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BEHAVIOR OF REINFORCED CONCRETE FLEXURAL MEMBER WITH HYBRID FIBRE UNDER CYCLIC LOADING

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Abstract: Concrete is the most widely used construction material because of its specialty of being cast into any desired shape. The main requirements of Earthquake resistant structures are good ductility and energy absorption capacity. Fibre reinforced concrete possesses high flexural and tensile strength, improved ductility, high energy absorption to the conventional concrete against dynamic loads. Because of the advantages of FRC, it can be used in Earthquake resistant structures. When concrete is reinforced with random dispersed fibres which prevent micro cracks from widening. Addition of two fibres of different properties can improve the properties of fresh concrete. This paper deals with the flexural behavior of Hybrid Fibre Reinforced Concrete beams (Namely RCC, SFRC, HFRC1, HFRC2) cast with Steel ,Glass and Recron-3s fibres under cyclic loading. The various parameters such as load carrying capacity, stiffness degradation, ductility characteristics and energy absorption capacity of FRC beams were compared with that of RC beam. The companion specimens were cast and tested to study strength properties and then the results were compared. In general, it is concluded that the effect of adding hybrid fibres influence the behavior of beams by increasing the ductility characteristics by 80% and energy absorption characteristics by more than 160%. Instead of adding single fibre, the combination of different types of fibres(Hybrid fibres) increases the energy absorption capacity substantially. This phenomenon is particularly advantageous in case of structures located in Earth quake prone areas.
Index Terms: Glass fibre, High performance concrete, Recron 3s fibre, Silica fume, Steel fibre.

1. INTRODUCTION

1.1 General

Construction is a major part of development plan of developing countries including India. To meet the large demand for infrastructure development, maintenance and life enhancement of structures are very important. Concrete is the most widely used man- made construction material. Plain concrete possesses a very low tensile strength, limited ductility and

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little resistance to cracking. Conventional concrete doesn't meet many functional requirements such as impermeability, resistance to frost adequately. The presence of micro cracks at the mortar–aggregate interface is responsible for the inherent weakness of plain concrete. Because of the poor tensile strength, cracks propagate with the application of load, leading to brittle fracture of concrete. Micro cracks are formed in concrete during hardening stage.

Natural disasters like earthquakes, cyclones, tsunami, etc destroy the high rise buildings, bridges, monumental structures, world wonders, etc. These deficiencies have led researchers to investigate and develop a material which could perform better in areas where conventional concrete has several limitations. 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 been two phase composite materials i.e. fibre reinforced concrete, in which cement based matrix is reinforced with ordered or random distribution of fibres. Fibre in the cement based matrix acts as cracks arrester which restricts the growth of flaws in the matrix, preventing these from enlarging under load, into cracks, which eventually cause failure.The weakness can be removed by inclusion of fibres in concrete. The fibres help to transfer loads at the internal microcracks. Fibres like steel, glass, recron 3s and nylon have been tried.

1.2 Fibre Reinforced Concrete

Fibre reinforced concrete is a concrete mix that contains Short, Discrete Fibres, that are uniformly distributed and randomly Oriented. The characteristics of fiber reinforced concrete are changed by the alteration of quantities of concretes, fiber substances, geometric configuration, dispersal, direction and concentration. The addition of fibres to the conventional concrete is varying from 1 -2 % by volume depending on the geometry of fibres and type of application.

1.3 Role of Fibres in Concrete

Fibres are available in different sizes and shapes. They can be classified into two basic categories, namely those having a higher elastic modulus than concrete matrix (called hard intrusion) and those with lower elastic modulus (called soft intrusion). High modulus fibres improve both flexural and impact resistance simultaneously where as low modulus fibres improve the impact resistance of concrete but do not contribute much to flexural strength.In contrast to reinforcing bars in concrete which are continuous and carefully placed in the structure to optimize their performance, the fibres are discontinuous and randomly distributed throughout the concrete matrix.

2. EXPERIMENTAL INVESTIGATION

2.1 Introduction

The FRC beams consist of steel fibres, glass fibres, recron 3s fibre, concrete mix and reinforcing steel. The behavior of such material has to be investigated under cyclic loading. The comparisons were made on the parameters like load carrying capacity, load deflection behavior, failure pattern, ductility and energy absorption characteristics.

2.2 Experimental Programme

Four beams namely RCC, SFRC, HFRC1, HFRC2 and companion specimens were cast and tested. Steel fibre reinforced concrete beam (SFRC beam) consists of 1% of steel fibre by volume of concrete, HFRC1 consists of 1% of steel fibre & 0.2% of glass fibre by weight of cement and HFRC2 consists of 1% of steel fibre & 0.3% of recron 3s fibre by weight of cement. All the four beams were tested under two point loading and subject to one- third concentrated cyclic loading upto failure.

2.3 Material

Ordinary Portland Cement of 53 grade with specific gravity 3.15 was used for the preparation of test specimen..Silica fume was used as a mineral admixture in concrete mixes having an average diameter about 0.1 microns. Silica fume is added as partial replacement of cement at 7.5% by weight of cement in order to get high performance concrete. The specific gravity of fine aggregate used for concrete is determined and found to be 2.6. The specific gravity of coarse aggregates were found to be 2.6.The portable water from the tap is used for mixing and curing the concrete. Conplast SP- 430 is a high range super plasticizing admixture used to increase the workability of concrete. A dosage of 1.0% by weight of binder is used for all the mixes. The main reinforcement used for four beams were TMT bars of (Fe 415)10 mm diameter at both top and bottom. 6mm diameter mild steel bars were used for stirrups at 100mm spacing. The round crimped Steel fibers of 1% by volume of concrete having 0.6 mm diameter, 12mm length and aspect Ratio 60 was used in this work. The glass fibres used are of Cem-FIL Anti-Crack high dispersion fibres. Fibres with Filament diameter 14 microns, length 12mm and aspect ratio of 857.1 was used.Recron-3s is used for improving the quality of construction in an optimum dosage of 0.3% by weight of cement.

2.4 Mix Proportioning

M30 grade concrete mix was designed as per IS 10262-1982. 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 1:1.22:2.6 and water cement ratio of 0.4 is used. In addition 1% of steel fibre(by volume of concrete), 0.2% of glass fibre(by wt of cement) and 0.3 % of Recron 3s fibre is added to the concrete mix. 7.5% of cement is replaced by silicafume.

2.5 Mould Details

The wooden beam mould of (100x170) mm in cross section and 1500mm long was selected for the casting of beam specimen.

2.6 Reinforcement Details

All the four beams were cast with the following reinforcement details. Two numbers of 10mm diameter rods at both top and bottom & 6mm diameter stirrups spaced at 100mmcentre as shear reinforcement grill before casting.

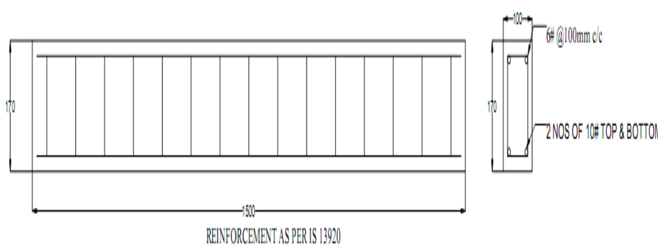

Fig 2.1. Reinforcement details

2.7 Casting Details

2.7.1 Casting and cuing of RC and FRC Beams

The cube moulds of size 150mm x 150mm x 150mm, cylindrical moulds of size 150mm diameter and 300mm height and beam moulds of size 100mm x 100 mm in cross section and 500mm length were selected for casting the companion specimens for compression test, split tension test and flexural strength test on plain concrete specimens with and without fibers. our numbers of beams namely RC beam, SFRC beam, HFRC 1 and HFRC 2 beams were cast to find the flexural behavior of beams. Hand mixing was adopted for casting the specimens. The beams were kept in the mould for one day. After the period of 24 hours, the beams were removed from the moulds and stored in the water for 28 days for curing. Two days before testing, the beams were taken from water to prepare them for testing and allowed to dry for about 4 hours. The beams were then white washed and horizontal and vertical lines were drawn.

2.7.2 Testing Of Beams

The beam specimen was placed on the loading frame as shown in figure 2.1(b). All the beams were tested under two-point loading condition. The forward and reverse cyclic load was applied by using screw jack. The beam was gradually loaded by increasing the load level in each cycle. The observed deflection at mid span was measured by using Dial gauge. At the end of each cycle, the load was released gradually and the deflection values for were also noted down.

Fig 2.1(b) The Schematic arrangement of test set-up

3. COMPARISON OF TEST RESULTS

3.1 Test Results on Companion Specimens

Table 3.1 Test Results on Companion Specimens

Property	PCC	SFRC	HFRC 1	HFRC 2
Cube Compressive Strength N/mm^2)	45.1	54.9	61.33	58.2
Cylindrical Compressive Strength(N/mm^2)	33.95	42.44	45.27	44.13
Split Tensile Strength (N/mm^2)	2.82	3.67	4.24	3.73
Flexural Strength (N/mm^2)	4.7	5.88	6.68	6.2

3.2 Load Carrying Capacity of RC, SFRC, HFRC1& HFRC2 Beams

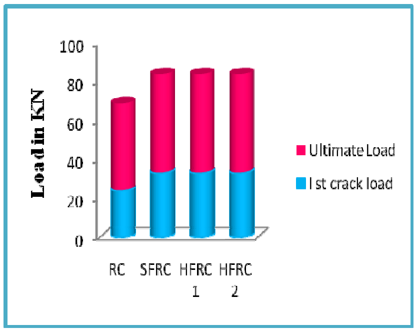

Fig 3.1 Comparison of First Crack and Ultimate Load of RC and FRC beams

3.3 Load – Deflection Behavior

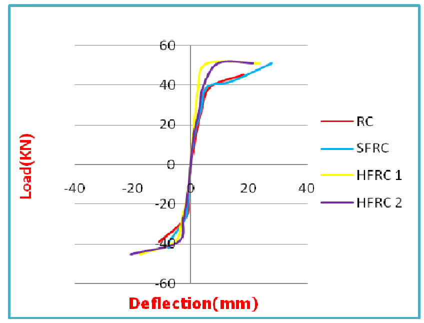

Fig 3.2 Load vs Deflection curve

3.4 Cumulative Ductility Factor Characteristics

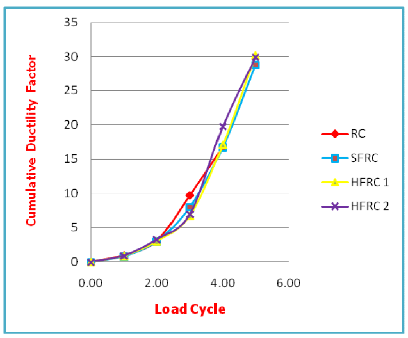

Fig. 3.3 Variation of Cumulative Factor with Load Cycles

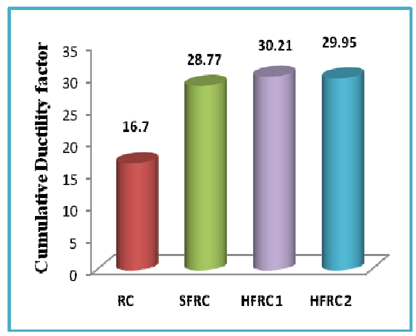

Fig. 3.4 Comparison of Cumulative Ductility Ductility factor

3.5 Cumulative Energy Absorption Capacity Characteristics

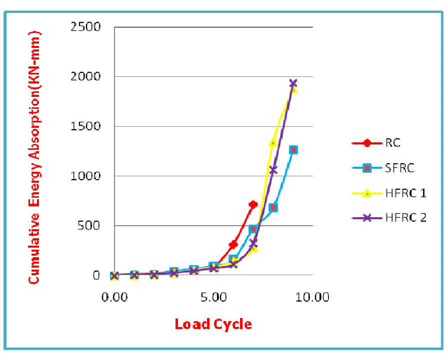

Fig 3.5 Variation of cumulative energy absorption

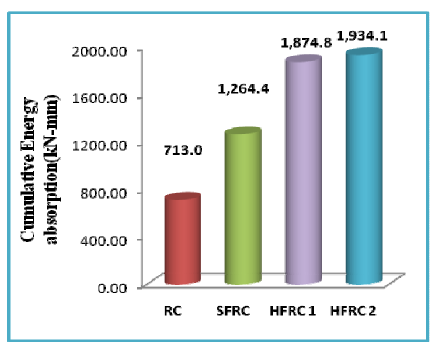

Fig. 3.6 Comparison of Cumulative Energy Absorption Capacity

3.6 Stiffness Characteristics

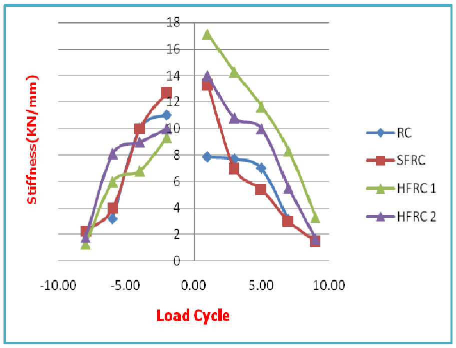

Fig.3.7 Variation of Stiffness with Load Cycles

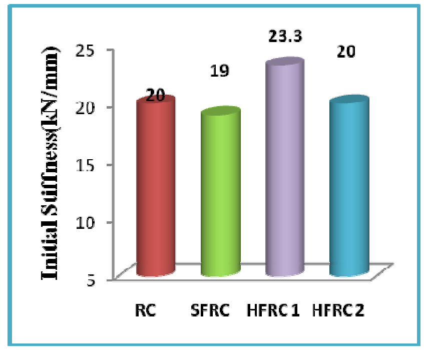

Fig.3.8 Comparison of Initial Stiffness

3.7 Behaviour and Mode of Failure

RC Beam

SFRC Beam

HFRC-1 Beam

HFRC-2 Beam

4. CONCLUSION

RESEARCH FINDINGS BASED ON RC AND SFRC BEAMS

The ultimate load carrying capacity of SFRC beam is about 1.13 times that of conventional beam where as the first crack load carrying capacity of SFRC has been increased by 40%.The cumulative ductility factor of SFRC beam is about 1.7 times that of conventional beam. Cumulative energy absorption capacity of SFRC beam is about 1.77 times that of conventional beam. The failure pattern of SFRC beams clearly indicates the role of fibres i.e. Series or multiple cracks have been formed.

RESEARCH FINDINGS BASED ON SFRC AND HFRC–1BEAMS

The ultimate load carrying capacity of HFRC-1 beam is same as that of SFRC.The cumulative ductility factor of HFRC-1 beam is about 1.05 times that of SFRC beam. Cumulative energy absorption capacity of HFRC-1 beam is about 1.48 times that of SFRC beam.

RESEARCH FINDINGS BASED ON RC AND HFRC–1BEAMS

The ultimate load carrying capacity of HFRC-1 beam is about 1.13 times that of conventional beam where as the first crack load carrying capacity as been increased by 40%.The cumulative ductility factor of HFRC-1 beam is about 1.8 times that of conventional beam. Cumulative energy absorption capacity of HFRC-1 beam is about 2.62 times that of conventional beam.

RESEARCH FINDINGS BASED ON HFRC–1 AND HFRC-2 BEAMS

HFRC-1 and HFRC-2 are giving more or less same results and its found that the behavior of both beams are identical showing no significant improvement in respect of the parameters like load carrying capacity, ductility, energy absorption etc., where as the SFRC beam exhibits only 50% higher energy absorption capacity

In general, it is concluded that the effect of adding hybrid fibres influence the behavior of beams by increasing the ductility characteristics by 80% and energy absorption characteristics by more than 160%. Instead of adding single fibre, the combination of different types of fibres(Hybrid fibres) increases the energy absorption capacity substantially. This phenomenon is particularly advantageous in case of structures located in Earth quake prone areas.

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