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Study on Performance of HFRC flexural member under cyclic loading

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Abstract— **The objective of this study is to investigate the behavior of Hybrid Fibre Reinforced Concrete Beam under Cyclic loading. As per IS10262-2009 concrete mix of M40 grade has designed with a water cement ratio of 0.4. The fibre combination of steel and Polypropylene at a volume fraction of 0.5% was chosen and six beams of size 1700mmx200mmx100mm were cast and tested. Cyclic load in both forward and reverse cycle was applied to determine the effect of using hybrid fibers in flexural member. In all beams, the first crack load and ultimate load is observed. The deflection at centre is measured using LVDT. Experimental results prove that the fibres when used in a hybrid form, increases its resilience by a large failure strain. HFRC specimen with a combination of S0.75P0.25 can be adjudged as the most appropriate combination to improve flexural strength and ductility.**

Index Terms—**Hybrid fibers, Flexural member, Deflection, Cyclic loading.**

I. INTRODUCTION

Reinforced concrete is a versatile material and its use in India is increasing in every sphere of activity mainly due to its economical material content and easy technology in construction. This has lead to finding ways to overcome its weakness in tension and inherent brittleness proving to be a major factor in seismic response. One of the popular and technologically easier way is to add fibers while casting the beam and making the cracking evenly spread and at the same time increasing its resilience by a large failure strain. Concrete composites with fibers are known to possess increased compressive strength, distributed minor cracking for better energy absorption. In the last 50 years discovery and acceptance of reinforcement and fibers for enhancement of concrete properties rapidly increased for use in concrete industries, research and development. Numerous types of fibers have successfully been adopted in the different applications of concrete. 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 micro cracks. 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 fibers improve both flexural and impact resistance simultaneously where as low modulus fibers 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.

II. EXPERIMENTAL PROGRAM

A. Materials

Cement

Portland-Pozzolana cement of grade 53 was used for casting all the specimens, confirming to IS 1489 (Part 1): 1991.Specific gravity and fineness modulus of cement is 3.15 and 7.5 respectively.

Fine aggregate

Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve was used for casting all the specimens. Specific gravity and fineness modulus is 2.64 and 2.79 respectively.

Coarse aggregate

Coarse aggregate passing through 12.5 mm sieve as given in IS 383 – 1970 was used for all the specimens. Specific gravity and fineness modulus is 2.77 and 5.90 respectively.

Water

Casting and curing of specimens were done using potable water available in the college premises which was free from deleterious materials.

Super Plasticizer

Super plasticizer CONPLAST SP 430, based on Sulfanated naphthalene polymers, complies with IS 9103-1999 and ASTM C-494 was used.

Steel fibers

Continuously crimped Steel fibers with an aspect ratio of 80 were used.

Polypropylene Fibers

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Polyolefin fibers with an aspect ratio of 380 were used.

B.Mix Proportion

Mix design has been adopted from IS 10262:2009 to design for M40 grade of concrete. No fibers were added in control mix specimen whereas Steel and Polypropylene fibers were added to concrete specimen at a volume fraction of 0.5%.

Table 1 Mix proportion for Hybrid concrete

Mix	Cement kg/m^3	FA kg/m^3	CA kg/m^3	Water kg/m^3	SP kg/m^3	Steel Fibre (%)	PP Fibre (%)
BCM	395	715	1150	158	7.9	-	-
BS0.5	395	715	1150	158	7.9	0.5	-
BP0.5	395	715	1150	158	7.9	-	0.5
BS0.25P0.75	395	715	1150	158	7.9	0.12	0.38
BS0.5P0.5	395	715	1150	158	7.9	0.25	0.25
BS0.75P0.25	395	715	1150	158	7.9	0.38	0.12

Steel fibers were added by the volume of concrete and polypropylene fibers were added by the weight of cement.

C.Preliminary Studies

In the Preliminary studies, the standard sizes of cube (150x150x150mm), cylinder (150mm diameter and 300mm height) and prism (500x100x100mm) were tested as per IS 516-1959. The concluding results were as follows: The cube compressive strength for S0.75P0.25 at 28 days is 61.23 N/mm^2 which is nearly 40% more than the control mix . Split tensile strength at 28 days for S0.75P0.25 is 12.84 N/mm^2 and flexural strength at 28 days is 15.8 N/mm^2 which is more than the concrete with steel fibers alone.

D. Beam Specimen Details

The beam has the cross section of 1700mmx200mmx100mm with an effective span of 1500mm. Figure 1 shows the cross section and reinforcement configuration for the beam specimen.

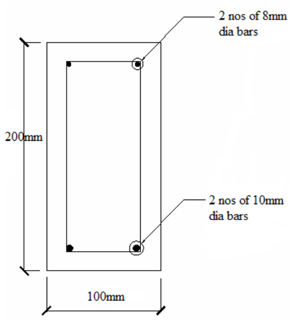

Fig 1 (a) Cross Section of Beam

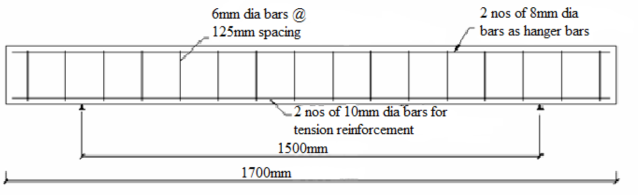

Fig.5.2 (b) Longitudinal Section of Beam

E. Casting and Testing of Specimens

Plywood moulds were used for casting the specimens. Reinforcement cages were fabricated and placed inside the moulds. Required quantities of cement, sand and coarse aggregate were mixed thoroughly in a drum type mixer machine and 50% of water was added to the dry mix. The remaining 50% water was mixed with the superplasticizer was added along with the steel fibre and polypropylene fibre. The mixes were poured into moulds in layers and the moulds were vibrated for thorough compaction. After 24 hours of casting, specimens were demoulded and cured under wet gunny bags for 28 days.

Specimens were tested in a loading frame of 100 tonne or 1000kN capacity. A hydraulic jack of 50 tonne or 500kN capacity was used to apply load at the beam. A load cell of 50 tonne capacity was used to measure the applied load accurately. Cyclic load with an increment of 10kN was applied to the beam by two point loading. Three Linear Variable Differential Transducers (LVDTs) was used to measure the deformations of beam. The schematic diagram of cyclic loading test set-up is shown in Figure 2.

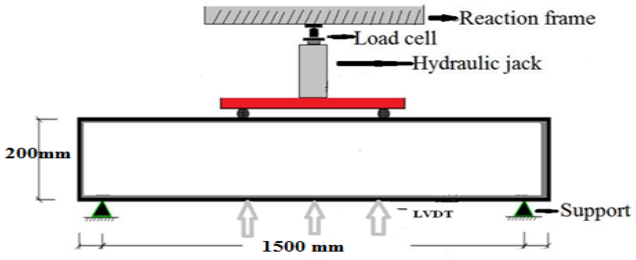

Fig 2 Schematic Diagram of Cyclic loading Test Set-up

III. RESULTS AND DISCUSSION

Fig 3 Beam Test Setup under Two point loading

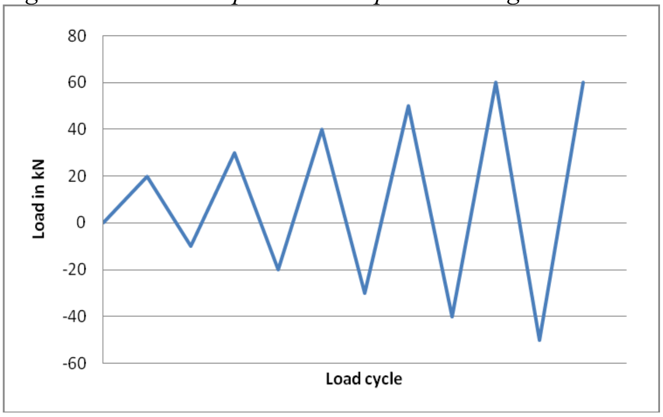

Fig 4 Loading sequence

The typical crack patterns of BP0.5, BS0.5, BS0.25P0.75 and BCS0.75P0.25 beam specimen are shown in Figures 5(a), 5(b) and 5(c) respectively

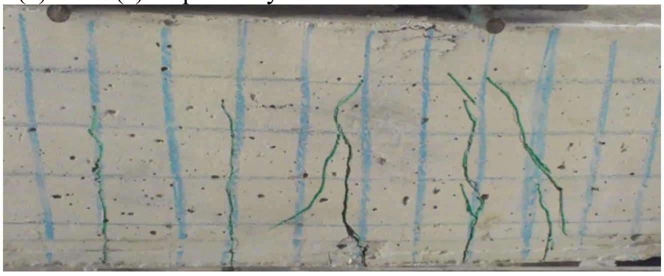

Fig 5(a) Failure pattern for BP0.5

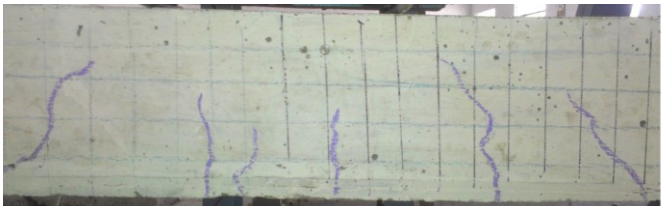

Fig 5(b) Failure pattern for BS0.25P0.75

Fig 5(c) Failure pattern for BS0.75P0.25

Table 2 Cracking load and Ultimate load of Beam under Cyclic loading

Mix	Cracking load in kN	Ultimate load in kN
BCM	28	45
BS0.5	34	50
BP0.5	32	49
BS0.25P0.75	35	51
BS0.5P0.5	37	53
BS0.75P0.25	39	57

All the beams have failed in flexural mode by yielding of tension steel. Crushing and spalling of concrete takes place after yielding in tension zone for conventional reinforced concrete beams and hybrid fibre reinforced concrete beams. Hybrid beams suffer lesser damage to other beams. It is also observed that the cracks are closely spaced in all the fibre reinforced concrete beams and also the crack widths in composite beams are consequently less than in the conventional beams. Hybrid beams takes an increase in load when compared to conventional beam.

IV CONCLUSION

When compared with single fibre reinforced concrete beams hybrid concrete beams takes some delay in cracking load and ultimate load. It was found that the addition of fibres bridges the cracking effects and delayed the formation of first crack.

The ultimate load carrying capacity increases by 26% for hybrid BCS0.75P0.25 when compared to conventional concrete beam and 14% in comparison with 0.5%steel fibre beam specimen.

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