Experimental Behavior of High Performance Fiber Reinforced Concrete

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Abstract- *An experimental investigation of the behavior of concrete beams reinforced with conventional beams subjected to flexural loading is presented. An experimental program consisting of tests on steel fiber reinforced concrete (SFRC) beams with conventional reinforcement and reinforced concrete (RC) beams was conducted under flexural loading. SFRC beams include two types of beams containing beams with fully hybrid fibers and beams with fibers only in hinged zones. The cross sectional dimensions and span of beams were fixed same for all types of beams. The dimensions of the beams were 150mm x 150mm x 1200mm. Tests on conventionally reinforced concrete beam specimens, containing Steel fibers in different proportions, have been conducted to establish load deflection curves. The various parameters, such as, first crack load, ultimate load and stiffness characteristics, energy absorption, toughness index of beams with and without steel fibers have been carried out and a quantitative comparison was made on significant stages of loading. It was observed that SFRC beams showed enhanced properties compared to that of RC beam. Finally calculate the ultimate strength of the conventionally reinforced beams with steel fibers. The ultimate loads obtained in the experimental investigation were also compared for all types of beams.*

I. INTRODUCTION

General : Concrete is a structural components exist in buildings and bridges in different forms. Understanding the response of these components during loading is crucial to the development of an overall efficient and safe structure. Different methods have been utilized to study the response of structural components. Experimental based testing has been widely used as a means to analyze individual elements and the effects of concrete strength under loading. It has now become the choice method to analyze concrete structural components. Concrete can withstand whatever compressive forces, more over its workable and durable material, can be formed to any shape, also it's a cheap material. At the same time it require special care and precaution during casting otherwise it could cause cracks and failure. Load-Deformation Response of control beam and Application of Effective Prestress, Self-Weight, Zero Deflection, Decompression, Initial Cracking, Secondary Linear Region, Behavior of Steel Yielding and Beyond, Flexural Limit State of prestressed concrete beam . Firstly, literature review was conducted to evaluate previous experimental procedures related to reinforced concrete. The observation was focused on reinforced concrete beam behavior at first cracking, behavior beyond first cracking, behavior of reinforcement yielding and beyond, strength limit state, load-deformation response, and crack pattern. High performance fiber reinforced concrete is developing quickly to a modern structural material with a high potential. At this moment studies are carried out with the aim to come to an international recommendation for the design of structures with HPFRC. The results obtained was focused on the same as before also comparison of first cracking load, ultimate load, work-done in linear and nonlinear region, and load deflection nature between these different reinforcement ratio of the analytical beam. An experimental program conducted to study the flexural behavior and redistribution in moment of reinforced high strength concrete (RHSC) continuous beams. Comparisons between experimental and predicted moment and load capacity show that the proposed model agrees very well with the test results, thus justifying the use of the proposed model for HSC and NSC in strengthened beams. Natural disasters like earthquakes, cyclones, tsunami, etc, destroy the high rise buildings, bridges, monumental structures, world wonders, etc. To protect the world from that kind of devastation, the field of civil engineering require some innovations in both materials and construction techniques. One such development has two phase composite materials i.e. fiber reinforced concrete, in which cement based matrix acts as cracks arresters which restricts the growth of flaws in the matrix, preventing these from enlarging under load into cracks. The weakness can be removed by inclusion of fibers in concrete the fibers help to transfer loads at the internal micro cracks. The fibers can be imagined as aggregate with an extreme deviation in shape from the smooth aggregate. Increases flexural toughness / residual strength. Provides post-crack performance with Increased impact and abrasion resistance, load bearing capacity of concrete and Potential reduction of concrete beam depth to the Concrete retains load carrying capability after cracking has occurred in

Increased durability and reduced maintenance costs with no requirement for crack control steel mesh, Concrete placement and crack control in one operation. Cost effective alternative to conventional steel mesh reinforcement no need to purchase and store additional material and no delays to fast track schedule with Easier positioning of joints to Reduced site labour requirement for on-site handling and cutting of steel reinforcement also no secondary steel mesh is required and reinforcement is automatically positioned Controls cracking which occurs in the hardened state even distribution of fibers throughout the concrete. A tougher surface with fewer bleed holes Enhanced load bearing capability which Improved flexural properties.

High Performance Concrete : High performance concrete has more uniform and also homogeneous micro structures than that of normal concrete. When silica fume is mixed with ordinary Portland cement low water cement ratio micro structure of such mixture has mainly crystalline hydrants, forming the dense matrix of low porosity. As the content of the silica fume is increased in concrete, major part of calcium hydroxide is transformed into calcium silicate hydrates while the left over calcium hydroxide has the tendency to for smaller crystals compared to those present in the OPC paste. All these three phases must be optimized, which means that each must be considered explicitly in the design process. It is very important to pay careful attention to all the aspects of concrete production (i.e. selection of materials, mix design, handling and placing). It indicates that quality control is an essential part of the production of high performance concrete and requires full co-operation among the materials, ready mixed supplier, the engineer and the contractor. High performance concrete has various advantages such as high modulus of elasticity, high abrasion resistance, high durability, and long life in severe environments Low permeability and diffusion Resistance to chemical attack high resistance to frost and de-icier scaling damage Toughness and impact resistance.

II. MATERIALS USED

Cement - Ordinary Portland cement of review 53 is utilized as a part of the pervious cement and the concrete is utilized as a coupling material.

Coarse aggregate - Locally accessible pulverized blue rock stones adjusting to reviewed total of ostensible size 20 mm according to Seems to be: 383 – 1970. Smashed rock total with particular gravity of 2.77 and going through 4.75 mm strainer and will be utilized for throwing all examples. A few examinations infer that most extreme size of coarse total ought to be confined in quality of the composite. Notwithstanding bond glue – total proportion, total sort impacts concrete dimensional dependability.

Water - Water utilized for blending ought to be compact drinking water having pH values between 6 to 8 and it ought to be free from natural matters and the strong substance ought to be inside as far as possible according to IS 456-2000 and fitting in with IS 3025-1964. In the present test concentrate the water accessible inside the school grounds is utilized for all reasons.

Silica Fume - This by-result of silicone generation comprises of superfine round particles which altogether increment the quality and solidness of cement. It can supplant concrete in amounts of 5-12%.

Hooked End Fiber - The length of the fiber is 30 mm. The aspect ratio of fiber is 60.The diameter of hooked end fibers is 0.5mm. The tensile strength of the fiber is 1100Mpa. Fig 4.1 shows the view of the hooked end fibers.

Fig: Hooked end fibers

Crimped Fiber - The length of the fiber is 30 mm. The aspect ratio is 60. The diameter of crimped fiber 0.5mm. The tensile strength is 600Mpa. The Material type of crimped fiber is low carbon drawn flat wire. The crimped fiber as shown in the Fig

Fig : Crimped fiber

S.No	Property	Hooked End Fiber	Crimped Fiber
1	Diameter	0.5	0.5
2	Length	30	30
3	Aspect Ratio	60	60
4	Deformation	Hooked at ends	Crimped at ends
5	Tensile	1100MPa	600MPa

	Strength		

III. MIX PROPORTION

Based on IS Method :

Characteristic strength of concrete is 40Mpa
Design average cube strength at 28 days
40/0.75 = 53.33 N/mm2
Optimum W/C ratio = 0.40
Density of Concrete = 2500 Kg/m3
Bulk Density of Cement = 1700 Kg/m3
Bulk Density of coarse aggregate = 1670 Kg/m3
Cement: F.A : C.A - 1: 1.05 : 2.28
Quantities of materials per m3 concrete:
Cement: 490 Kg/m3
Coarse aggregate: 1121.74 Kg/m3
Water: 196 Kg/m3
Silica fume (10%): 41Kg/m3
Fiber (1.5%): 60Kg/m3

IV. CONCRETE CASTING

Casting - The round and hollow form and cubical shape of standard example size is utilized for the throwing reason.

Cylindrical form – 150*300 mm
Cube shaped form – 150*150*150 mm
Prism form – 100*100*500mm

At first the solid is threw for various test outcomes and the casting depends on routine, in part utilizing silica rage, supplanting flotsam and jetsam with silica smolder, somewhat supplanting totals with garbage of 10% and supplanting trash with 20% along the steel fiber is threw. While throwing legitimate blending and less water substance is utilized as a part of specific.

The casting system is same for the all blend extents and it is important to apply oil before throwing.

Compacting - Normally standard cement requires more compaction where great compaction will bring about great quality angle though in pervious the whole cement is took into account less compaction as over compaction will diminish the porousness of water stream level.

Curing - Curing is took into consideration three diverse days and according to standard curing for 7 days,14 days, and 28 days is permitted according to IS method. The test results are acquired for nowadays and results demonstrates a significant increment in the quality in 14 and 28 days contrasting with 7 day quality outcome where 28 days curing is recommended for the great quality level.

V. TEST ON HARDENED CONCRETE

A. **Compressive strength test**

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc.

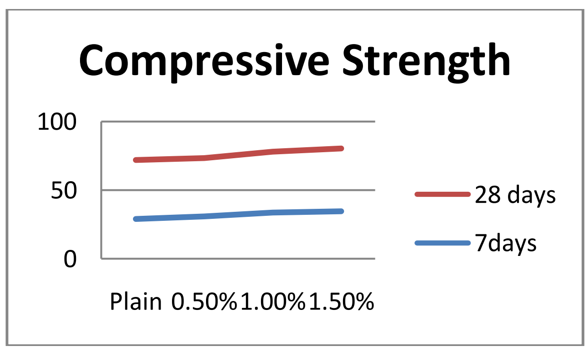
For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used.

The compressive strength is calculated by using the formula.

$$\text{Compressive strength} = \frac{\textbf{load (P)}}{\textbf{area(A)}}$$

Where,
P - load is in KN
A - Area of cube in mm^2.

Sample	Days	Compressive Strength			
		0%	**0.5%**	**1%**	**1.5%**
1	7	25.1	33.1	34.2	34.5
	28	42.8	49.3	51.3	53.3
2	7	27.5	35.3	36.1	36.6
	28	44.2	50.8	52.8	53.7
3	7	30.5	36.7	36.8	36.9
	28	46.4	48.8	51.5	55.11



B. Spilt tensile strength test

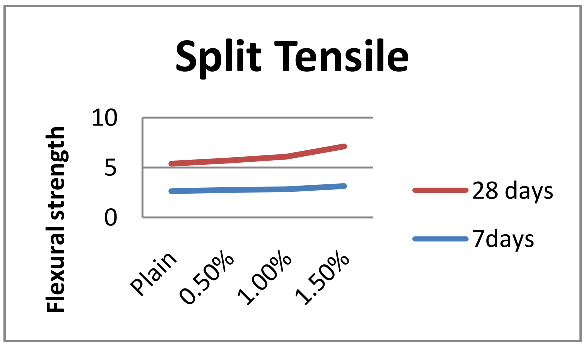
The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The tensile strength of the specimen is calculated using the mentioned formula.

$$\text{Split Tensile Strength} = \frac{2P}{\pi\, DL}$$

Where ,

P = compressive load on the cylinder,
L = Length of the cylinder,
D = Diameter of the cylinder.

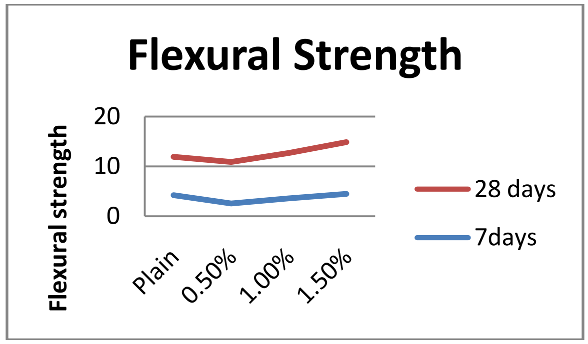
Sample	Days	Split Tensile Strength			
		0%	0.5%	1%	1.5%
1	7	2.6	2.7	3.0	3.3
	28	2.8	2.9	3.9	4.2
2	7	2.6	2.7	2.9	3.1
	28	3.1	3.4	3.5	4.1
3	7	2.8	3.0	2.9	3.3
	28	3.2	3.2	3.5	4.3



C. Flexural Test

Concrete beams of size 100*100*500 mm were cast for M40 grade of concrete. The plain concrete, 0.5%,1%,1.5% of fibres used concrete were tested for 7 and 28 days flexural strength. The results are given in flowchart. The flexural strength of concrete is compared.

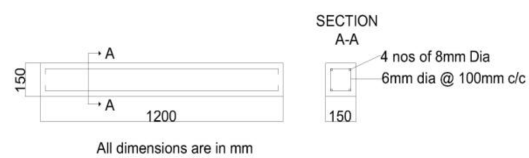
Sample	Days	Flexural Strength			
		0%	0.5%	1%	1.5%
	7	5.12	5.8	6.3	7.1
1	28	7.2	8.0	8.8	9.6
	7	5.5	6.3	7.0	7.3
2	28	7.4	8.5	8.8	9.8
	7	5.6	6.4	7.1	7.5
3	28	7.4	8.4	9.2	9.9



VI. EXPERIMENTAL ANALYSIS

A. Dimensions of beams

The beam mould was prepared by standard steel mould having cross section. It is used for casting the beams with and without fibers. Hence the size of the beam is of 150 x 150 x 1200mm.All the beams were cast with following reinforcement details. Four bars of 8mm diameter are used as main reinforcement 2 numbers at top and 2 numbers at bottom, 6mm diameter stirrups are spaced at 100mm c/c to act as shear reinforcement. The reinforcement details for the beam specimens shown in fig



B. Casting of specimen

The exact quantities of materials for the specimen were weighted and kept separately before the mixing started. Machine mixing was adopted and the concrete mix was placed in mould layer by layer and compacted well. Hand mixing was adopted for convenient handling of steel fibre. Sand and cement with silica fume were mixed dry and kept separately. Then coarse aggregate was added and approximately quantity of water was sprinkled on the dry mix. In order to avoid the formation of lumps by gentle sprinkling the fibres were randomly oriented in the concrete mix. Beams casted with fully hybrid fibres and fibres only in hinged zone for flexural strength of plain concrete with and without fibres. Fig shows the casting of beams.

C. Experimental program testing specimens :

Test specimens consist of four conventional HPC beams with two different reinforcement with 10mm diameter main reinforcement and 8mm diameter as stirrups and 8mm diameter as main reinforcement and 6mm diameter as stirrups. Then the five SFRC beams are casted with one conventional beam and four SFRC containing0.8% hybrid steel fibers by volume of concrete. The cross sectional dimensions and span of beams were fixed same for all types of beams. The dimensions of the beams were 150mm x 150mm x 1200mm. Two types of SFRC beams specimens were cast using hybrid steel fibers for full length of beams with volume fractions of 15% with the described reinforcements. The ultimate tensile strength of steel fibers was 584.59 MPa. The aspect ratio of all fibers was kept constant at 60. The reinforced concrete beams were designated as C and the two types of steel fiber reinforced beams were designated as FH and FHZ respectively.

D. Preparation of test specimens

For the preparation of specimens the concrete mix proportion was adopted was 1:1.2:2.2 by weight (cement: sand: coarse aggregate) with water cement ratio of 0.4. The concrete mix was designed to achieve strength of 40 MPa. A suitable dose of admixture named cera-hipher plasticizer and silica fume was added in mixes to improve the workability of mixes. For casting of beams steel moulds were used. Beams were filled in 4-5 layers, each of approximately 50mm deep, ramming heavily and vibrating the specimens on vibrating table till slurry appears at surface of the specimen. In this way concrete was very well compacted. The side forms of moulds were stripped after 24 hours and then these beams were cured for 28 days in curing pond specially constructed for the investigation.

E. Loading arrangement :

All beam specimens were tested under a loading frame of 1000 kN capacity. Beams were continuous over a span of 1200 mm. The load was applied through a screw jack which is connected with proving ring for applying manual loading. The load was distributed as two point loads kept apart symmetrical to centerline of beam on the top face. An I section has been place over the beam for the application of two point loading. Then three dial gauge on the loading point for normal deflection and dial three will be used to measure upward deflection. A proving ring of 1000 Ton capacity was placed between test frame and load distributor placed on the test specimen. Gap between test frame and plate was filled by spacers. Loading arrangement for beam specimens is shown in Fig

VII. RESULTS AND DISCUSSION

A. General

The structural behavior of HPFRC beam has been studied in this project. Two types of beam namely HPC and HPFRC beams has been cast and tested under monotonic loading. Six conventional concrete beams are cast as high performance concrete and HPFRC beams were cast namely with fully hybrid fibres and fibre only in hinged zone and beam without fibres respectively. In hybrid fibre reinforced concrete beam, the specimen is incorporated with hooked end and crimped fibres in the mix proportion of 70%-30% by volume at a total volume fraction of

1.5%. Then the eight beams are subjected to monotonic loading and eight beams are subjected to monotonic loading with the help of screw jack and the deflection is measured by using deflectometer. After testing, various parameters such as energy absorption, cumulative ductility, first crack load and ultimate load are compared with that of conventional concrete beam.

B. Behaviour of continuous beam under monotonic loading

There are six numbers of continuous beams were cast and tested. Two beam is made with conventional concrete, Two is made with fully fibre and other two is made by adding fibres only in hinged zones. The beams were designated as follows for easy reference and presentations of the test result. Continuous beam with conventional concrete with 8mm diameter main reinforcement and 6mm diameter stirrups with BEAM- A&B.

Continuous beam with conventional concrete – CB

Continuous beams with two numbers of fully Hybrid fibre (1.5% Vf) – FH

Continous beam with two numbers of fibres in hinged zones only (1.5%Vf) – FHZ

C. Results and Discussion:

Totally six specimens have been tested for their behaviour under monotonic loading. In order to study the influence of fibres. The test results are discussed as below. The different parameters such load carrying capacity, stiffness, ductility, energy absorption capacity etc. have been calculated for all beams are shown in Table.1 and 2.

Table.1 Test results

S. No	Parameter	Beam	
		A	B
1	% of fibre (Vf)	0	0
2	First crack load (kN)	21	19.5
3	Ultimate load (kN)	58	60
4	Ultimate Deflection (mm)	10.1	9.9
5	Stiffness (kN/mm)	45	43
6	Ductility Factor	4.6	4.7
7	Energy Absorbtion (kN mm)	410	430

D. Load Carrying Capacity:

The ultimate load carrying capacities of all the beams are shown in figure 4.6.1 and figure 4.6.2. The load carrying capacity of FH beam with fully hybrid fibres behaves more resistance than the beam having fibres only in hinged zone. The conventional concrete beam without fibre will only carries minimum load carrying capacity compare to both fully hybrid fibre beams and beams with fibres only in hinged zone. The ultimate crack load of FH beam was higher than that of FHZ beam. First crack load increased with increase in fibre content. The beam FH carries maximum ultimate load of 75kN. Theoretical ultimate load for RC beams was calculated as per IS 456: 2000. The beam strength of control specimens were used to determine the ultimate load, stiffness, ductility, energy absorption and toughness index of RC beams tested under monotonic loading.

E. First Crack load:

The first crack load was determined from the dominant in the load deflection curve at initial stages of loading. All the SFRC beams showed significant increase in first crack load over reinforced concrete beams. In the case of beams with 1.5 percent steel fibres. The conventional concrete beam without fiber will only carries minimum load carrying capacity compare to both fully hybrid fiber beams and beams with fibers only in hinged zone. The first crack load of FH beam was higher than that of FHZ beam. First crack load increased with increase in fibre content. The beam FH carries maximum First crack load of 28kN

S.No	Parameter	Beam			
		FHZ1	FHZ2	FH1	FH2
1	% of fibre (Vf)	1.5	1.5	1.5	1.5
2	First crack load (kN)	25	26.5	27.2	28.7
3	Ultimate load (kN)	70.11	68.25	73.25	75.11
4	Ultimate Deflection (mm)	11.9	12.4	13.6	13.9
5	Stiffness (kN/mm)	67	65	67	69
6	Ductility Factor	6.5	6.75	7.3	7.1
7	Energy Absorbtion (kN mm)	560	530	590	630

Table.2 Test Results

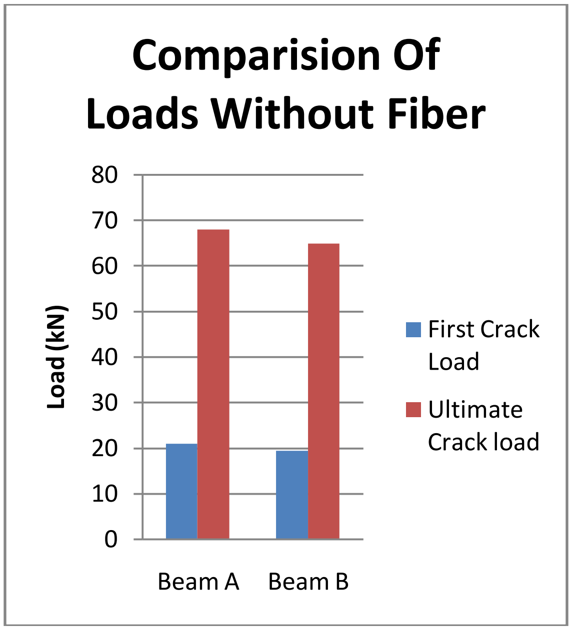


Fig. First crack load and Ultimate load for without fiber

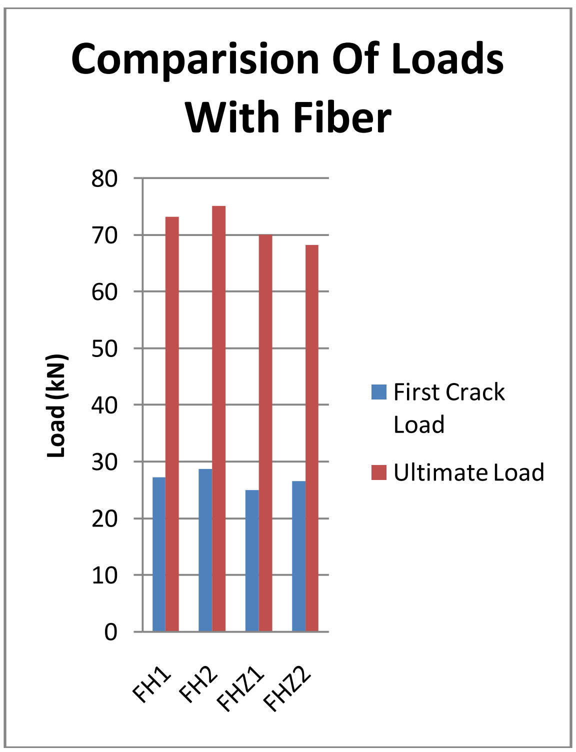


Fig. First crack load and Ultimate load with fiber

F. Load deflection behavior

These investigations it is observed that the load deflection curve is linear up to the first crack load. Further increase in load, caused multiple cracks and the curve deviated from linearity in to a non-linear region. From the Beam-B which carries minimum load carrying capacity. From the comparisons the Beam FH(with fully hybrid fibres) carries a maximum load 75 kN. Then the specimen two of FH will carries 73 kN. Then this beams behave flexural cracks only. Then the other type of beam with fibers in hinged zone will carry load of 70 KN for specimen one and 68 KN for specimen two respectively. This beam also behaves only in flexural zone. These beams are compared to the conventional beam which carries 68kN & 65KN which behaves only in flexural zone. From the investigations all these beams behaves only in flexure no shear cracks are occurred in any of these beams.

G. Stiffness characteristics:

Stiffness is defined as the load required to cause unit deflection of the beam. The Deflection calculated in each beams gave the stiffness of the beam. The 1.5% volume fraction of fibers in HPFRC increased the stiffness of the beams. The beam are casted in two different forms one with fully hybrid fiber and fibers only in hinged zone as FH and FHZ. Each beams to calculate the deflection from continuous beams. From the values stiffness has been calculated. The stiffness of beam FHZ specimen one will be having more similar stiffness value. The specimen two of FHZ carries a maximum stiffness values in both dial one and dial two. The various of stiffness characteristics for all the beams are shown in figure.. The beams FH and FHZ are almost similar in stiffness characteristic with 67kN/mm with FHZ slightly more consistent than FH based on stiffness characteristics.

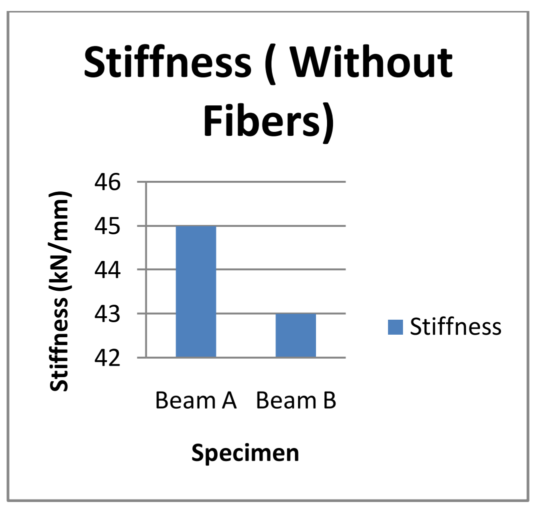


Fig. Comparison of Stiffness characteristics for all the beams WOF

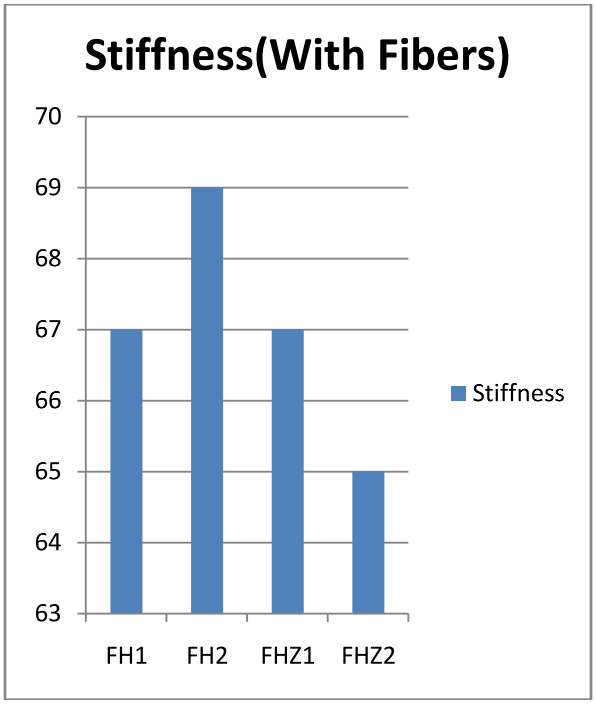
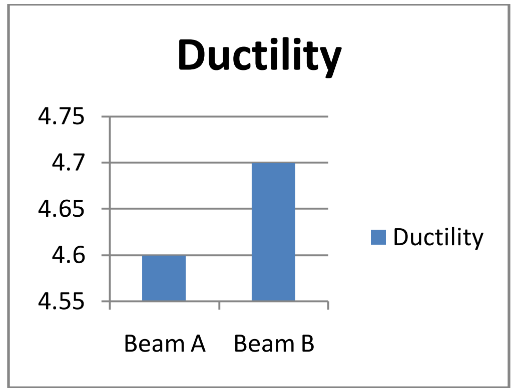


Fig. Comparison of Stiffness characteristics for all the beams WF

H. Ductility Factor:

It is defined as the ability of a member undergoes inelastic deformations beyond the yield deformations without significant loss in its load carrying capacity. The 1.5% volume fraction of fibres in HPFRC increased the ductility of the beams. The ductility of beam FH specimen two will be have a maximum at dial two values. At the same FHZ specimens has both dial one and two are almost equal. The specimen one of FHZ carries a minimum of ductility in both dials. The specimen two of FHZ is also minimum ductility. The various of ductility for all the beams are shown. The beams FH are comparatively higher than FHZ. The beam FH has a maximum of 7. The ductility of a flexural member can be obtained from its load-deflection curve. The variations of ductility of all the five beams are shown in figure5.8.1 & 5.8.2.



FigComparison of Ductility for all the beams WOF

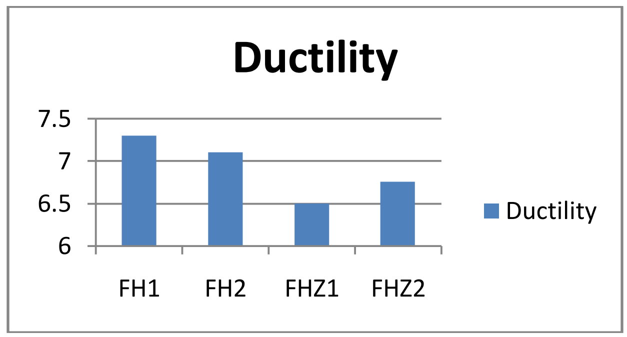


Fig. Comparison of Cumulative Ductility for all the beams WF

I. Energy absorption capacity:

The area under the load-deflection curve represents the energy absorption capacity of the all specimen. The beam are casted in two different forms one with fully hybrid fiber and fibers only in hinged zone as FH and FHZ. The energy absorption of beam FH specimen one will be have a maximum at both dial values. The cumulative energy absorption capacity of FH beam was 630kNmm while that of FZH and CB beams have the values as 530kNmm, 450 kNmm respectively. The cumulative energy absorption capacity of FH (hybrid) beam was higher than that of other beams as shown in figure.5.10.1

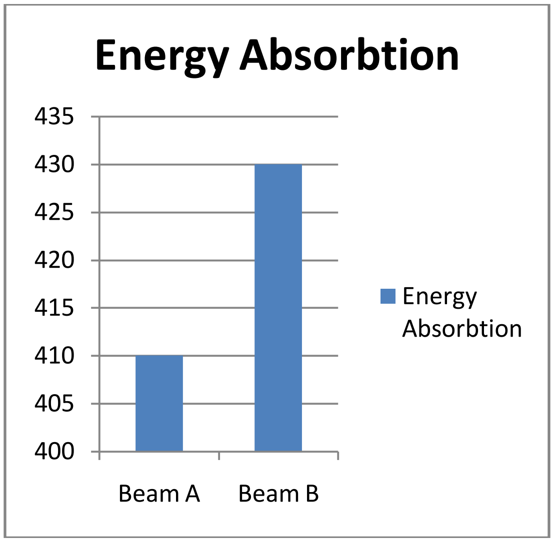


Fig. 1 Comparison Energy absorption capacity for all the beams WOF

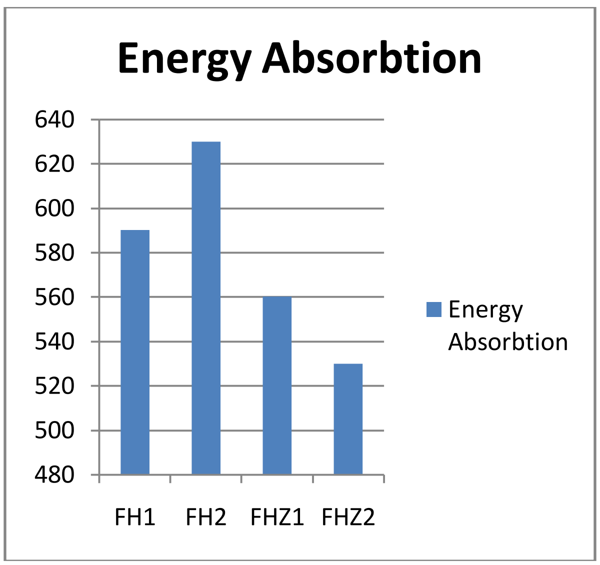


Fig. Comparison Energy absorption capacity for all the beams WF

J. **Behaviour and mode of failure**

The loading was increased in all the specimens, the number of cracks appeared in the beam. Further increasing the load, additional cracks formed in the beams. It is observed that, specimens additionally reinforced with steel fibres, a large number of finer cracks formed in the flexure zone and widening when the load increased. The presence of steel fibre inside the beam will resist the crack development by forming a bridge across the crack i.e. the steel fibres act as crack arresting material during initial stage of loading. The tested specimens of HPC and HPSFRC beams were shown in figure.8.

Fig Failure pattern for all the beams

VIII. CONCLUSION

The experimental investigation is carried out to study the behavior of High Performance Fibre Reinforced Concrete Beam. The test results are compared with that of the Conventional high performance reinforced concrete beam. It based on study parameters such as first crack load, ultimate load, ductility factor and energy absorption, we compare all the beams with that of conventional concrete beam.

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