Ductile behavior of confined hybrid fibre reinforced concrete in the plastic hinging zone of RC beams

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ABSTRACT

This paper is an outcome of the research conducted on the ductile behavior of Hybrid fiber reinforced concrete (HYFRCB) beams along with stirrup confinement. Thirteen beams of cross-section 120×200 mm with varying volume fraction of steel and polypropylene fibre were examined in the laboratory with an effective span of 1800mm. Out of 13 beams one beamwas kept as a reference beam without fibre reinforcement, four beams were designed with steel fibre and the remaining with hybrid fibres. Except for reference beam all the other beams were placed with fibers at the plastic hinging region .Test was performed on all these beams till the ultimate load. By adding fibre to the beams, the following findings were made: first crack load, ultimate load, first crack deflection, ultimate deflection, deflection ductility, energy ductility were examined. The test results revealed that incorporation of hybrid fibres along with stirrup confinement showed improved ductile performance compared to the high strength concrete beam and steel fibre reinforced high strength concrete beam.

KEY WORDS: Confinement, Hybrid, Ductility, Plastic hinging area, Steel fibre.

1. INTRODUCTION

High strength concrete is an essential latest progress in construction materials with high compressive strength, but this type of concrete is considered as a brittle material because of its low tensile strength and poor flexural behavior. Ductility of the structure mainly depends on percentage of steel reinforcement provided in the tensile zone and confinement provided.

Kwan (2006) studied the performance of the High strength concrete beam by adding compression and confining reinforcements. In this research work they have assessed the complete moment curvature behavior of the beam with different grades of concrete, tensile, compressive and confining reinforcement to achieve the flexural ductility. They have concluded that by the addition of the confining reinforcement effectively improved the flexural ductility of the beam.

Ahmed (2007) studied the performance of the over-reinforced concrete beam with different techniques to enhance the strength and ductility of the beam, in this experimental work they have examined the behavior of the beam either internally confined stirrups with varying parameters such as helix pitch, helix diameter, and longitudinal reinforcement ratio or externally confined with steel plates. Results indicate that contribution of these techniques to the structural ductility will definitely improve the behavior of such beam.

Eswari (2008) studied the performance of the hybrid fibre reinforced concrete beam. They have analyzed the parameters such as modulus of rupture, Energy ductility and deflection ductility. From the analysis they have concluded that addition of 2% by volume of hybrid fibre he enhanced the ductile behavior of the beam.

Sudhakar (2009) studied the performance of the steel fibre reinforced concrete beam. They have examined the flexural behavior and moment carrying capacity of the beam by incorporating steel fibre only at the possible hinging regions along with stirrup confinement. Finally they have concluded that increased use of steel fibre appreciably enhanced the moment curvature and ductile behavior of the beam.

Saaid (2011) studied the flexural performance of steel slag concrete and compared with normal concrete, 8 beams with different tensile reinforcement ratio were caste and tested.it has been observed that these beams produced satisfactory results in terms of flexure and other mechanical properties.

Mariappan Mahalingam (2013) studied the behavior of RC beam strengthened with externally bonded glass fibre and polymer laminates. All the beams were evaluated in terms of stiffness, strength and ductility. The test results revealed that beams with externally provided GFRP laminates shows better performance than inner fibre reinforcement.

Magda Mousa (2015), investigated the flexural behavior of the RC beam With Different Lengths of Tension Reinforcement Lap slice. An experimental program has been performed on two different grades of concrete and different percentages of silica fume. Spliced tensile reinforcement on the constant moment region shows adequate ductile response than the reference beam.

Almost all the research work has been done on the flexural and ductile behavior by incorporating different methodologies. Only few literatures are available in exhibiting the maximum possible hinging zone. Hence this experimental program is an effort which has been put forth to strengthen the maximum possible hinging zone by means of hybrid fibre along with stirrup confinement which improves both flexural and ductile behavior.

2. MATERIALS AND METHODS

The cement used in concrete was ordinary Portland cement 53 grade as per IS 12269-1987, and sand used was local river sand and the coarse aggregate whose maximum size is 12.5mm.

Commercially available micro silica grade 920 (Undensified 920 D) has been used in this study as a mineral admixture. A high-range water-reducing admixture [hyper-plasticizer] by a trade name classic super flow SP (Naphthalene Sulphonate) was used during mixing operations to ensure proper workability.

The properties of steel and polypropylene fibre used in this investigation are presented in Table 1. The dramix steel fibre of length 35mm having hooked ends with an aspect ratio of 65 and polypropylene fibre of length 12.5mm were used in this investigation.

Table.1. Properties of fibre used in study

Fibre Properties	Fibre Details	
	polypropylene	Steel
Length (mm)	12.5	35
Shape	Straight	Hooked at ends
Size / Diameter (mm)	0.05	0.55 mm
Aspect Ratio		65
Density (kg / m^3)	910	7850
Specific Gravity	0.90-0.92	-
Young's Modulus (GPa)	3.70	210
Tensile strength (MPa)	330	532

Preparation of test specimen: The test program was designated to study the performance of high-strength fibre reinforced concrete with and without fibre with varying volume fractions such as 0.5%, 1.0%, 1.5% & 2.0%. In this research work four high-strength concrete beams reinforced with continuous bars and with steel fibre and eight high strength hybrid fibre combination of steel-polypropylene reinforced concrete beams were tested together with one high-strength reinforced concrete beam without fibre. The beam specimens were cast in batches using wooden mould and these moulds were arranged to conserve the precise size of the beam. At the outset oil was applied on all the sides of the mould before placing reinforcement. Later, to maintain an effective depth of the beam a cover block was placed at the bottom of the mould. Next, a concrete mix with three different batches were prepared and placed at the critical section using hybrid fibres in different volume fractions simultaneously on two sides without adding fibres. Further, compaction is done uniformly using needle vibrator. The beam specimens were demoulded after 24 hours of casting and finally curing was done in a regular basis.

Testing of Beams: All the beams were tested, under third-point loading as per ASTM C 78 in a loading frame of 750 KN capacity and 150mm bearing was specified on both the ends, with the effective span of 1800mm. Mid span deflection are measured and also at the load points using mechanical dial gauges of 0.01mm precision. Two dial gauges were placed on the compression side of the beam and above the supports to measure slope at the ends. Specifically designed mechanical gauges are provided to measure the deflection at the ultimate loads. The strain value of each beam is measured using demountable mechanical gauge. The crack widths are observed by means of a crack detection microscope with the least count of 0.02mm. Crack initiation and propagation was also examined during testing.

3. RESULTS

The test results which includes first crack load, ultimate load, deflection at first crack load and ultimate load for all the beams were tabulated in Table2. A graph was plotted from the load deflection values and with reference to that deflection ductility and energy ductility was calculated and represented in Fig.1

DISCUSSION

- From the experimental results it was noticed that the moment carrying capacity of the beam shows significant increases with increase in strength and volume fraction of the steel and polypropylene fibre when compared to reference beam (without fibre) and beam with steel fibre.
- Incorporation of hybrid fibre (Steel &Polypropylene) along with stirrup confinement in high Strength concrete beams improved load deflection behavior.
- HSC beam with higher percentage of steel more than limiting percentage in the tensile zone can be made to develop ductile failure by the hybrid fibre.
- Improvement in curvature is found about 167% by the addition of hybrid fibres than steel fibre is 135% and high strength over reinforced concrete.
- The high-strength hybrid fibre reinforced concrete beams exhibit greater reduction in crack width at all load levels when compared to the steel fibre and the reference beam.

- The maximum reduction in crack width at ultimate load was found to be 87.65% when compared to the reference beam and 85% when compared to the high-strength steel fibre reinforced concrete beam containing 100% steel fibres.

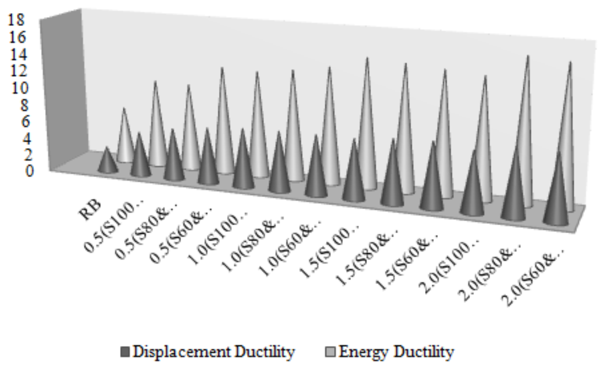

Figure.1. Ductility of beam specimens

Table.2. Test results of beam specimen

Beam Designation	First Crack Load(KN)	Ultimate Load(KN)	Ultimate moment (KNm)	Deflection at First Crack Load(mm)	Deflection at Ultimate Load(mm)	Maximum Crack Width(mm)	Displacement Ductility	Energy Ductility
RB	12	135.1	40.17	7	20.59	1.62	2.94	6.56
F 0.5 S 100 / P 0	20.52	136.78	40.89	4.99	25.5	0.65	5.11	10.23
F 0.5 S 80 / P 20	21.56	137.11	41.04	4.87	29.01	0.51	5.96	10.12
F 0.5 S 60 / P 40	21.53	136.91	40.95	4.66	29.95	0.53	6.43	12.56
F 1.0 S 100 / P 0	22.61	137.43	41.27	4.56	30.98	0.46	6.79	12.34
F 1.0 S 80 / P 20	22.26	141.75	42.57	5.23	35.89	0.43	6.86	12.87
F 1.0 S 60 / P 40	22.65	144.35	43.35	5.21	35.99	0.42	6.91	13.56
F 1.5 S 100 / P 0	23.42	149.48	44.89	4.91	33.75	0.32	6.87	14.87
F 1.5 S 80 / P 20	23.5	150.85	45.12	4.84	35.3	0.27	7.29	14.56
F 1.5 S 60 / P 40	23.03	149.18	44.8	5.26	39.34	0.28	7.48	14.2
F 2.0 S 100 / P 0	24.25	155.24	46.62	5.52	38.23	0.23	6.93	13.87
F 2.0 S 80 / P 20	24.95	158.57	47.62	5.71	44.95	0.21	7.87	16.34
F 2.0 S 60 / P 40	23.89	156.9	47.12	5.73	43.25	0.2	7.55	15.98

4. CONCLUSION

- An amount of 12% of silica fume as replacement of cement shows improved performances in terms of strength.
- The confinement provided along the length of the beam significantly increases the first crack load, more number of cracks and better crack transmission especially in the area of maximum possible hinging zone
- By providing higher percentage of steel shows improvement in load carrying capacity and the ultimate load.
- Incorporation of hooked end steel fibres plays vital role in enhancement of flexural behavior.
- The HYFRC beam reveals greater ductility than that of the steel fibre reinforced concrete beam and high strength concrete beam.
- Increment in Deflection ductility and Energy ductility is observed.
- From the results it was observed that the consequence of utilizing hybrid fibre along with stirrups shows better performance in terms of ductility.
- Hence the mode of the failure has been changed from brittle to ductile failure even though the beam is an over reinforced one.

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