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EXPERIENTAL STUDY OF BEHAVIOUR OF STEEL FIBER REINFORCED CONCRETE BEAMS

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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 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 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.

KEYWORDS: Silica Fume, Crimpled Fibers, Fiber Reinforced Concrete, SFRC

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, Behaviour 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 behaviour at first cracking, behaviour beyond first cracking, behaviour 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.

An experimental program conducted to study the flexural behaviour 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.

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

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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-icer scaling damage Toughness and impact resistance.

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 with stand loads.

The characteristic of fiber reinforced concrete are 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 cement based matrix is reinforced with ordered or random distribution of fiber. The addition of fibers to the conventional concrete is varying from 1-2% by volume depending on geometry of fibers and type of application. The inclusion of steel fibers in concrete is to delay and control 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 behaviour and significantly enhances the ductility and energy absorption capacity of the composite. This composite consists of one or more phases that are discontinuous embedded in a continuous phase. Discontinuous phase is usually harder and stronger than the continuous phase and is called as reinforcement or reinforcing material. The continuous phase is known as matrix.

HYBRID FIBER REINFORCED CONCRETE

Hybrid Fiber Reinforced Concrete can be produced by suitably combining different types of fibers. The use of optimised 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 the 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.

NECESSITIES OF SFRC

Improve mix cohesion, improving pump ability 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 construction of crimped and hooked steel fibers are in order to 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 bar in reinforced concrete. There are increasing numbers of tunnelling projects using precast lining segments reinforced only with steel fibers.

NEED FOR THE PRESENT STUDY

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

SCOPE AND 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 behaviour of FRC beams in the ultimate and post ultimate region. To study the influence of shapes and geometry of the fiber by conducting experiment. 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 behaviour of RC beam with hybrid fibers as secondary reinforcement. To determine the moment carrying capacity, ductility and energy characteristic of RC beam. To compare the behaviour of RC beams with and without fiber.

EXPERIMENTAL INVESTIGATION

General

Two different types of fibers crimped steel fiber and hooked end steel fiber are used in casting FRC beam separately and mixed together. A proportion of 70% hooked fibers and 30% crimped fibers are adopted in this investigation. The volume fraction of fiber is fixed as 1.5% for all the beams.

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 by-product in the Silicon and ferrosilicon industry was used as a mineral admixture in concrete mixes. It contains 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 more dense.

Aggregates are the major ingredients of concrete. It acts as 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 specific gravity 2.66 and Zone II River sand 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 pieces of disintegrated stones, soft, flaky, elongated particles, salt, alkali, vegetable matter or other deleterious materials. Crushed stone aggregate of maximum size 12.5mm are used as coarse aggregate. Thus have specific gravity value of 2.7 and 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

Hooked End Fibers

The length of the fiber is 30 mm. The aspect ratio of fiber is 48.4.The diameter of hooked end fibers is 0.62mm. The tensile strength of the fiber is 1100Mpa. Fig 2.1 shows the view of the hooked end fibers.

Figure 2.1: Hooked End Fibers

Crimped Fiber

The length of the fiber is 38 mm. The aspect ratio is 69.09). The diameter of crimped fiber 0.55mm. 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 2.2.

Figure 2.2: Crimped Fiber

Portable water available in the laboratory is used for mixing and curing concrete. cerahyperplast a type of plasticer 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 Fe-415 grade with 2 nos of 8mm diameter bar provided at both top and bottom. 6mm diameter tor steel bars were used for stirrups.

Mix Proportioning

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

DIMENSIONS AND REINFORCEMENT DETAILS

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 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 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 2.3 & 2.4

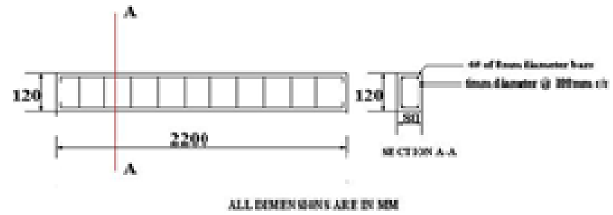


Figure 2.3: Reinforcement details.

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 mould layer by layer and compacted well. Hand mixing was adopted for convenient handling of steel fiber. 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 fibers were randomly oriented in the concrete mix. Beams casted with fully hybrid fibers and fibers only in hinged zone for flexural strength of plain concrete with and without fibers. Fig 2.4 shows the casting of beams.

Figure 2.4: Casting of Beam

Experimental Program Test 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 containing 0.8% 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 80mm x 120mm x 2200mm. Two types of SFRC beams 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.

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 0.3. 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 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.

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 screwjack 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 10 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.

RESULTS AND DISCUSSION

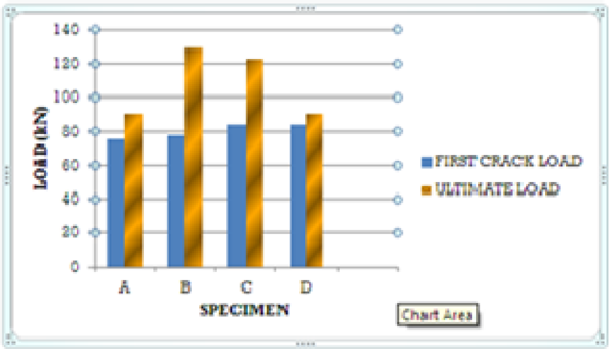
Totally nine specimens have been tested for their behaviour under monotonic loading. In order to study the influence of fibers. The test results are discussed as below. The different parameters such load carrying capacity, stiffness, ductility, energy absorption capacity, toughness index etc. have been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

Table 1: Test Results

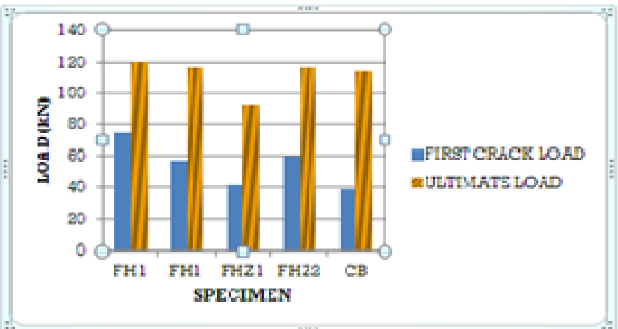
Parameter		Beam			
		A	B	C	D
% of fiber (Vf)		1.5	1.5	1.5	1.5
First crack load (kN)		75	78	84	84
Ultimate load (kN)		90	129	123	90
Stiffness (kN/mm)		66.67	100	100	66.67
Ductility factor		6.8	6	4.09	4.28
Energy absorption (KN.mm)	Absolute	870	840	640	720
	Reality	1	0.96	0.73	0.94
Toughness Index (I5)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

Table 2: Test Results

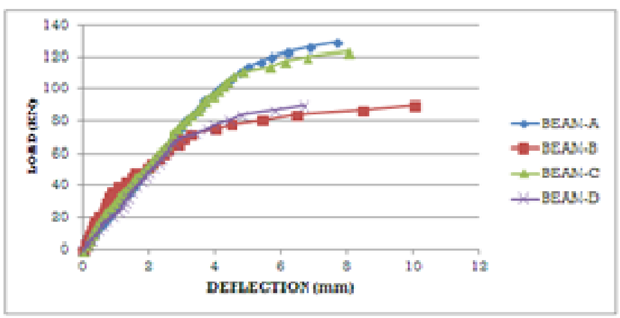
Parameter		Beam				
		FH1	FH2	FHZ1	FHZ2	CB
% of fiber (Vf)		1.5	1.5	1.5	1.5	1.5
First crack load (kN)		75	57	55	60	39
Ultimate load (kN)		120	117	93	117	114
Stiffness (kN/mm)		66.6	57.5	66.67	66.67	50
Ductility factor		5.46	7	5.46	6.156	4.85
Energy absorption (KN.mm)	Absolute	610	650	620	675	570
	Reality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



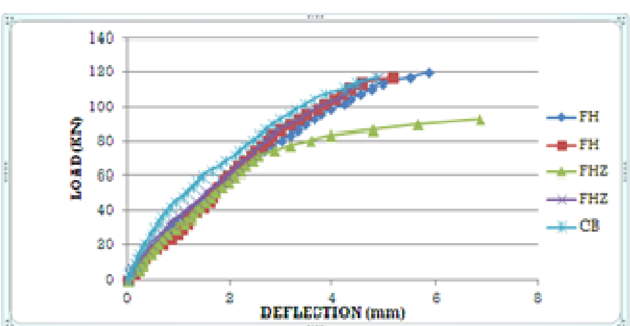
First crack load and Ultimate load for without fiber



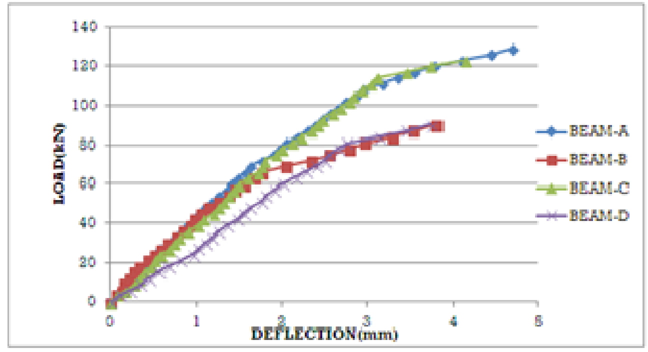
First crack load and Ultimate load for with and without fiber



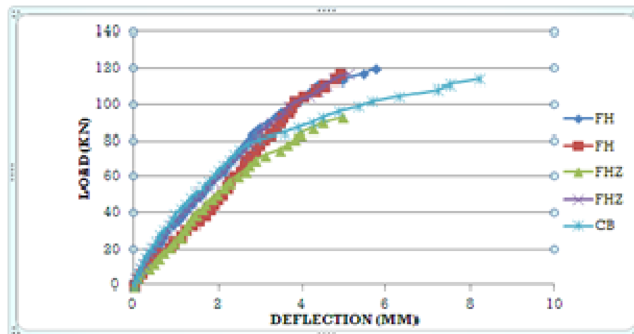
Comparison of Load deflection behavior for D1of all the beams WOF



Comparison of Load deflection behavior for D1of all the beams WF



Comparison of Load deflection behavior for D2 of all the beams WOF



Comparison of Load deflection behavior for D2 of all the beams WF

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. 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.

1. The ultimate load for the FH fiber reinforced concrete beam was greater than that of both FHZ and conventional RC beam. The beam FH carries maximum Ultimate load of 120kN.
2. The stiffness for the hybrid fiber reinforced concrete beam was greater than that of conventional RC beam with FH and FHZ are 66.67 kN/mm. The stiffness for FH and FHZ beams are almost similar. Both FH and FHZ are more than that of conventional RC beam.

3. The ductility value of FH RC beam is maximum 7 which will be comparatively more than that of both FHZ and conventional RC beam.
4. The energy absorption of capacity of FH beam was 710kNmm while that of FZH and CB beams have the values as 675kNmm, 570 kNmm respectively. The cumulative energy absorption capacity of FH (hybrid) beam was higher than that of CB and FHZ beams.
5. The toughness index(I_5) of FHZ beam was 7.71 while that of FH and CB have the values as 7.21 and 5.26 respectively. Therefore the toughness index (I_5) capacity of FHZ beam was higher than that of other beams.
6. The toughness index(I_{10}) of FHZ beam was 14.37 while that of FZH and CB beams have the values as 13.75 and 10.24 respectively. Therefore toughness index(I_{10}) of FHZ beam was higher than conventional beam.

   In general, the presence of hybrid fiber in full length of beam results in higher load carrying capacity in both stiffness and ductility as consider and beam carries only fiber in hinged zone carries higher values considering energy absorption and toughness index parameters calculated above.

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