinforced concrete. SFRC specimens with relatively high static compressive strength were tested at strain rates between about 20 and 100 s21 produced by impact from two specially designed striker bars on the SHPB facility; different impact load durations were produced using these striker bars. The reason for adopting this strategy is explained. Tests confirmed that the unconfined uniaxial compressive strength of SFRC increases with strain rate in the same way as plain concrete. Further, strain rate has a significant influence on the ductility of SFRC. At a high strain rate, the post peak ductility is absent. This is in direct contrast to the behavior of the same material subjected to static loading. They concluded that SFRC possesses good post peak ductility at a strain rate below a specific value dictated by the entire loading process; a recommendation on the strain rate is proposed

Jeffery R. Roesler et al (2004) are investigated the Monotonic load tests have been conducted on plain and fiber-reinforced concrete slabs on ground to monitor the effect of fiber type and dosage on the strength properties of concrete slabs. The results revealed that simple material tests do not always successfully predict the contribution of fibers in cases where structural geometry and boundary considerations control redistribution of load. The tensile cracking loads of plain and fibrous slabs were found to be similar, which had previously been reported for small- scale fiber specimens, but, there was a significant increase in the flexural strength of fiber-reinforced concrete slabs, relative to plain concrete slabs. Companion beam flexural strength tests also significantly underestimated the concrete slab flexural strength for both the plain and fibrous concrete slabs. It was found that the addition of fibers increased the collapse load of slabs, with the key factors affecting the magnitude of the collapse load being fiber type and quantity. Strain and deflection profile measurements showed that fibers assisted in crack propagation resistance, crack bridging, and load redistribution.

Balasubramanian et al (1996) are studied the impact resistance of steel fiber reinforced concrete with help of Drop Weight Impact test. Trough fiber, crimped fiber, straight fibers are distributed randomly at four different volume fractions of 0.5, 1, 1.5 and 2 percent. They tested the specimen of cylindrical disc having 152mm diameter and 62.5 mm thickness. Test has been carried at for 7, 28, 90 days. Finally they concluded that the impact resistance at 90 days was found to be more when compare with 28 days in the case of all the three types of fibers and for all the volume fractions. The impact resistance increase appreciable in the case of crimped fibers for higher volume fractions.

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
- To study the strength characteristics like Compressive strength and Split tensile strength
- To study the impact resistance of slabs.
- To study the first crack load, failure cracks on slabs.

- To study the crack pattern.
- Micro structural property like Water absorption.

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
- Distilled 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

Fig 2.3 Glued DRAMIX Steel Fiber (Ferrous)

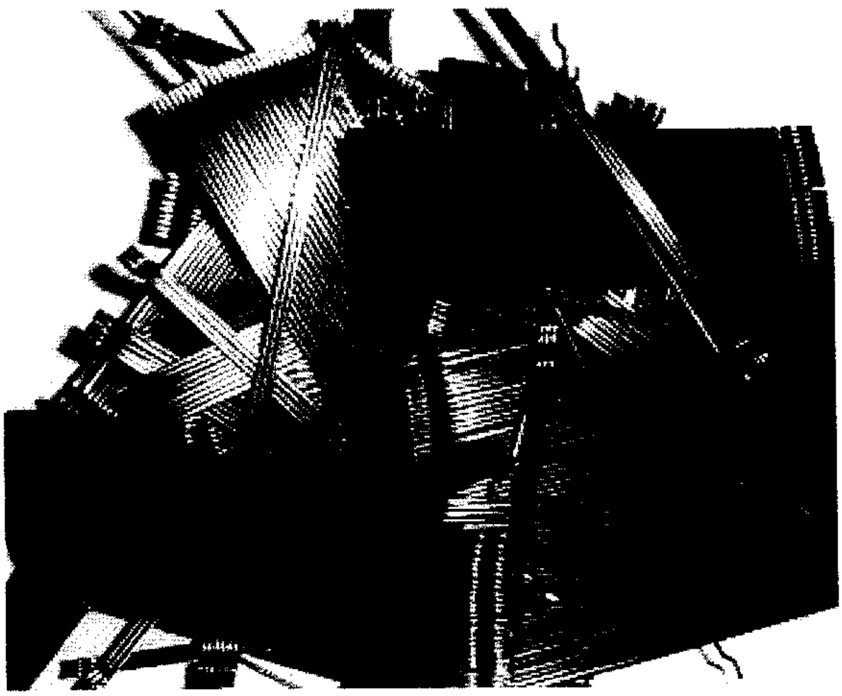


Fig 2.4 Polypropylene (non ferrous) Fiber

2.4 PERFORMANCE CHARACTERISTICS OF MATERIAL

2.4.1 Test on cement

Cement used in this research was 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 Tests on Fine aggregate

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 Tests on Coarse aggregate

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 concrete

2.4.3.1 Test on 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 Test on 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 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 M_{25} and M_{30} grades as per IS 10262-1982 was done for concrete with and without ferrous and non-ferrous fibers. Volume of concrete mix was calculated for 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 mixed together.

The aggregates and cement were mixed dry in a pan mixer for 3 minutes for concrete without fibers and water was added gradually. For concrete with fibers, fibers are added in small quantity after 80% of water was added to the mix as over dosage of fibers lead to balling of concrete and mixed for another 3 to 4 minutes. The mixture was cast in cubes, cylinders in three layers and was placed on the vibrating table for 10 seconds.

150 mm x 150 mm x 150 mm cube specimens were used 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. 1000 mm x 1000 mm x 25 mm slabs specimens were used for determine the energy absorption, crack pattern.

Drop weight test setup

It consisted of a square support frame, which was kept rigid. The specimen was laid on the frame which as a fixed end condition. For each impact, the 11.5 kg hammer hemispherical tip of diameter mm was raised to a height of 30mm and allowed to drop freely under its free weight onto the center of the specimen.

Details of casted specimens

Number of Cubes (150 x 150 x 150mm)	= 30 (Compression Test)
Number of Cylinders (150mm dia & 300mm height)	= 30 (Split & Stress-Strain Curve)
Number of Slabs (1000 x 1000 x 25 mm)	= 30 (Impact Resistance)

Fig 2.5 Reinforcement

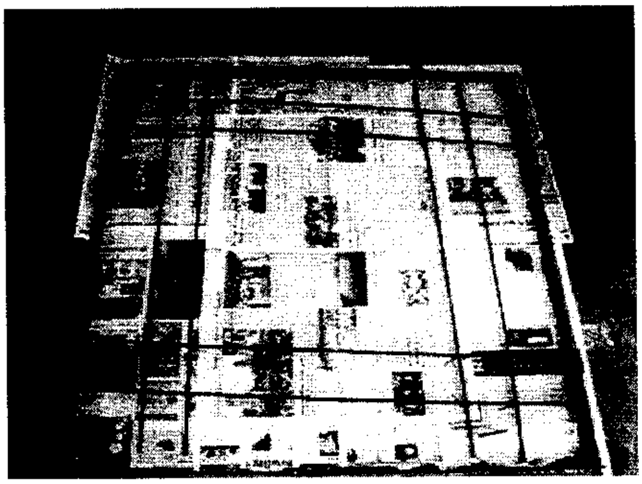


Fig 2.6 Casting Works

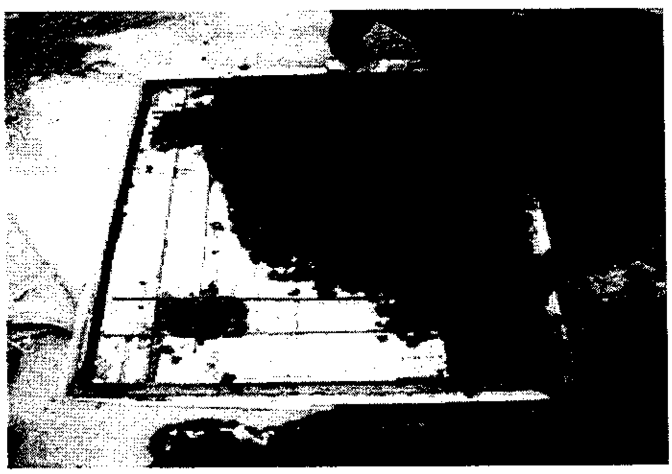


Fig 2.7 Slabs after Casting

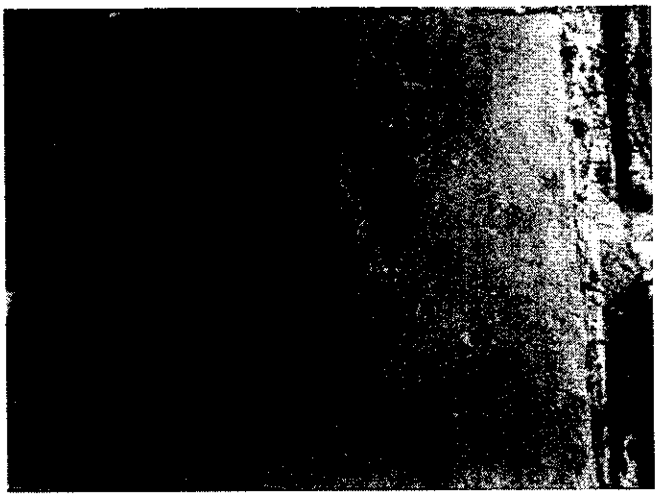
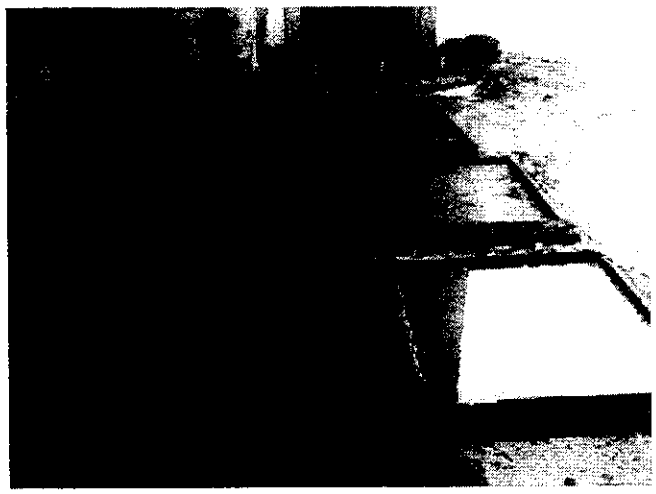


Fig 2.8 Curing process (pond method)



Chapter 3

Test Results and Discussions

CHAPTER 3

TEST RESULTS AND DISCUSSIONS

3.1 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

Test	**Result obtained**	**As per IS 4031-1998**
Consistency	33	-
Initial setting time	90 minutes	Not less than 30 min.
Final setting time	5 hours	Not less than 600 min.
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

Test	**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

Test	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 are used in M_{25} and M_{30} mix and optimum fiber dosage was obtained for which beam specimens were casted.

3.3.1 Fiber Reinforced Concrete Mixture

Concrete mixture design is vast and generally based on performance criteria. Based on the information given above, some simple guidelines for the design of fiber reinforced concrete.

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 (i.e., as a rain of individual fibers) 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/m^3. 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/m^3 (60%) of 20mm aggregates, 475 Kg/m^3 (40%) of 12.5mm aggregates and 576 Kg/m^3 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. In hybrid fibers, both the ferrous and non-ferrous fibers were kept constant to 0.50%. The numerous batches of FRC with and without ferrous and non-ferrous fiber mixtures were manufactured as shown in Table 3.4

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

Design Mix	Cement content Kg/m^3	F.A content Kg/m^3	Total C.A content Kg/m^3	60% 0f 20mm C.A content Kg/m^3	40% of 12.5mm C.A content Kg/m^3	Water content Kg/m^3
M25	377.6	576	1187.5	712.5	475	188.8
M30	420	547.3	1181	708.5	472.5	184

Design Mix	Fiber Content Kg/m^3
M25 SFRC 0.25	3.38
M25 SFRC 0.50	6.92
M25 SFRC 0.75	10.17
M25 PFRC 0.25	0.79
M25 PFRC 0.50	1.58
M25 PFRC 0.75	2.37
M30 SFRC 0.25	3.83
M30 SFRC 0.50	7.67
M30 SFRC 0.75	11.50
M30 SFRC 0.25	0.87
M30 SFRC 0.50	1.75
M30 SFRC 0.75	2.63

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 in mm

Design mix	0%	0.25%		0.50%			0.75%	
		SFRC	PFRC	SFRC	PFRC	HFRC	SFRC	PFRC
M25	65	63	59	60	50	55	54	45
M30	60	61	58	57	55	54	52	42

From the observed slump test result, the degree of workability of concrete was medium where the slump values lies between 50-100.

3.5 TEST RESULTS ON HARDENED CONCRETE

3.5.1 Compressive Strength

The compressive strength of FRC 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 after 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 Avg. Test Result of Compressive Strength in MPa

Design mix	0%	0.25%			0.50%			0.75%		
		SFRC	PFRC	HFRC	SFRC	PFRC	HFRC	SFRC	PFRC	HFRC
M25	27	28.5	24	30	30.5	25.5	31.5	31	27	33
M30	33.5	35.5	28	36	37	29.5	37	37.5	30	38

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 at the age of 28th day after casting. 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 Avg. Test Result of Split Tensile Strength in Mpa

Design mix	0%	0.25%		0.50%			0.75%	
		SFRC	PFRC	SFRC	PFRC	HFRC	SFRC	PFRC
M25	3.6	4.1	3.8	4.7	4.1	5.3	4.9	4.3
M30	3.7	4.4	4.1	4.9	4.3	5.3	5.2	4.6

3.5.3 Stress-Strain Characteristics

The test for Stress-Strain curve of the specimen was 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

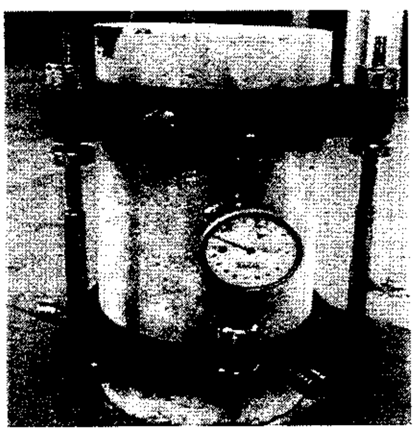


Table 3.8 Test Result of Stress- Strain characteristics of FRC

Design Mix	Stress (40% of Load) Mpa	Strain μ	Young's Modulus Mpa x 10^3
M25	1.5	97.5	15.38
M25 SFRC 0.25	1.8	98.9	18.20
M25 SFRC 0.50	2.1	100.5	20.89
M25 SFRC 0.75	2.3	106.8	21.53
M25 PFRC 0.25	1.7	126.8	13.40
M25 PFRC 0.50	1.9	137.4	13.83
M25PFRC 0.75	2.0	148.6	13.45
M25 HFRC	2.8	178.9	15.65
M30	1.8	98.5	18.27
M30 SFRC0.25	2.2	93.8	23.45
M30 SFRC0.50	2.5	110.8	22.56
M30 SFRC 0.75	2.8	118.2	23.60
M30 PFRC 0.25	1.8	120.2	14.97
M30 PFRC 0.50	2.1	147.4	14.25
M30 PFRC0 0.75	2.4	158.6	15.13
M30 HFRC	3.2	196.2	16.31

Fig 3.4 Experimental set up of Stress-strain characteristics

3.5.4 Micro Structural Property

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.

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

The values of saturated water absorption of the specimen at 28 days are obtained and are tabulated as shown in Table 3.9.

Fig 3.5 Saturated Water

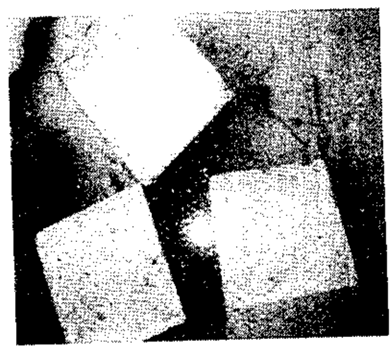


Fig.3.9 Test Result of Saturated Water Absorption

Design mix	**0%**	**0.25%**		**0.50%**			**0.75%**	
		SFRC	PFRC	SFRC	PFRC	HFRC	SFRC	PFRC
M25	2.7	2.3	1.8	2.1	1.4	1.9	1.9	1.2
M30	2.8	2.4	1.4	2.2	1.1	1.7	2.0	1.1

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

3.6 IMPACT TESTS ON SLABS

3.6.1 Experimental procedure

A drop weight test setup was adopted as shown in Fig 3.6 .It consisted of a square support frame, which was kept rigid by bolted on all sides. The specimen was laid flat resisting on floor 20 mm bars simulating a square line support shown in Fig 3.6. A manually operated winch was used to raise the hammer to the required height. A central impact in the vertical direction was achieved means of smooth rollers so that the hammer can slide freely. Grease was applied on the rollers to reduce friction and to ensure a smooth fall.

3.6.2 Test Procedure

Drop weight tests were conducted on slab specimens of thickness 25mm.the test program is divided into two parts: (a) studying the impact resistance of different materials, namely SFRC, PFRC, HYBRID. (b) Evaluating the performance of SFRC, PFRC slabs and compare with control specimens. For each impact, the 11.5 kg hammer with a hemispherical tip of diameter 30mm Fig 3.7. was raised to a height of 30 cm and allowed to drop freely under its free weight onto the center of the specimen. For each type of specimen, resistances under multiple impacts were monitored repeatedly until the panels were totally perforated.

Fig 3.6 Experimental set up of Slabs in Loading Frame

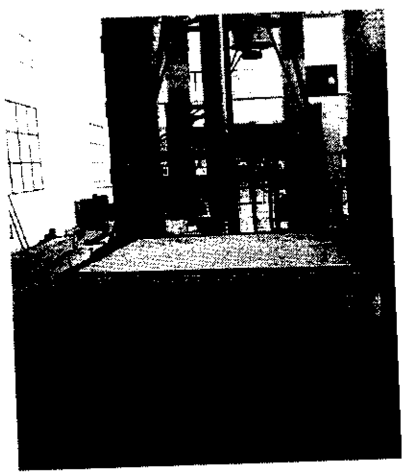


Fig 3.7 Hemispherical tip

Table 3.10 Test Results of Drop Weight Impact Tests on M25 at first crack

Sl.No	Mix designation		Average No. of Blows At First Crack	Avg. Energy Absorption At first Crack (N-m)
	Type of fibers	% of fibers		
1	SFRC	0	5	169.22
2		0.25	12	406.13
3		0.50	19	643.05
4		0.75	29	981.50
5	PFRC	0.25	15	507.67
6		0.50	24	812.26
7		0.75	36	1218.40
8	HYBRID (0.25 SFRC &0.25 PFRC)		45	1523.00

Table 3.11 Test Results of Drop Weight Impact Tests on M25 at failure

Sl.No	Mix designation		Average No. of Blows At failure	Avg.Energy Absorption At failure (N-m)
	Type of fibers	% of fibers		
1	SFRC	0	20	676.89
2		0.25	37	1252.24
3		0.5	56	1895.29
4		0.75	63	2132.20
5	PFRC	0.25	41	1387.62
6		0.5	57	1929.14
7		0.75	79	2673.72
8	HYBRID (0.25 SFRC &0.25 PFRC)		89	3012.16

Table 3.12 Test Results of Drop Weight Impact Tests on M30 at first crack

Sl.No	Mix designation		Average No. of Blows At first Crack	Avg.Energy Absorption At first crack (N-m)
	Type of fibers	% of fibers		
1	SFRC	0	8	270.76
2		0.25	17	575.36
3		0.5	27	913.80
4		0.75	33	1116.86
5	PFRC	0.25	23	778.42
6		0.5	34	1150.71
7		0.75	49	1658.38
8	HYBRID (0.25 SFRC &0.25 PFRC)		54	1827.60

Table 3.13 Test Results of Drop Weight Impact Tests on M30 at failure

Sl.No	Mix designation		Average No. of Blows At failure	Avg.Energy Absorption At Failure (N-m)
	Type of fibers	% of fibers		
1	SFRC	0	31	1049.18
2		0.25	49	1658.38
3		0.5	60	2030.67
4		0.75	71	2402.96
5	PFRC	0.25	51	1726.06
6		0.5	67	2267.58
7		0.75	86	2910.63
8	HYBRID (0.25 SFRC &0.25 PFRC)		110	3722.90

Fig 3.8 Avg. Energy absorption of M25 SFRC at First Crack and Failure

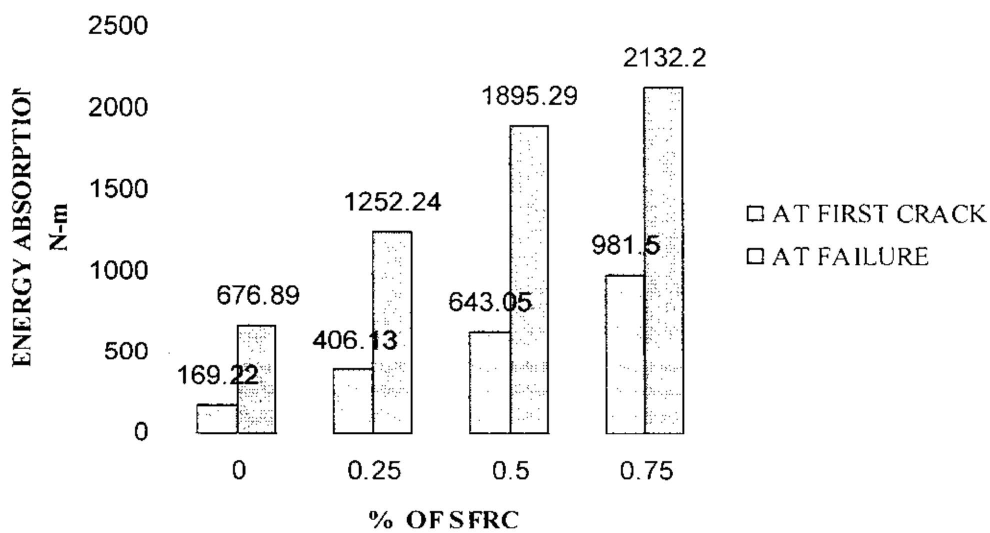


Fig 3.9 Avg. Energy absorption of M25 PFRC at First Crack and Failure

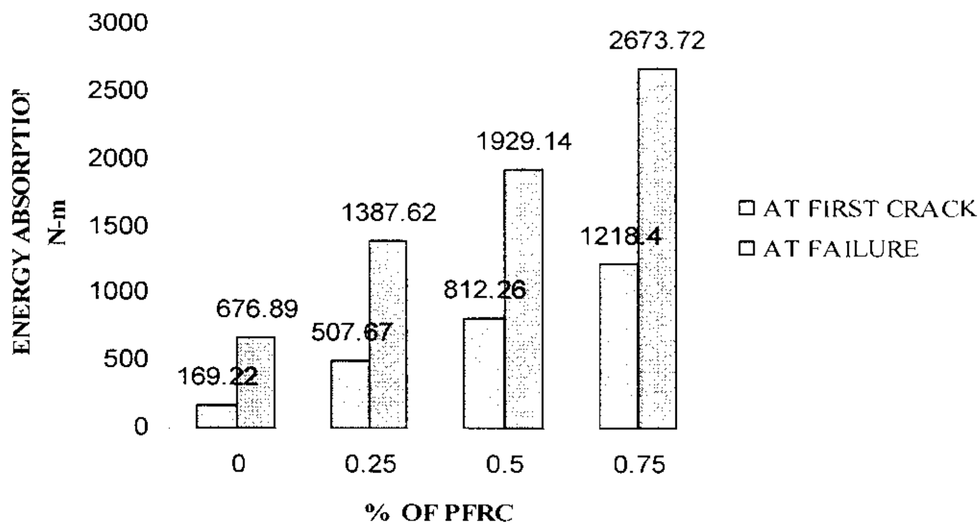


Fig 3.10 Avg. Energy absorption of M30 SFRC at First crack and Failure

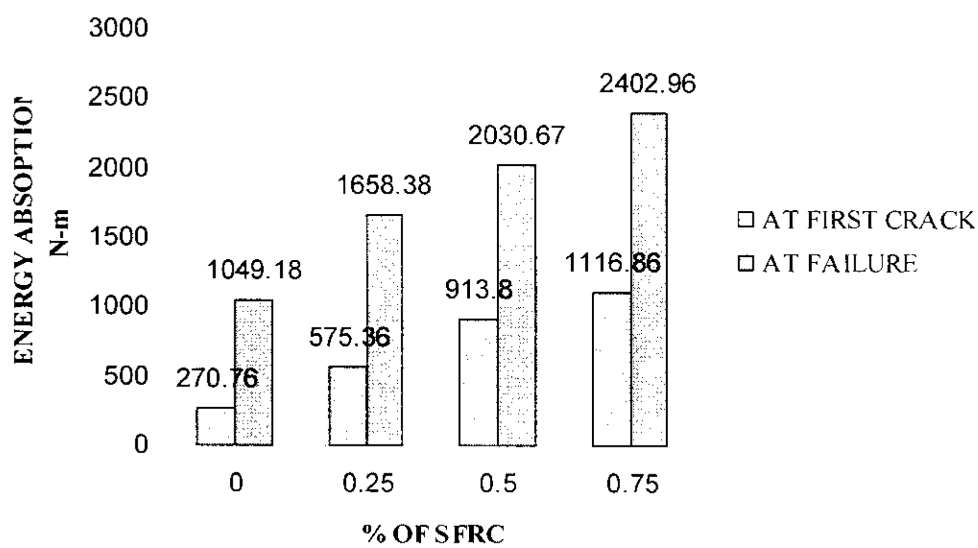


Fig 3.11 Avg. Energy absorption of M30 PFRC at First crack and Failure

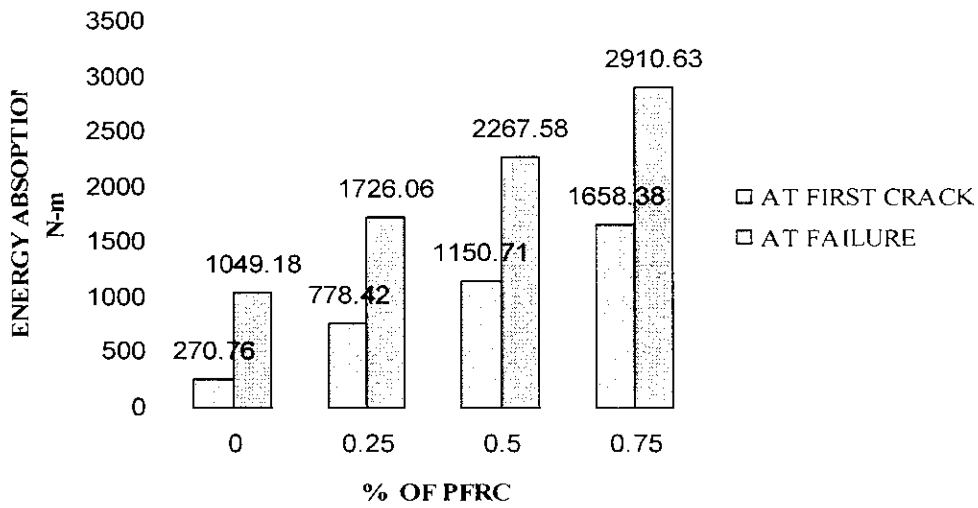


Fig 3.12 Avg. Energy absorption of HYBRID at First crack and Failure

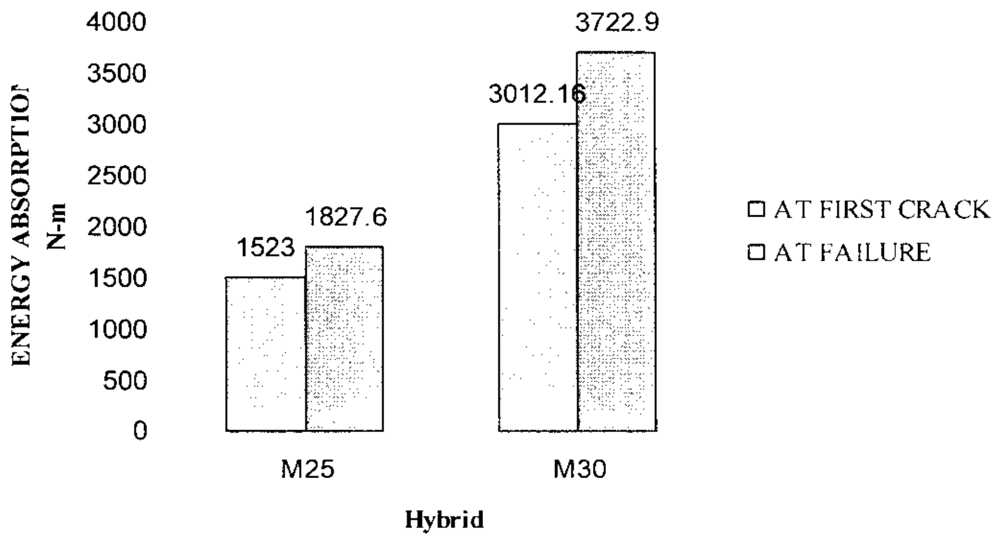


Fig 3.13 Avg. Energy Absorption of M25 SFRC between First Crack & Failure

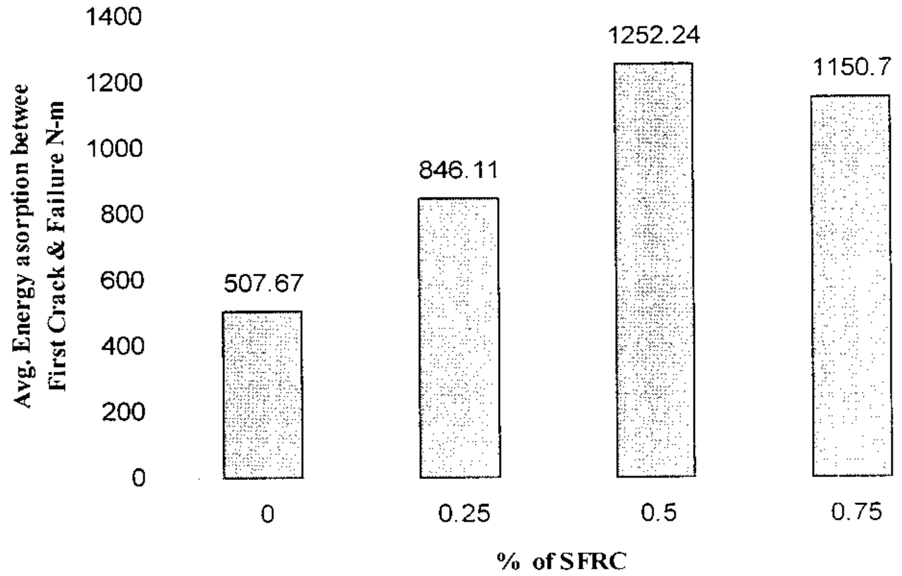


Fig 3.14 Avg. Energy Absorption of M25 PFRC between First Crack & Failure

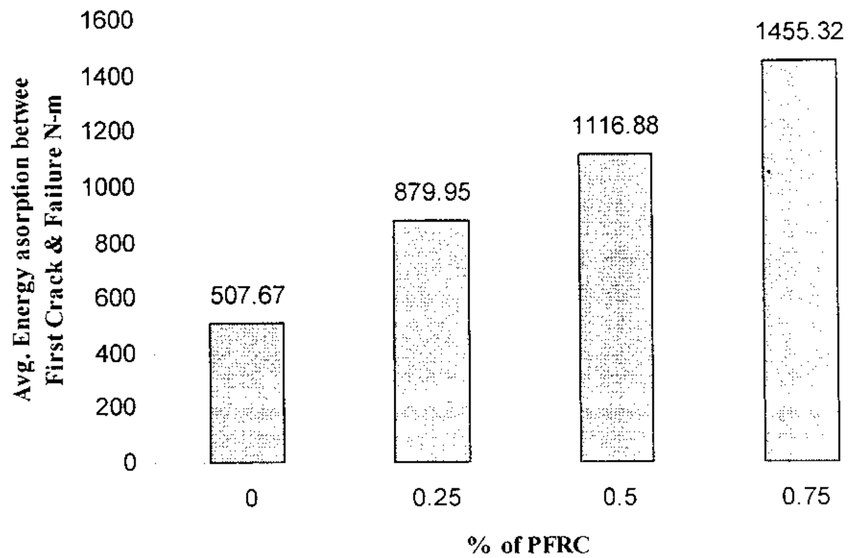


Fig 3.15 Avg. Energy Absorption of M30 SFRC between First Crack & Failure

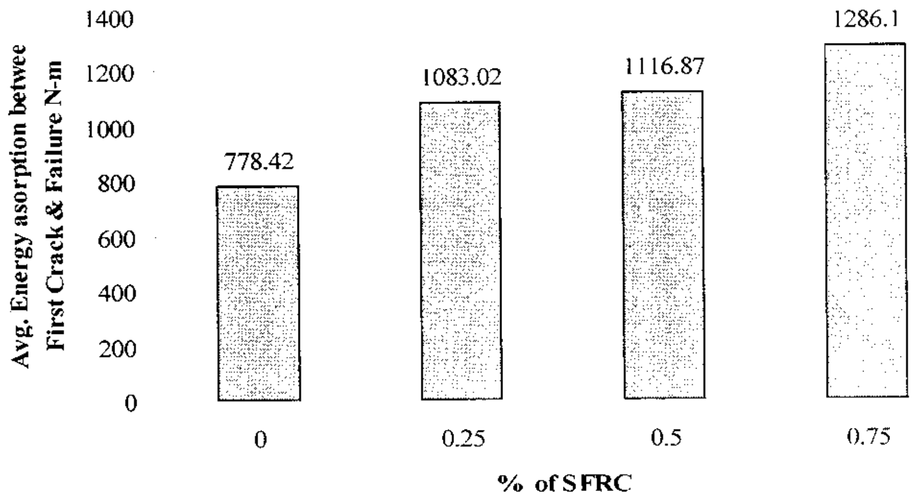


Fig 3.16 Avg. Energy Absorption of M30 PFRC between First Crack & Failure

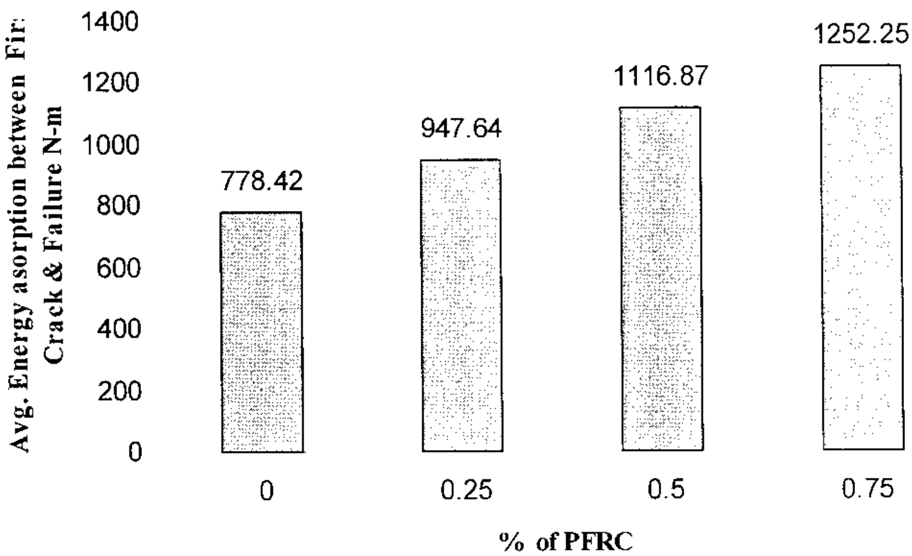


Fig 3.17 Avg. Energy Absorption of Hybrid Fibers between First Crack & Failure

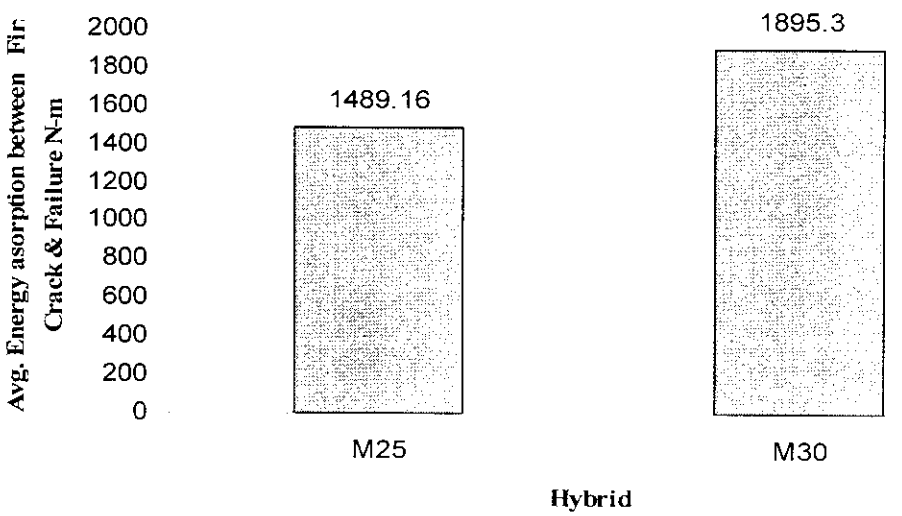


Fig 3.18 Percentage Variation of energy absorption on M25

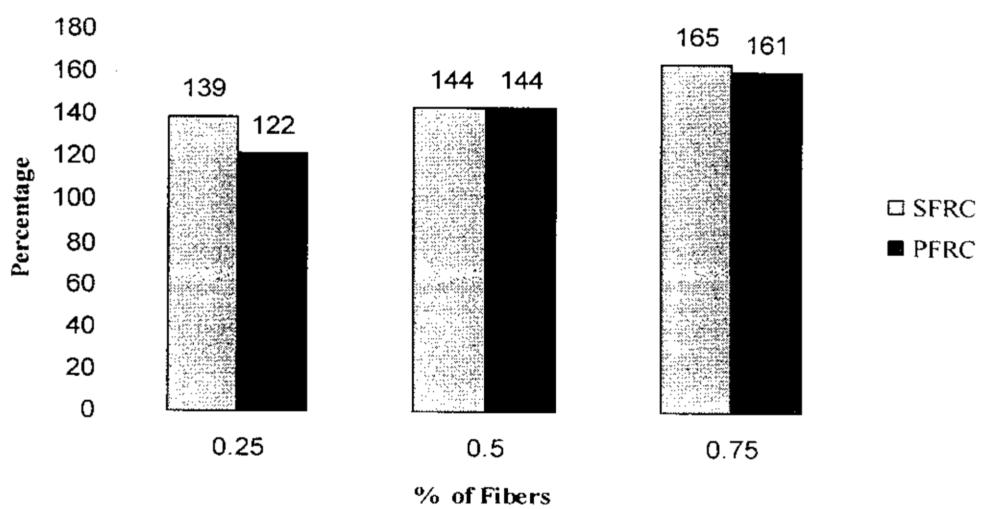


Fig 3.19 Percentage Variation of energy absorption on M30

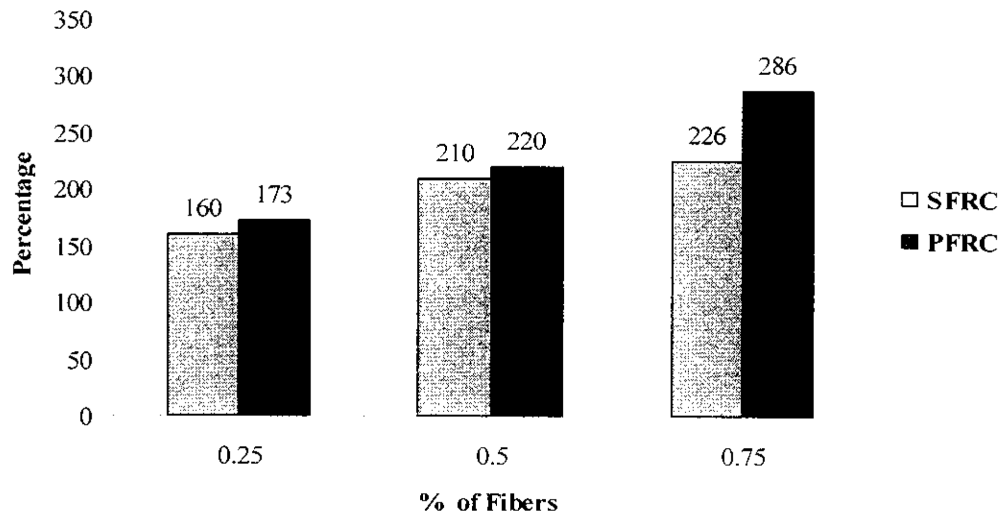


Fig 3.20 Percentage Variation of energy absorption on Hybrid

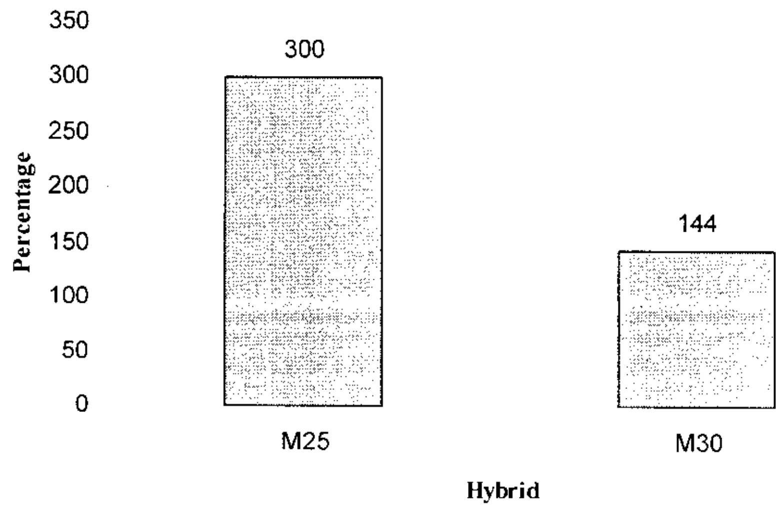


Fig3.21 Comparison of SFRC and PFRC for M25 at failure

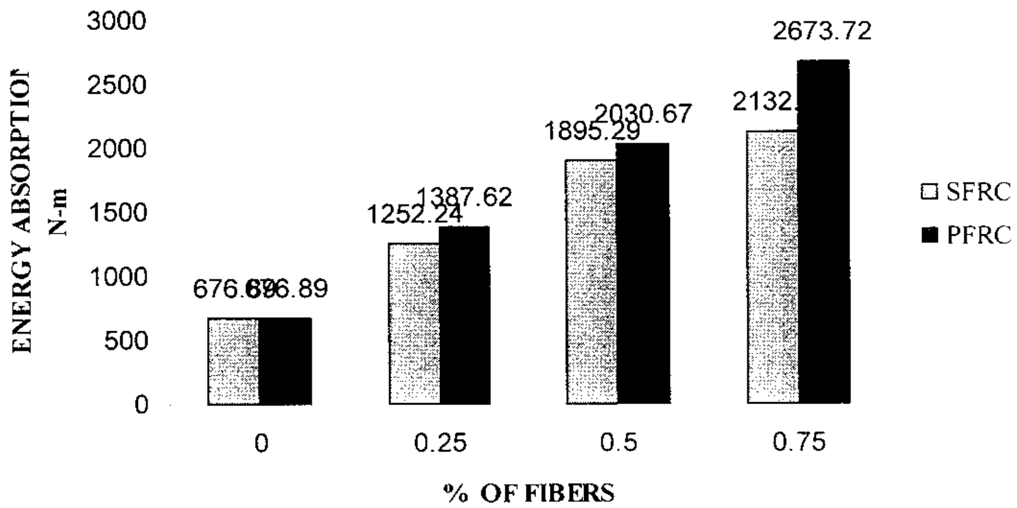


Fig3.22 Comparison of SFRC and PFRC for M30 at failure

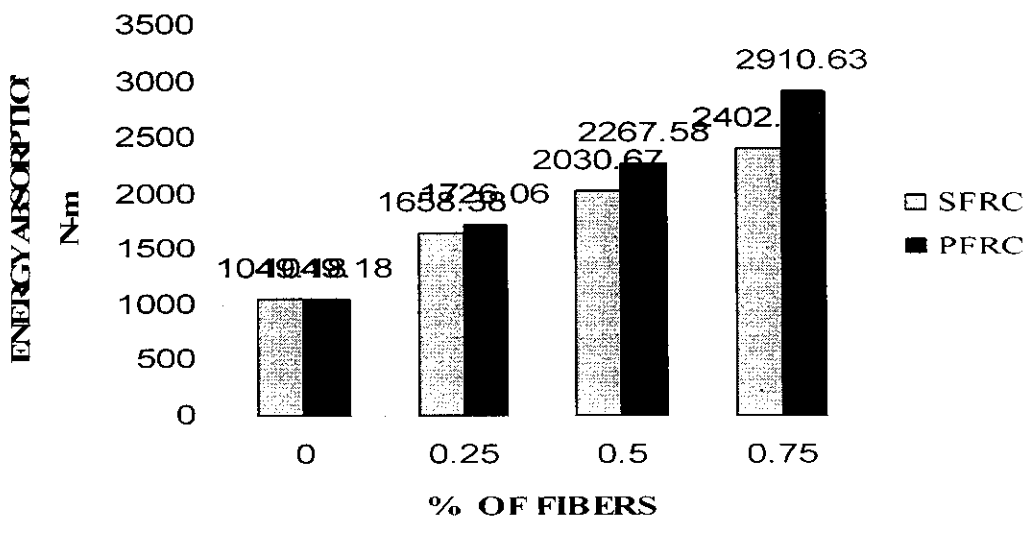
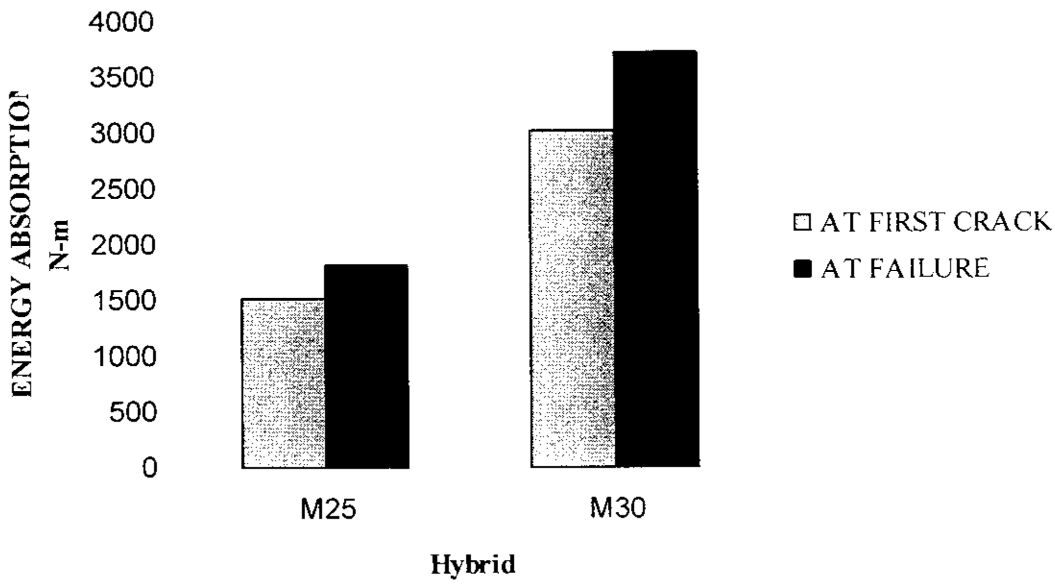


Fig 3.23 Comparison of hybrid Fibers of M25 and M30 at failure



DISCUSSION OF RESULTS

Table 3.10 to table 3.13 shows the results of Drop weight impact Tests that shows the First Crack Strength they show Hybrid fibers are taking more energy absorption. Compare to SFRC, PFRC taking more energy absorption. In SFRC slabs the higher percentage takes more energy absorption. Similarly, In PFRC slabs the higher percentage takes more energy absorption.

In Fig 3.13 to 3.16 shows they Average energy absorption of fibers between first crack & failure in that higher percentage fibers are taking more energy absorption after the first crack was found. In Fig 3.17 shows the Hybrid fibers of M30 grade absorbs more energy absorption.

In Fig 3.18 SFRC fibers have more percentage variation of energy absorption on M25.In Fig 3.19 PFRC fibers have more percentage variation of energy absorption on M30.

3.6.3 Study on Crack Pattern

The slabs are follows the crack pattern of yield line theory. When compare to the SFRC slabs the PFRC slabs have more minor cracks and absorb the more energy. When hybrid fibers are used, extend of the clack is low compare to the other two fibers.

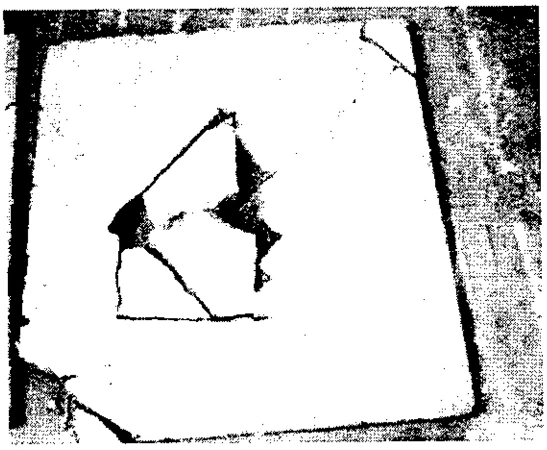


Fig 3.24 M25 Conventional

Fig 3.25 M30 Conventional

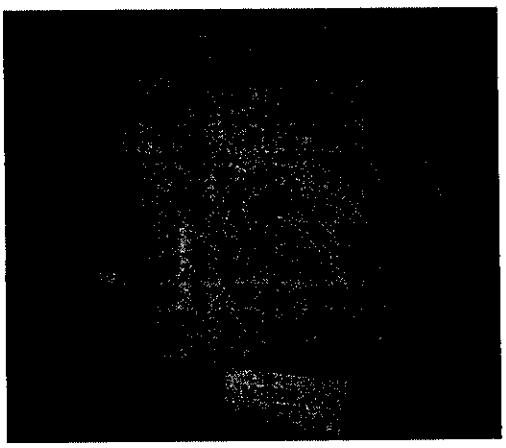


Fig 3.26 M25 SFRC 0.25%

Fig 3.27 M25 PFRC 0.25%

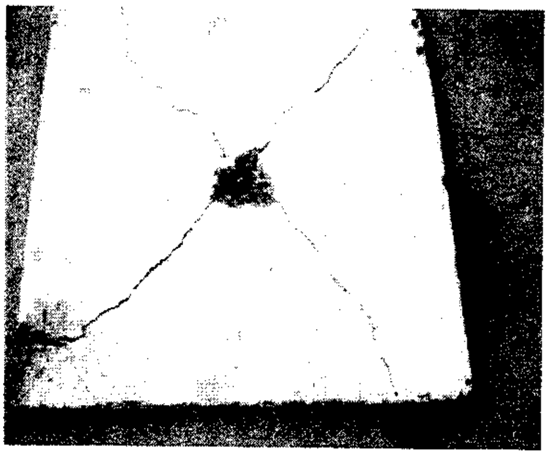


Fig 3.28 M25 SFRC 0.50%

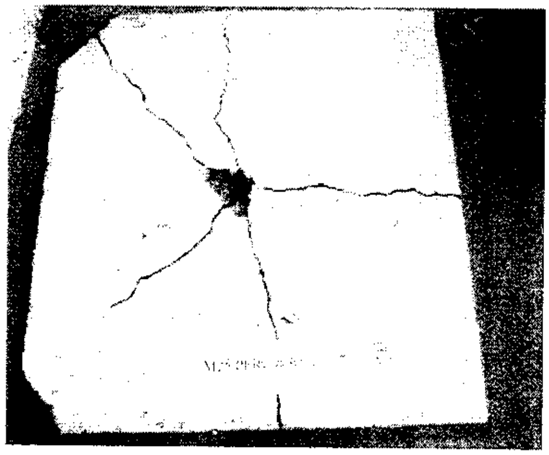


Fig 3.29 M25 PFRC 0.50%

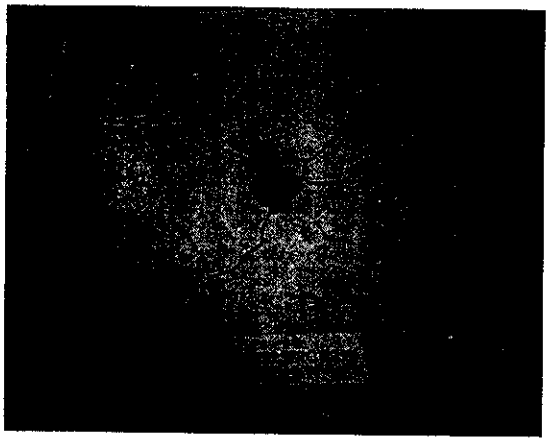


Fig 3.30 M25 SFRC 0.75%

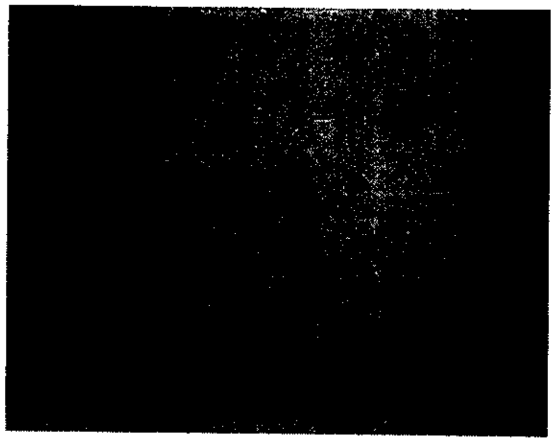


Fig 3.31 M25 PFRC 0.75%

Fig 3.32 M30 SFRC 0.25%

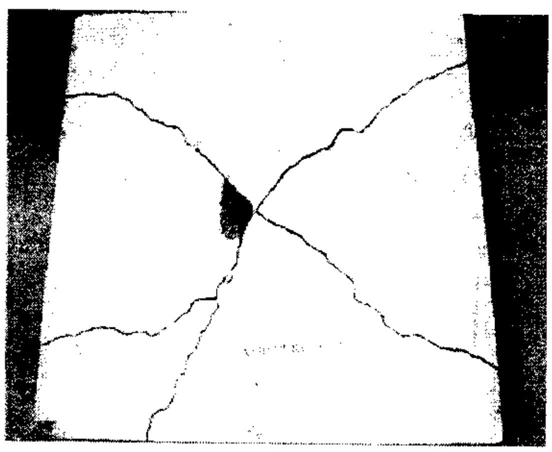


Fig 3.33 M30 PFRC 0.25%

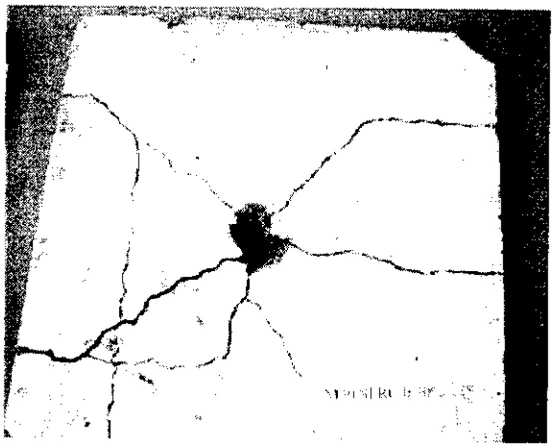


Fig 3.34 M30 SFRC 0.50%

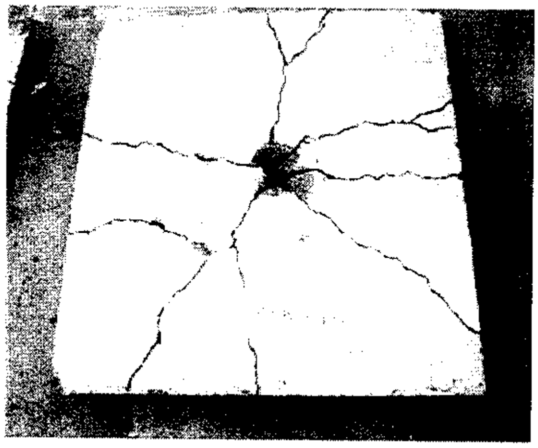


Fig 3.35 M30 PFRC 0.50%

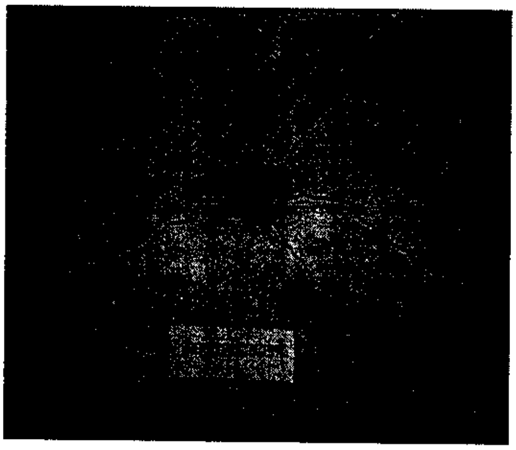


Fig 3.36 M30 SFRC 0.75%

Fig 3.37 M30 PFRC 0.75%

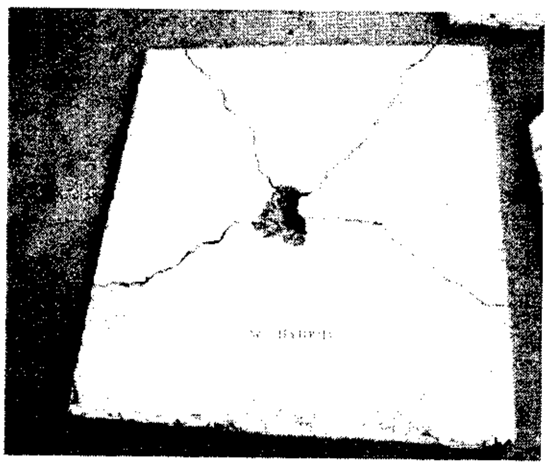


Fig 3.38 M25 HYBRID

Fig 3.39 M30 HYBRID

Chapter 4

Conclusions

CHAPTER4

CONCLUSIONS

The following conclusions were drawn within the limitation of experimental investigation

4.1 General Conclusions

- The Compressive Strength increases gradually in fiber reinforced concrete than concrete without fibers
- As the fiber dosage increases, the tensile strength increases accordingly. The hybrid fibers shows 17% increase in tensile strength than normal concrete
- Modulus of elasticity obtained from Stress-Strain characteristics is high for SFRC
- Water absorption is less incase of PFRC when compared to SFRC and normal concrete.
- The FRC concrete showed an ability to control the cracking under impact loading and is found to absorb substantially higher number of blows when compared with the plain concrete.
- Addition of fibres, even in a small quantity, considerably improves the impact resistance of concrete.
- Fibers with higher aspect ratio provided for higher energy absorption.

4.2 Specific Conclusions

- The energy absorption of slabs with fiber volume of 0.25% was about twice that of plain concrete slabs.
- The slabs with fiber volume of 0.5% experienced energy absorption of about 1.5 times that of slabs with 0.25% fibers.
- In 0.75% slabs, the energy absorption was about 1.5 times that of slabs with fiber volume of 0.5%.
- In slabs with low fiber volume (0.25%) the resisting load after cracking was relatively small.

- The rate of improvement in energy absorption reduced with increase in fiber content.
- When compared to SFRC, PFRC slabs withstand more energy absorption.
- Hybrid fibers take more energy absorption when compared to the SFRC 0.5% and PFRC 0.5%.
- The energy absorption between first crack and failure in SFRC is more on M25 and PFRC is more on M30

4.3 Scope for Future Work

- Fiber dosage can be varied and studied for impact test
- Acid resistance test can be studied
- Hybrid fiber dosage can be varied and studied.
- Thickness of slabs can be varied and studied.
- Height of the drop weight can be varied and studied.
- Shrinkage and creep study
- Orientation of fibers can be studied

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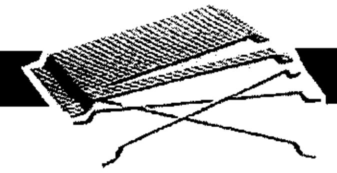
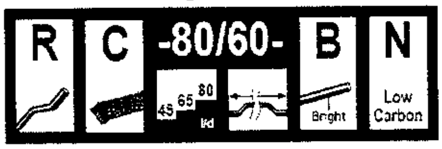
Appendix-A

APPENDIX-A

PRODUCT DATA SHEET **BEKAERT**



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:

Length (l)
60 mm

Diameter (d)
0,75 mm

80 Performance class: 80

Aspect ratio (= l/d): 80

4600 fibres/kg

Approvals:

Conforms to
ASTM A820

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

ISO 9001

Product

Belgium
ATG 04/1857

The Netherlands
22702

Turkey
TS 10513

Czech Republic
C.070-021415

Product

Poland
AT-15-2117/2001

Romania
007-01/068-2003

Germany
Z-3.71-1745

Slovak Republic
1402A/02/0771/1/C/C04

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

- $f_{fctm,eq,300}$, $f_{fctk,eq,300}$ = average and characteristic **equivalent flexural strength to** a deflection of 1,5 mm according to NBN B 15-238, 239, JSCE-SF4 and CUR35.
- $f_{fctm,eq,150}$, $f_{fctk,eq,150}$ = 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

$f_{ctm,fl}$ (1) ►	3,7 (C20/25) (2)		4,3 (C25/30)		4,8 (C30/37)		5,3 (C35/45)		5,8 (C40/50)	
Dosage ▼	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$
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	4,9	4,3
50	3,9	3,5	4,2	3,7	4,4	4,1	4,8	4,3	5,0	4,4

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

$f_{fctk,eq,300} = 0.7 \times f_{fctm,eq,300}$
$f_{fctk,eq,150} = 0.7 \times f_{fctm,eq,150}$
According to Dramix® guideline unless more specific data available

2 Equivalent axial tensile strength

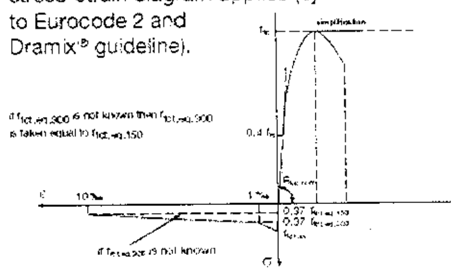
- Equivalent axial tensile strength = 0,37 x equivalent flexural strength.

Dramix®

R C -80/60- B N

3 Stress-strain diagram

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



4 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

Dosage ▼	Re1.5 (%)	Re3 (%)
15	45	42
20	56	52
25	65	60
30	74	68
35	80	75
40	86	80
45	90	86
50	94	90

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

N.V. Bekaert S.A. - Bekaertstraat 2 - 8550 Zwevegem - Belgium
Tel. +32 (0) 56 / 76 69 86 - Fax +32 (0) 56 / 76 79 47
Internet: http://www.bekaert.com/building

Recommendations - mixing

1. General

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

Max. aggregate size (mm)	Dosage (kg/m³)	
	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

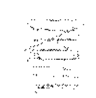
Bags are non-degradable and may not be thrown into the concrete.

2.3. 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

Protect the pallets against rain



Do not stack the pallets on top of each other

Delivered in

non water-solubie bags of 20 kg on pallet 1200 kg

big bag 1100 kg

Certificate

NCFA[redacted]8

KOVAIPUDUR, COIMBATORE - 641 042.

DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

NATIONAL CONFERENCE ON FRONTLINE AREAS OF CIVIL ENGINEERING

This is to certify that Mr. / ~~Ms.~~ S. BOPATHY RAJA

KUMARAGURU COLLEGE OF TECHNOLOGY - COIMBATORE

~~participated~~ / presented a paper titled EXPERIMENTAL STUDIES ON FIBER REINFORCED CONCRETE SLABS WITH AND WITHOUT FERROUS AND NON-FERROUS FIBRES.

in the National Conference organised by the Department of Civil Engg. VLBJCET, Kovaipudur, Coimbatore during April, 24 - 25 , 2008.

Prof. Jino John	Mr.D. Maruthachalam	Dr. B. G. Vishnuram	Dr. S.C. Natesan
CO ORDINATOR	CO ORDINATOR	CONVENOR	CHAIRMAN