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EXPERIMENTAL STUDY ON FLEXURAL BEHAVIOR OF HIGH-PERFORMANCE FIBER-REINFORCED CONCRETE

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Abstract : 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 the same for all types of beams. The dimensions of the beams were 80mm x 120mm x 2200mm. 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 RC beams. 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.

***IndexTerms* - Steel fiber reinforced concrete (SFRC), beams, ultimate loads.**

I. INTRODUCTION

Concrete is structural components that 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 compressive forces, moreover, it's a workable and durable material, that can be formed in any shape, also it's a cheap material. At the same time, it requires 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, a 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 into a modern structural material with high potential. At this moment studies are carried out to come to an international recommendation for the design of structures with HPFRC. The results obtained were focused on the same as before also a comparison of the first cracking load, ultimate load, work done in the linear and nonlinear region, and load-deflection nature between these different reinforcement ratios of the analytical beam. An experimental program was conducted to study the flexural behavior and redistribution in a 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, tsunamis, etc., destroy high-rise buildings, bridges, monumental structures, world wonders, etc. To protect the world from that kind of devastation, the field of civil engineering requires 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 the 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, the 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 labor 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.

1.2 PROPERTIES AND BEHAVIOR OF CONCRETE

The Properties and strength development of concrete depend upon the characteristics of the hardened cement paste, aggregates, and interface transition zone between the hardened cement paste and aggregates. It is a fact that the strength of the hardening cement paste depends on the degree of porosity. The smaller the pore ratio, the greater the strength; this can be achieved by reducing the water-cement ratio which increases the amount of hydrate generated during the hydration process.

The concrete used in the mixture is of a usual type, although the proportions should be varied to obtain good workability and take full advantage of the fibers. This may require limiting the aggregate size, optimizing the gradation, increasing the cement content, and perhaps adding fly ash or other admixtures to improve workability. The fibers may take many shapes. Their cross sections include circular, rectangular, half-round, and irregular or varying cross sections. They may be straight or bent, and come in various lengths. A convenient numerical parameter called the aspect ratio is used to describe the geometry. This aspect ratio is the fiber length divided by the diameter. If the cross-section is not round, then the diameter of a circular section with the same area is used.

There is a reduction in the total pore volume of concrete with the increase in the amount of hydrates. The proportions of hydrates can be increased by the use of high early-strength cement or silica fume. Mineral additives with ultrafine particles are also used in HPC. Silica fume, blast furnace slag or fly ash, and meta-kaolin are the commonly used mineral admixtures in the production of high-performance concrete. The amount of hydrates in concrete mainly depends on the curing condition and its time. The strength at the interface between aggregates and cement paste plays an important role in the development of the strength. The replacement of the cement by silica fume can increase the strength remarkably. This is attributed to calcium silicate hydrates generated by ultra-fine particles. Silica fumes and calcium hydroxide around the aggregates improve the bond between the aggregates and the cement matrix.

1.3 HIGH-PERFORMANCE CONCRETE

High-performance concrete has more uniform and also homogeneous microstructures than that of normal concrete. When silica fume is mixed with ordinary Portland cement low water-cement ratio microstructure of such mixture has mainly crystalline hydrants, forming a dense matrix of low porosity. As the content of the silica fume is increased in concrete, a major part of calcium hydroxide is transformed into calcium silicate hydrates while the left-over calcium hydroxide tends to form 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 cooperation 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, long life in severe environments Low permeability and diffusion Resistance to chemical attack high resistance to frost, and deicer scaling damage Toughness and impact resistance.

1.4 DEVELOPMENT OF FIBER REINFORCED CONCRETE

Fiber Reinforced Concrete is a concrete mix that contains short, discrete fibers that are uniformly distributed and randomly oriented. Fibers used are steel fibers, synthetic fibers, glass fibers, and natural fibers. The main function of the fibers in members is that of resisting the opening of the cracks due to micro cracking, increasing the ability of the member to withstand loads.

The characteristic of fiber-reinforced concrete is changed by the alteration of quantities of concrete, fiber substances, geometric configuration, dispersal, direction, and concentration. It is a special type of concrete in which a cement-based matrix is reinforced with an ordered or random distribution of fiber. The addition of fibers to conventional concrete is varying from 1-2% by volume depending on the geometry of fibers and the type of application. The inclusion of steel fibers in concrete is to delay and control the tensile cracking of composite material.

Steel fiber reinforcement thus transfers an inherent unstable tensile crack propagation to slow controlled crack growth. This crack-controlling property of fiber reinforcement delays the onset of flexure and shear cracking. It imparts extensive post-cracking behavior and significantly enhances the ductility and energy absorption capacity of the composite. This composite consists of one or more phases that are discontinuous and embedded in a continuous phase. Discontinuous phase is usually harder and stronger than the continuous phase and is called reinforcement or reinforcing material. The continuous phase is known as the matrix.

1.5 HYBRID FIBER REINFORCED CONCRETE

Hybrid Fiber Reinforced Concrete can be produced by suitably combining different types of fibers. The use of an optimized combination of two or more types of fibers in the same concrete mixture can produce a composite with better engineering properties than that of individual fibers. It improves impact resistance fatigue endurance and shear strength. HFRC increases crack resistance, ductility, energy absorption, or toughness. It increases the ultimate load-carrying capacity and provides uniform multi-directional reinforcement in concrete.

1.6 NECESSITIES OF SFRC:

Improve mix cohesion, improving pumpability over long distances Improve freeze-thaw resistance and also Improve resistance to explosive spalling in case of a severe fire Improve impact resistance to plastic shrinkage during curing and improve structural strength Reduce steel reinforcement requirements Improve ductility Reduce crack widths and control the crack widths tightly thus improve durability Improve impact & abrasion resistance Improve freeze-thaw resistance. Both concrete often used in the construction of crimped and steel fibers combine the benefits of both products; structural improvements provided by steel fibers and the resistance to explosive spalling and plastic shrinkage improvements provided by polymeric fibers. In certain specific circumstances, steel fiber can entirely replace traditional steel reinforcement bars in reinforced concrete. There are increasing numbers of tunneling projects using precast lining segments reinforced only with steel fibers.

1.7 NEED FOR THE PRESENT STUDY

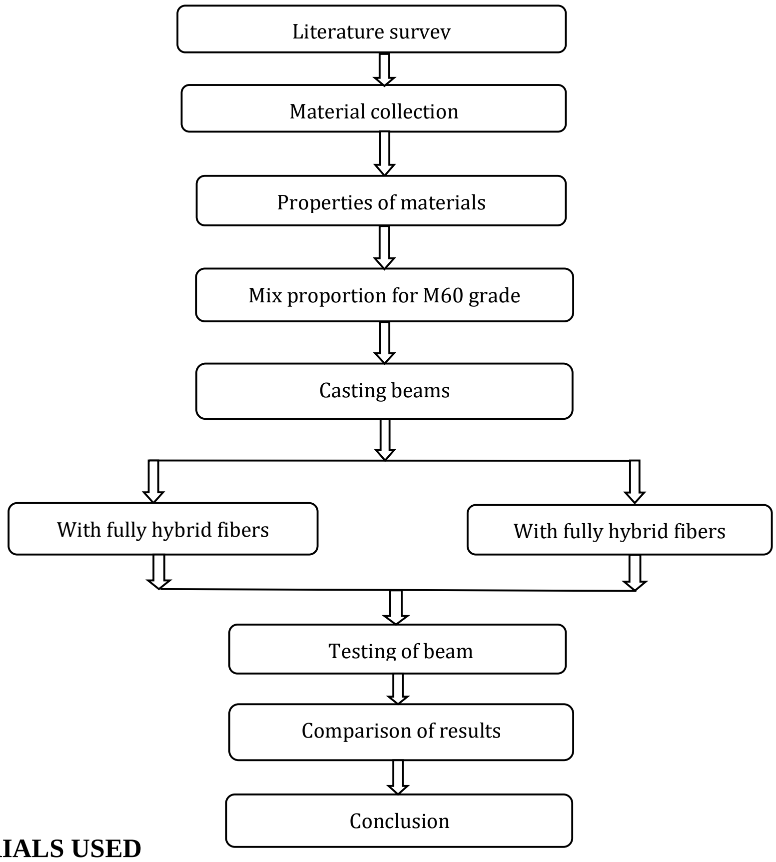
Nowadays natural disaster such as earthquakes, wind forces, etc. plays an important role in the construction industry. So, buildings and other construction work should be designed in a good manner, which resists higher loads and seismic forces. Ductility and energy absorption capacity are the main requirements of the earthquake-resistant structure. Fiber-reinforced concrete possesses high strength, improved ductility, and enhanced energy absorption capacity. So, a study on the flexural behavior of beams with fibers under monotonic loading is needed.

1.8 SCOPE & OBJECTIVE

Concrete is weak in tension and micro-cracks are developed in conventional reinforced concrete. To avoid the propagation of micro-cracks in RCC, fibers are added as secondary reinforcement and it also improves the mechanical properties of concrete. The influences of hybrid fibers in conventional RCC will be studied in this project. The beams with fibers and without fibers are to be tested under monotonic loading, to study the behavior of FRC beams in the ultimate and post-ultimate region.

To study the influence of shapes and geometry of the fiber by experimenting. To get the optimum fiber content for each type of fiber. To study the influence of hybrid fiber in HPFRC. To study the load-deformation behavior of RC beams with hybrid fibers as secondary reinforcement. To determine the moment carrying capacity, ductility, and energy characteristic of RC beam. To compare the behavior of RC beams with and without fiber.

II. METHODOLOGY



III. MATERIALS USED

PPC cement of 53 grade is used for this experiment study. The cement has a specific gravity of 3.1 Silica fume is a byproduct in the Silicon and ferrosilicon industry was used as a mineral admixture in concrete mixes. It contains a large proportion of silicon-di-oxide (sio_2) which is about 90%of silica fume constituents. The fineness in silica fume in terms of specific surface area is around 20000cm^2/g. Silica fume consists of ultra-fine (<1um) particles and increases the bond strength between cement paste and aggregate by making the interfacial zone denser.

Aggregates are the major ingredients of concrete. It acts as an economical space filler. The IS 383 specifies the requirements of aggregate. They are inert and are broadly divided into two categories i.e., fine and coarse aggregate depending on their size. The crushed rock is used as coarse aggregate with a specific gravity of 2.66 and Zone II River sand is preferred for fine aggregate.

Coarse aggregate shall consist of clean, hard, strong, dense, non-porous, and durable pieces of crushed stone. They shall not consist of pieces of disintegrated stones, soft, flaky, elongated particles, salt, alkali, vegetable matter, or other deleterious materials. The crushed stone aggregate of the maximum size of 12.5mm is used as coarse aggregate. Thus, have a specific gravity value of 2.7 and a fineness modulus of about 7. Fine aggregates shall not contain dust, lumps, soft or flaky materials, mica, or other deleterious materials. Fine aggregates, having positive alkali-silica reaction shall not be used. The fineness modulus of fine aggregate shall neither be less than 2.0 nor greater than 3.5

3.2 CRIMPED FIBER

The length of the fiber is 38 mm. The aspect ratio is 69.09). The diameter of the crimped fiber is 0.55mm. The tensile strength is 600. The Material type of crimped fiber is low carbon drawn flat wire. The crimped fiber is shown in the Fig 3.2. Portable water available in the laboratory is used for mixing and curing concrete. cero hyper plats a type of plasterer is used to increase the workability of concrete. It is a high-range super plasticizing admixture. A dosage of 0.8 % by weight of binder is used for all the mixes. Steel of Fe415 grade with 2 nos of 8mm diameter bar provided at both top and bottom. 6mm diameter tor steel bars were used for stirrups.

Fig 3.2 Crimped Fiber

3.3 MIX PROPORTIONING

M60 grade concrete mix was designed as per IS 10262-2009. The proportion of concrete should be selected to make the most economical use of available materials to produce concrete of the required quality. The mix ratio for casting the specimen used is 1:1.2:2.2 and water water-cement ratio 0.3. Volume fractions of 1.5% fibers are used. Also, 10 % of cement is replaced by silica fume intended to make HPC 70% end fiber combined with 30 % crimped fiber mixed in the required quantity of fibers.

3.4 DIMENSIONS AND REINFORCEMENT DETAILS

The beam mold was prepared by standard steel mold having a cross-section. It is used for casting the beams with and without fibers. Hence the size of the beam is 80 x 120 x 2200mm. All the beams were cast with following reinforcement details. Four bars of 8mm diameter are used as main reinforcement 2 numbers at the top and 2 numbers at the 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 3.3 & 3.4

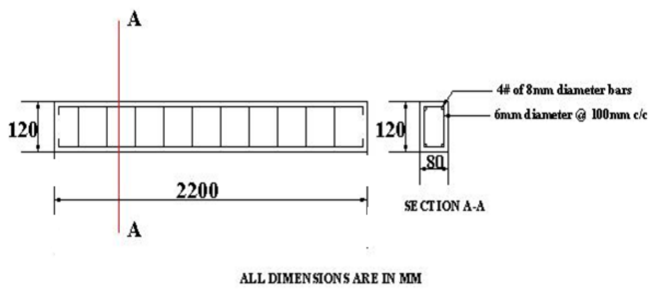


Fig 3.3 Reinforcement details.

Fig 3.4 Reinforcement details.

3.5 CASTING OF THE 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 the mold layer by layer and compacted well. Hand mixing was adopted for the convenient handling of steel fiber. Sand and cement with silica fume were mixed dry and kept separately. Then coarse aggregate was added and approximately a quantity of water was sprinkled on the dry mix. To avoid the formation of lumps by gentle sprinkling the fibers were randomly oriented in the concrete mix. Beams cast with fully hybrid fibers and fibers only in the hinged zone for flexural strength of plain concrete with and without fibers. Fig 3.4 shows the casting of beams.

FIGURE 3.4 CASTING OF BEAMS

3.6 EXPERIMENTAL PROGRAM TEST SPECIMENS

Test specimens consist of four conventional HPC beams with two different reinforcements with 10mm diameter main reinforcement 8mm diameter as stirrups and 8mm diameter as main reinforcement and 6mm diameter as stirrups. Then the five SFRC beams are cast with one conventional beam and four SFRC containing 0.8% hybrid steel fibers by volume of concrete. The cross-sectional dimensions and span of beams were fixed the same for all types of beams. The dimensions of the beams were 80mm x 120mm x 2200mm. Two types of SFRC beam specimens were cast using hybrid steel fibers for full-length of beams with volume fractions of 1.5% 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 75. The reinforced concrete beams were designated as C and the two types of steel fiber reinforced beams were designated as FH and FHZ respectively.

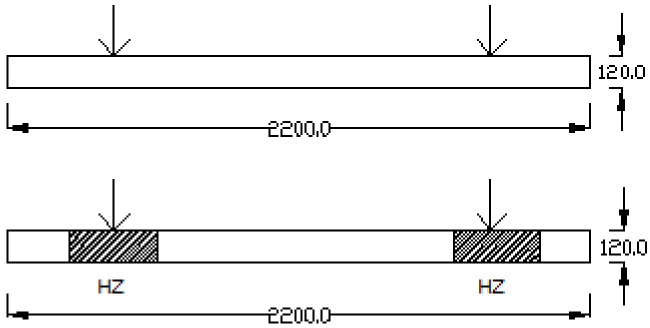


Fig.3.6. Experimental specimen set up

3.7 PREPARATION OF TEST SPECIMENS:

For the preparation of specimens, the concrete mix proportion adopted was 1:1.2:2.2 by weight (cement: sand: coarse aggregate) with water cement ratio of 0.3. The concrete mix was designed to achieve strength of 60 MPa. A suitable dose of admixture named cerahipher plasticizer and silica fume was added in mixes to improve the workability of mixes. For casting of beams steel mould were used. Beams were filled in 4-5 layers, each approximately 50mm deep, ramming heavily and vibrating the specimens on a vibrating table till slurry appeared at the surface of the specimen. In this way, concrete was very well compacted. The side forms of mold were stripped after 24 hours and then these beams were cured for 28 days in a curing pond specially constructed for the investigation.

3.8 LOADING ARRANGEMENT

All beam specimens were tested under a loading frame of 500 KN capacity. Beams were continuous over a span of 2200 mm. The load was applied through a screw jack which is connected to the proving ring for applying manual loading. The load was distributed as two-point loads kept apart symmetrical to the centerline of the 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 10 Ton capacity was placed between the test frame and load distributor placed on the test specimen. The gap between test frame and plate was filled by spacers. Loading arrangement for beam specimens is shown in Fig.2

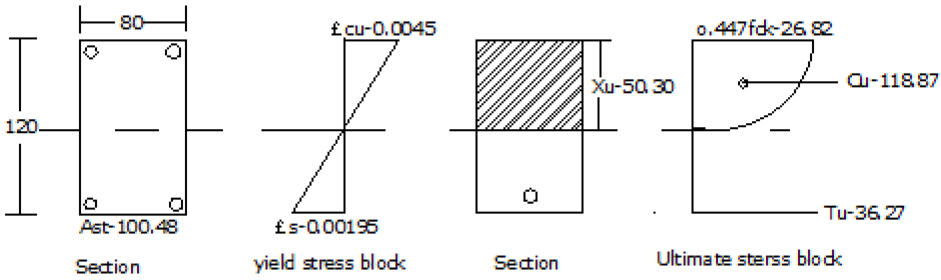
Fig.3.5. Experimental set up

IV. RESULTS & DISCUSSION

The structural behavior of HPFRC beam has been studied in this project. Two types of beams namely HPC and HPFRC beams have been cast and tested under monotonic loading. Four conventional concrete beams are cast as high-performance concrete and in HPFRC beams were cast namely with fully hybrid fibers and fiber only in hinged zone and beam without fibers respectively. In a hybrid fiber-reinforced concrete beam, the specimen is incorporated with crimped fibers 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 a screw jack and the deflection is measured by using a deflectometer. After testing, various parameters such as energy absorption, cumulative ductility, first crack load, and ultimate load are compared with that of a conventional concrete beam.

4.2 BEHAVIOR OF CONTINUOUS BEAM UNDER MONOTONIC LOADING

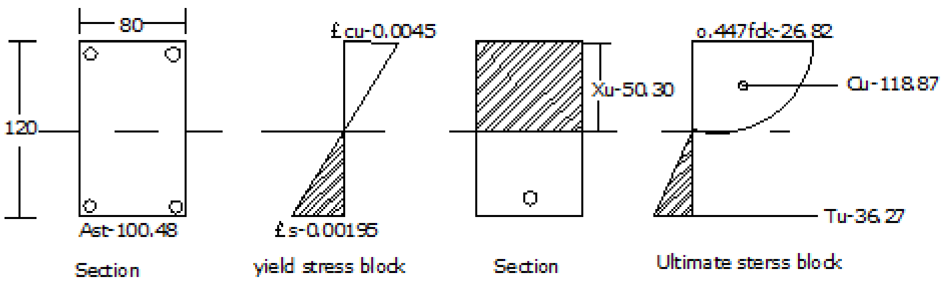
There are nine numbers of continuous beams were cast and tested. Five beams are made with conventional concrete, two is made with full fiber, and the other two are made by adding fibers only in hinged zones. The beams were designated as follows for easy reference and presentations of the test result. Continuous beam with conventional concrete with 8mm diameter main reinforcement and 6mm diameter stirrups with curtailment BEAM- A



Continuous beam with conventional concrete with 10mm diameter main reinforcement and 8mm diameter stirrups with curtailment BEAM- B. Continuous beam with conventional concrete with 10mm diameter main reinforcement and 8mm diameter stirrups without curtailment BEAM-C. Continuous beam with conventional concrete with 8mm diameter main reinforcement and 6mm diameter stirrups without curtailment BEAM- D. Continuous beam with conventional concrete – CB Continuous beams with two numbers of fully Hybrid fiber (1.5% Vf) – FH. Continuous beam with two numbers of fibers in hinged zones only (1.5%Vf) – FHZ Continuous beam with Hybrid fiber (+30% Crimped)

4.3 STRESS BLOCK:

The stress blocks determine the area of steel in tension and compression also used to determine the proper dimensions in the section with the compression and tension that are applied in both the form of with and without fibers for both steel and concrete.



4.3 Stress block with fiber

4.4 Results and Discussion:

Totally nine specimens have been tested for their behavior under monotonic loading. To study the influence of fibers. The test results are discussed below.

The different parameters such as load carrying capacity, stiffness, ductility, energy absorption capacity, toughness index, etc. have been calculated for all beams re shown in Tables 1 and 2.

Parameter		BEAM			
		A	B	C	D
% Of fiber (Vf)		1.5	1.5	1.5	1.5
First crack load (KN)		75	78	84	84
Ultimate load (KN)		90	129	123	90
Stiffness (KN/mm)		66.67	100	100	66.67
Ductility factor		6.8	6	4.09	4.28
Energy Absorption (KN.mm)	Absolute	870	840	640	720
	Reality	1	0.96	0.73	0.94
Toughness Index (I5)		5.1	6	6.28	4.28
Toughness Index (I10)		10.4	13.44	14.55	11.9

Table 1 Test results

Parameter		BEAM				
		FH1	FH2	FHZ1	FHZ2	CB
% Of fiber (Vf)		1.5	1.5	1.5	1.5	1.5
First crack load (KN)		75	57	55	60	39
Ultimate load (KN)		120	117	93	117	114
Stiffness (KN/mm)		66.6	57.5	66.67	66.67	50
Ductility factor		5.46	7	5.46	6.156	4.85
Energy Absorption (KN.mm)	Absolute	610	650	620	675	570
	Reality	1.24	1.22	1.08	1.24	1
Toughness Index (I5)		7.5	7.5	7.71	7.21	5.26
Toughness Index (I10)		13.75	13.45	14.375	13.87	10.24

Table 2 Test results

4.5 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 Beam-A carries maximum load and Beam-D carries minimum load-carrying capacity initially to choose the reinforcement. The load-carrying capacity of the FH beam with fully hybrid fibers behaves with more resistance than the beam having fibers only in the hinged zone. The conventional concrete beam without fiber will only carry minimum load-carrying capacity compared to both fully hybrid fiber beams and beams with fibers only in the hinged zone. The ultimate crack load of the FH beam was higher than that of the FHZ beam. The first crack load increased with increase in fiber content. The beam FH carries a maximum ultimate load of 120kN. The theoretical ultimate load for RC beams was calculated as per IS 456: 2000. The beam strength of control specimens was used to determine the ultimate load, stiffness, ductility, energy absorption, and toughness index of RC beams tested under monotonic loading.

4.6 First Crack load:

The first crack load was determined from the dominant in the load-deflection curve at the 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 fibers, the conventional concrete beam without fiber will only carry minimum load-carrying capacity compare to both fully hybrid fiber beams and beams with fibers only in hinged zone. The first crack load of the FH beam was higher than that of the FHZ beam. First crack load increased with increase in fiber content. The beam FH carries a maximum First crack load of 75kN

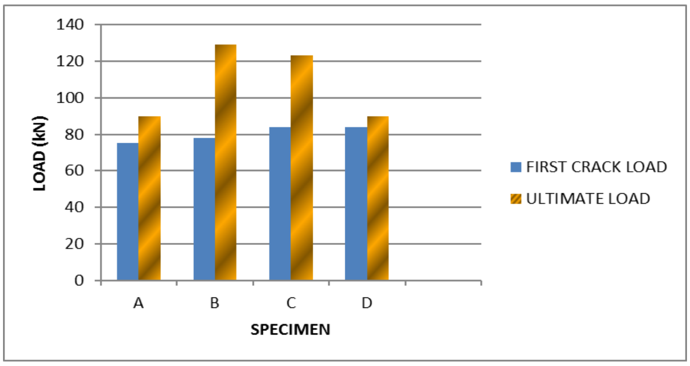


Fig.4.6.1 First crack load and Ultimate load for without fiber

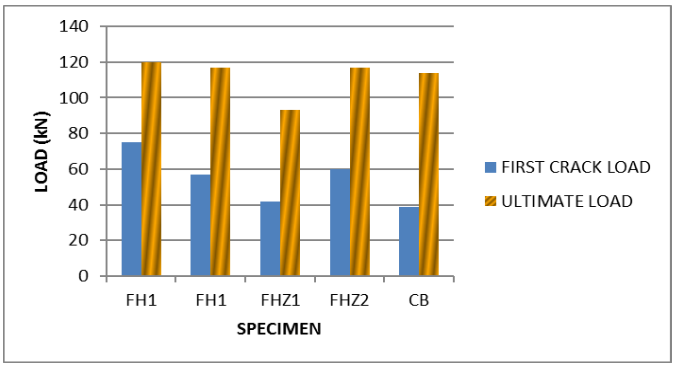


Fig.4.6.2 First crack load and Ultimate load for with and without fiber

4.7 Load deflection behavior

In 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 into a non-linear region. Comparisons of load-deflection behavior for all the beams are shown in fig4.7.1, fig4.7.2, fig4.7.3, fig4.7.4. From the Beam-D which carries minimum load carrying capacity. From the comparisons, the Beam FH (with fully hybrid fibers) carries a maximum load 120 KN.

Then specimen two of FH will carry 117 KN. Then these beams behave flexural cracks only. Then the other type of beam with fibers in the hinged zone will carry the load of 93 KN for specimen one and 117 KN for specimen two respectively. This beam also behaves only in the flexural zone. These beams are compared to the conventional beam which carries 114 KN and behaves only in flexural zone. From the investigations all these beams behave only in flexure no shear cracks occurred in any of these beams.

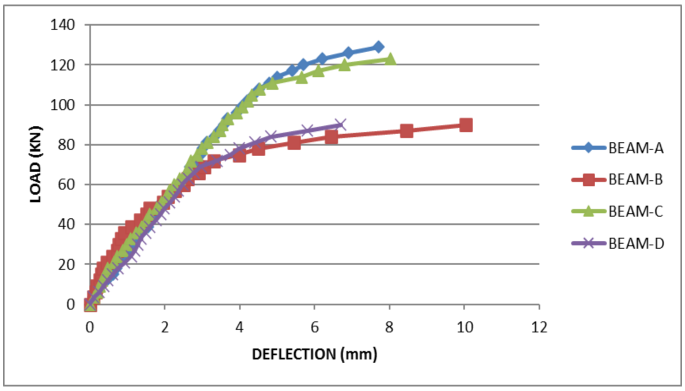


Fig.4.7.1 Comparison of Load deflection behavior for D1of all the beams WOF

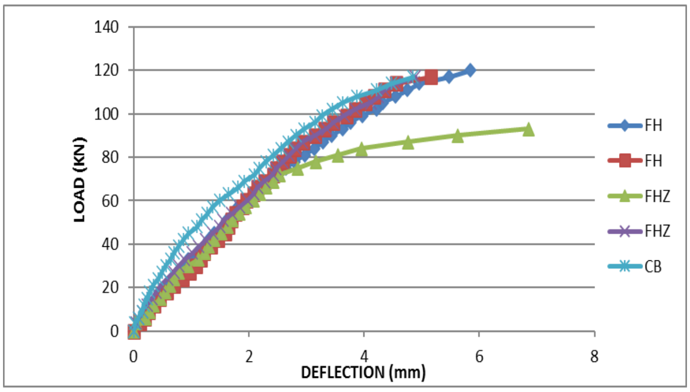


Fig.4.7.2 Comparison of Load deflection behavior for D1of all the beams WF

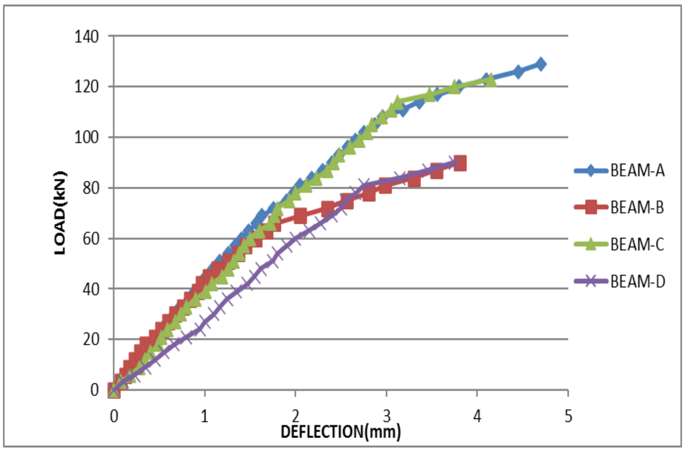


Fig.4.7.3 Comparison of Load deflection behavior for D2 of all the beams WOF

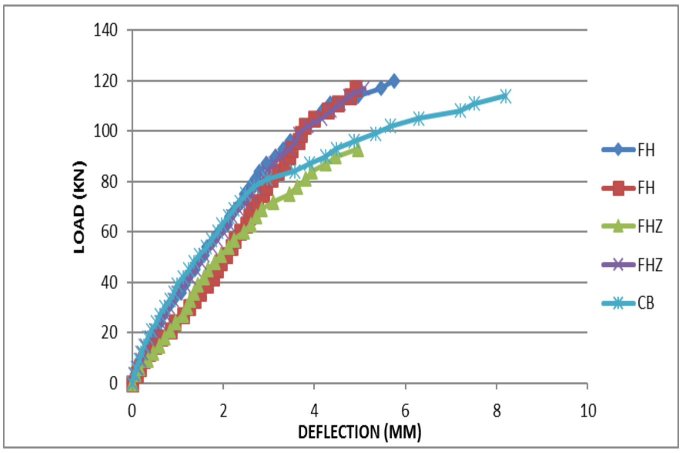


Fig.4.7.4 Comparison of Load deflection behavior for D2 of all the beams WF

4.8 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 is cast in two different forms one with fully hybrid fiber and fibers only in hinged zone as FH and FHZ. Each beam to calculate the deflection from continuous beams. From the values, stiffness has been calculated. The stiffness of beam FHZ specimen one will have having more similar stiffness value. Specimen two of FHZ carries a maximum stiffness value in both dial one and dial two. The various stiffness characteristics for all the beams are shown in Figure 5. The beams FH and FHZ are almost similar in stiffness characteristic with 66.67kN/mm with FHZ slightly more consistent than FH based on stiffness characteristics.

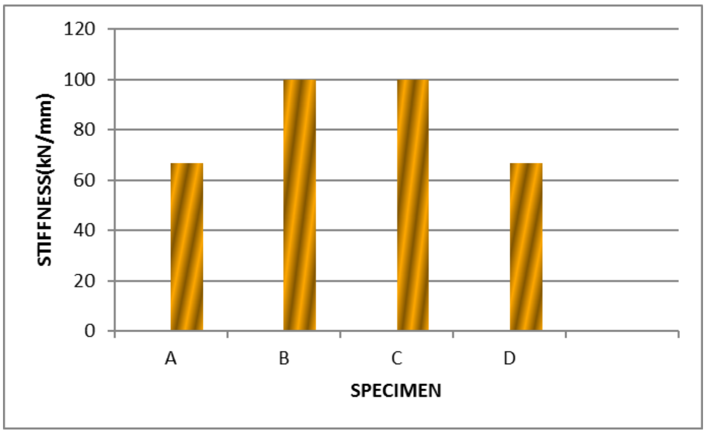


Fig.4.8.1 Comparison of Stiffness characteristics for all the beams WOF

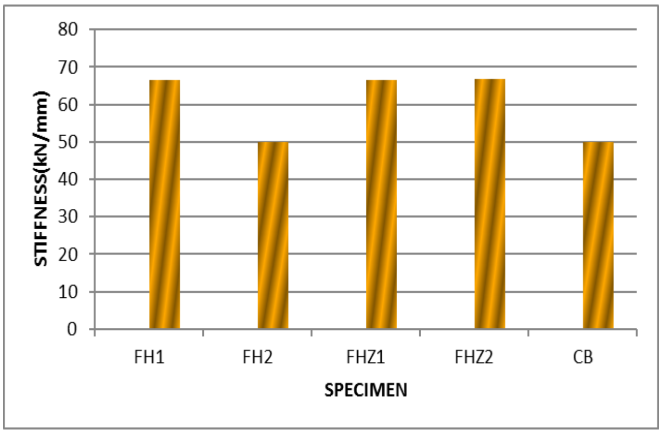


Fig.4.8.2 Comparison of Stiffness characteristics for all the beams WF

4.9 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 fibers in HPFRC increased the ductility of the beams. The ductility of beam FH specimen two will have a maximum at dial two values. At the same FHZ specimens, both dial one and two are almost equal. Specimen one of FHZ carries a minimum of ductility in both dials. Specimen two of FHZ is also minimum ductility. The various ductility for all the beams is shown in Figure 5.

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 figure4.9.1 & 4.9.2.

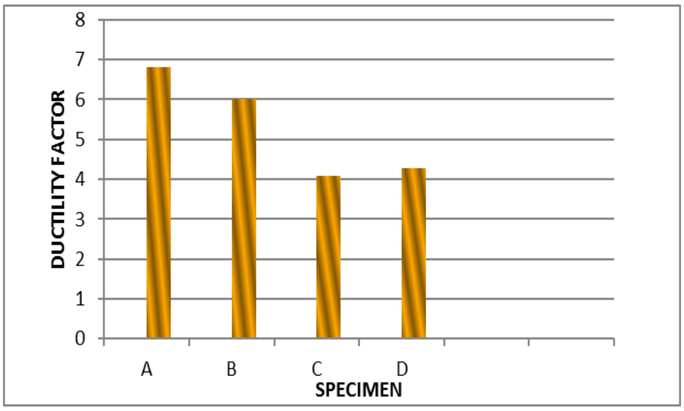


Fig.4.9.1 Comparison of Ductility for all the beams WOF

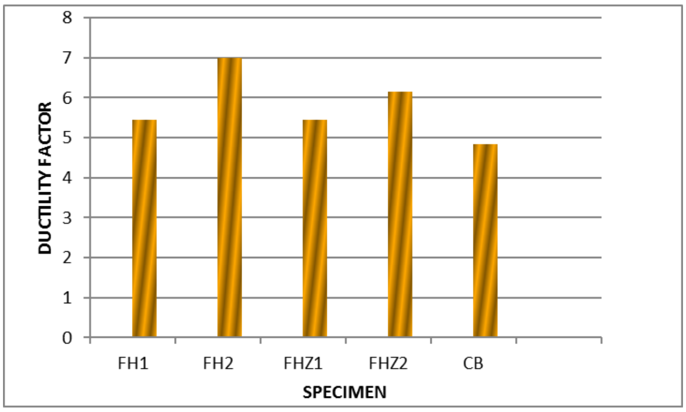


Fig.4.9.2 Comparison of Cumulative Ductility for all the beams WF

4.10 Energy absorption capacity:

The area under the load-deflection curve represents the energy absorption capacity of the whole specimen. The beam is cast 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 have a maximum at both dial values.

The cumulative energy absorption capacity of the FH beam was 710kNmm while that of FZH and CB beams have the values of 675kNmm, and 570 kNmm respectively. The cumulative energy absorption capacity of the FH (hybrid) beam was higher than that of other beams as shown in figure.4.10.2

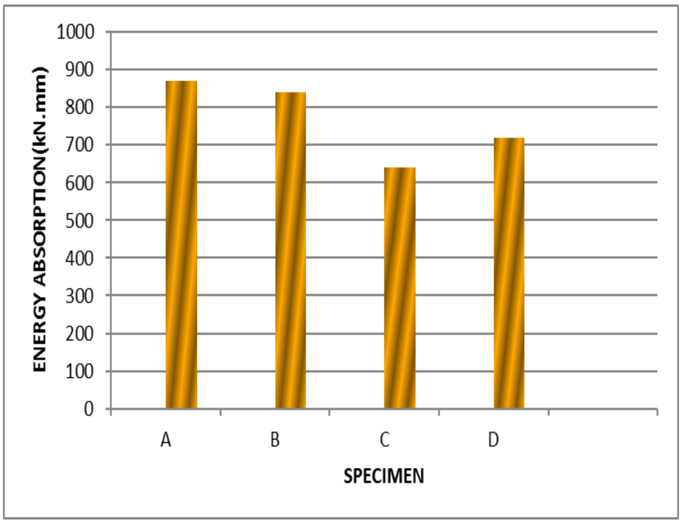


Fig.4.10.1 Comparison Energy absorption capacity for all the beams WOF

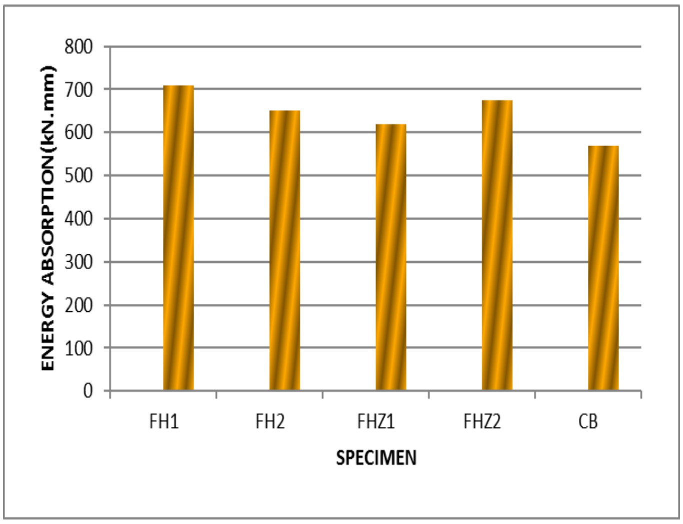


Fig.4.10.2 Comparison Energy absorption capacity for all the beams WF

4.11 Toughness index(I_5) & (I_{10})

The area under the load-deflection curve represents the energy absorption capacity of the whole specimen. The cumulative energy absorption capacity of FHZ beam was 7.71 while that of the FZH and CHPC beams have values as 7.5 and 5.26 respectively. The cumulative Toughness index(I_5) capacity of FHZ (hybrid) beam was higher than that of other beams as shown in Figure 8.

The cumulative energy absorption of the FHZ beam was 14.37 while that of FZH and CHPC beams have the values as 13.75 and 10.24 respectively in(I_{10}). The cumulative Toughness index(I_5) capacity of the FHZ (hybrid) beam was higher than that of other beams as shown in Figure 9.

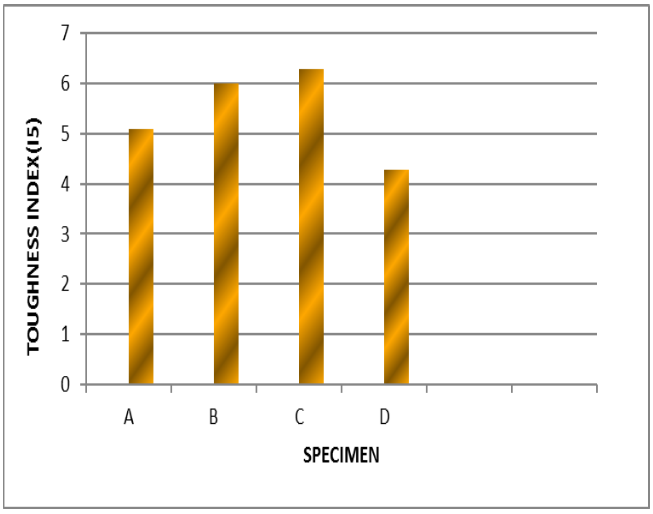


Fig.4.11.1 Comparison Toughness Index(I_5) for all the beams WOF

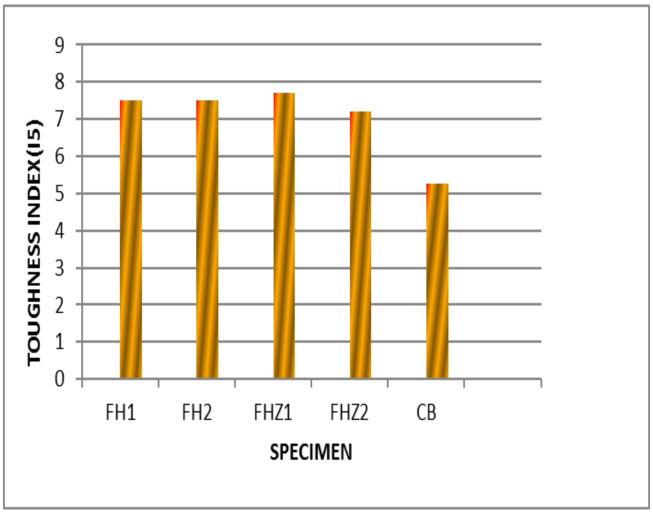


Fig.4.11.2 Comparison Toughness Index(I_5) for all the beams WF

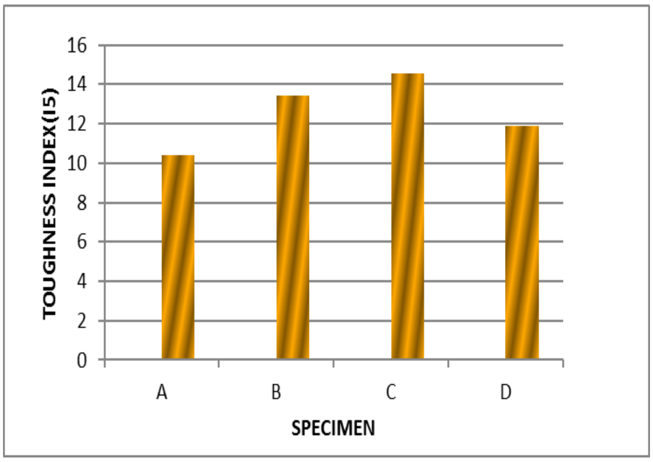


Fig.4.11.4 Comparison Toughness Index(I_{10}) for all the beams WOF

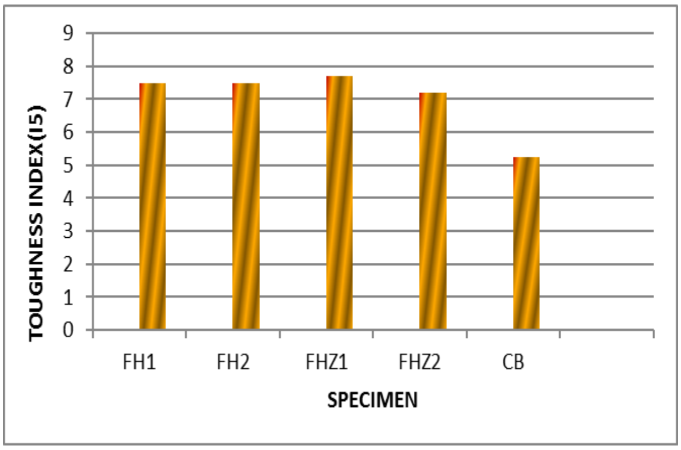


Fig.4.11.5 Comparison Toughness Index(I_{10}) for all the beams WF

4.12 Behavior and mode of failure

The loading was increased in all the specimens, and 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 fibers, a large number of finer cracks formed in the flexure zone and widened when the load increased. The presence of steel fiber inside the beam will resist the crack development by forming a bridge across the crack i.e., the steel fibers act as crack-arresting material during the initial stage of loading. The tested specimens of HPC and HPSFRC beams are shown in Figure 8.

Fig.4.12 Failure pattern for all the beams.

V. CONCLUSION

The experimental investigation is carried out to study the behavior of High-Performance Fiber Reinforced Concrete Beam. The test results are compared with that of the Conventional high-performance reinforced concrete beam. 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.

The following observation has been from the experimental program.

- The ultimate load for the FH fiber-reinforced concrete beam was greater than that of both FHZ and conventional RC beams. The beam FH carries a maximum Ultimate load of 120kN.
- The stiffness for the hybrid fiber-reinforced concrete beam was greater than that of the conventional RC beam with FH and FHZ are 66.67 KN/mm.
- The stiffness for FH and FHZ beams is almost similar. Both FH and FHZ are more than that of conventional RC beam.
- The ductility value of FH RC beam is maximum of 7 which will be comparatively more than that of both the FHZ and conventional RC beam.
- The energy absorption capacity of the FH beam was 710kNmm while that of FZH and CB beams have the values as 675kNmm, and 570 KNmm respectively. The cumulative energy absorption capacity of the FH (hybrid) beam was higher than that of CB and FHZ beams.
- The toughness index(I_5) of the FHZ beam was 7.71 while that of FH and CB have values of 7.21 and 5.26 respectively. Therefore, the toughness index (I_5) capacity of the FHZ beam was higher than that of other beams.
- The toughness index(I_{10}) of FHZ beam was 14.37 while that of the FZH and CB beams have values of 13.75 and 10.24 respectively. Therefore, the toughness index(I_{10}) of the FHZ beam was higher than conventional beam.
- In general, the presence of hybrid fiber in the full length of the beam results in higher load-carrying capacity in both stiffness and ductility as consider and the beam carrying only fiber in the hinged zone carries higher values considering energy absorption and toughness index parameters calculated above.

VI. REFERENCES

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