Study on Mechanical behavior of Hybrid Fiber Reinforced Concrete Beams with and without Notch

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Abstract - *In this paper, the results obtained during the study on mechanical behavior of hybrid fiber reinforced concrete beams have been reported. A concrete mix of grade M20 with water to cement (W/C) ratio of 0.45 was used for casting of small beams. The hybrid fibers used were basalt fiber (BF) and polypropylene fiber (PF). The addition of hybrid fibers to the concrete were in equal proportions of 0%,0.3%, 0.6 %,0.9% of each fiber to the total volume of specimen. A total of three beams with notch and three beams without notch for the best fiber proportions along with the control beam were cast. In order to study the mechanical behavior of concrete only due to performance of hybrid fibers, no reinforcements were provided for all beams. Thrid-point loading flexural tests were conducted on the beam specimens with and without notch. The results obtained showed that the specimen with least fiber proportions and without notch performed well in flexure than specimen with other fiber proportions.*

Key Words: Hybrid fiber reinforced concrete (HFRC),Notch, Single point loading, Mechanical behaviour.

1. INTRODUCTION

Plain concrete is a composite brittle material with lower tensile strength and lower strain limit. One of the solutions for this problem is the hybridization of fibers, which results in a complex composite with high resistance to cracking. Fibers are used to control cracking and to improve flexure behavior of specimens thereby increasing the ductility and durability of material when it is used as the reinforcement for concrete. Short discrete fibers are used to enhance the engineering properties of concrete such as tensile, flexure, toughness and fatigue properties. Various kinds of fibers were used in mortar or concrete. Fibers can be a natural or synthetic. The kind of fiber to be incorporated in concrete or mortar is based on the application of concrete or mortar. The incorporation of more than one fiber in concrete can enhance more than one property of concrete. The short fibers into the concrete prevents crack initiation and crack propagation by crack bridging thereby increasing the time of specimen failure. The fibers such as basalt fibers, polypropylene fibers were chosen to improve the flexure behavior of specimen. The hybrid fiber reinforced concrete finds its application in several engineering projects such as bridges, earthquake resistant structures and waterproof structures.

The main object of this report is to study the mechanical behavior of concrete compared with hybrid fiber reinforced concrete (HFRC) without notch and the influence of notch in mechanical properties of the specimen. The fundamental properties of hybrid fiber reinforced concrete such as compressive strength, splitting tensile strength were studied and flexural strength was tested and analyzed for control specimen and hybrid fiber reinforced specimen with and without notch.

2. EXPERIMENTAL PROGRAM

2.1 Materials

The commercially available Ordinary Portland Cement 53 grade is used in all mixture. Fine aggregate of size below 4. 75mm which conforming to Zone II of IS383-1970 is used. The coarse aggregate is of angular shape retained on 4.75mm and have to pass through 20mm as per the requirements of IS383-1970. The mix design was tabulated in table 1. Two types of fibers such as basalt fiber of length of 18 mm and polypropylene fiber of length of 19 mm are used for hybrid fiber reinforced concrete. The basalt fibers were provided by Go Green Products, Chennai whereas the polypropylene fibers were provided by Sivamalai associates, Coimbatore. The fiber mixing content of polypropylene fibers was 0%, 0.3%, 0.6% and 0.9% respectively. The properties of both fibers are described in table21. The polypropylene and basalt fibers used are shown in fig 1 and fig 2 respectively.

Table-1: Concrete Mixture proportions of M_{20}mix

Cement(kg/m³)	Fine aggregate(kg/m³)	Coarse aggregate(kg/m³)	Water(kg/m³)
438. 13	628. 94	1129. 464	197. 11

Table-2: Properties of Basalt and Polypropylene fibers

Type	Length (mm)	Dia (µm)	Aspect Ratio	Density(g/cm³)
BF	18	15	1200	2.56
PF	19	30	634	0.91

Fig -1: Polypropylene fiber

Fig -2: Basalt fiber

2.2 Mixing, Casting and Curing

Initially, the mixing is done by dry mixing of fine aggregate and cement for a minute. Then the coarse aggregate was added and then dry mixing is done for another 1 min. After that, fibers were added followed by dry mixing for another 1 min. Finally, water was added to the mix gradually. The fresh concrete obtained was mixed for another 2 min in order to ensure proper and even dispersion of fibers in concrete. Then the fiber reinforced concrete was placed into respective molds for casting of cubes, cylinders, beams respectively. Prior to casting, oil was applied to the inner portion of mold for easy removal of specimen. After 1 day from casting, cubes were separated from their respective molds and are allowed to cure under water for 28 days in order to obtain strength. For casting of notched beams, notch is inserted into the mold prior to casting. After that, casting is done followed by initial curing. After initial curing, mold with notch can be removed from specimen.

2.3 Testing methods

The compressive strength test of the specimens is conducted as per with reference to IS 516-1959.The tensile strength of concrete can be determined indirectly by splitting tensile test. The test is performed in accordance with IS 5816-1970. The flexural strength of specimens is obtained either by third-point loading or center point loading test with reference to ASTM C293 & IS 516-1959.

3. RESULTS AND DISCUSSION

3.1 Compressive strength

The results of compressive strength of concrete specimens at 28 days are given in Table 3. The specimens were prepared with fiber combinations such as specimen with a constant proportion polypropylene fiber of 0.3% of volume fraction and with varying proportions of basalt fibers as 0.3%, 0.6% and 0.9% respectively. The specimen with constant proportion of polypropylene fibers with 0.6% and 0.9% of total volume fraction with varying basalt fiber proportion as above were also prepared. All these specimens were tested for compressive strength of specimen. Compared with plain concrete, the compressive strength of hybrid fiber reinforced concrete with both basalt and polypropylene fibers with the volume fraction of 0.3% (P1B1) showed an increase of 11.15% of compressive strength of plain concrete. The remaining fiber combinations showed a gradual decrease in compressive strength of specimens in the range of 4.085% - 32.54% of compressive strength of plain concrete from chart 1. The reason may be drop in bonding capacity of the interface between fibers and concrete matrix due to aging.

Table -3: Results of compressive strength test

Specimen	Compressive strength at 28 days N/mm^2
Control mix	27.17
P1B1	30.2
P1B2	26.06
P1B3	21.17
P2B1	23.27
P2B2	22.83
P2B3	22.15
P3B1	22.08
P3B2	20.05
P3B3	18.33

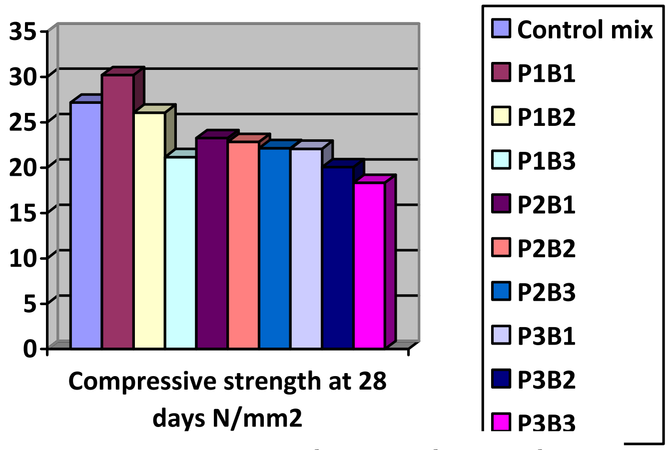

Chart -1: Compressive strength test results at 28 days

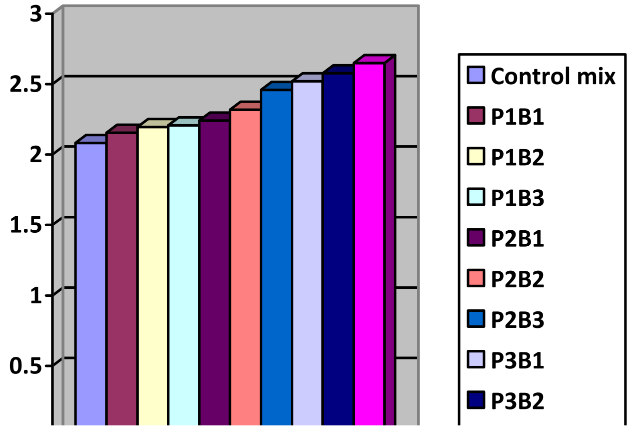

Chart -2: Splitting tensile strength test results at 28 days

days (N/mm2)

3.2 Spitting tensile strength

The results of splitting tensile strength of concrete specimens at 28 days are given in Table 4. The specimens were prepared with fiber combinations same as that prepared for compressive strength test. All these specimens were tested for splitting tensile strength of specimen. Compared with plain concrete, the tensile strength of hybrid fiber reinforced concrete with both basalt and polypropylene fibers with the volume fraction of 0.9% (P3B3) showed an increase of 27.2% of tensile strength of plain concrete specimen. The remaining fiber combinations showed a gradual increase in tensile strength of specimens up to 3.4% of tensile strength of plain concrete from chart 2. The reason may be the prevention of microcracks at earlier stage with the help of randomly oriented short fibers. This in turn delays the macro crack development thereby improving the tensile strength.

Table -4: Results of Splitting tensile strength test

Specimen	Splitting tensile strength at 28 days N/mm^2
Control mix	2.083
P1B1	2.154
P1B2	2.195
P1B3	2.207
P2B1	2.24
P2B2	2.319
P2B3	2.459
P3B1	2.519
P3B2	2.576
P3B3	2.65

3.3 Flexural strength

The results of flexural strength of concrete specimens at 28 days are given in Table 5. The specimens with and without notch were prepared with optimum fiber combinations obtained from compressive strength test. All these specimens were tested for third-point loading test for determining the flexural strength of specimen. Compared with plain concrete, the flexural strength of hybrid fiber reinforced concrete with both basalt and polypropylene fibers with the volume fraction of 0.3% and without notch showed an increase of 3.12 MPa of flexural strength of plain concrete specimen. The second maximum was obtained in hybrid fiber reinforced concrete with both basalt and polypropylene fibers with the volume fraction of 0.3% and with notch showed an increase of 1.335 MPa of flexural strength of plain concrete specimen. The remaining fiber combinations of hybrid fiber reinforced specimen without notch showed a gradual decrease in flexural strength of specimens up to 2.265 MPa of flexural strength of plain concrete from chart 3. The reason of drop in flexural strength may be difficulty in fiber dispersion beyond 0.3% of both the fibers of total volume fraction of the specimen (P1B1). In case of remaining notched specimens, there strength decreases up to 0.3 MPa. It was observed that P1B1 specimen without notch shows a flexural strength of 1.785 MPa greater than that of P1B1 specimen with notch. The reason for the early failure of notched specimens were the crack is predetermined and the region of notch experience greater stress than any other parts of the specimen. This in turn makes the notched specimens to lose its load carrying capacity and fail earlier than specimens without notch.

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Table -5: Results of Flexural strength test

COMBINATION	FLEXURAL STRENGTH(MPa)
CONTROL MIX	2.4
P1B1	5.52
NOTCHED P1B1	3.735
P2B1	5.025
NOTCHED P2B1	3.195
P3B1	4.665
NOTCHED P3B1	2.7

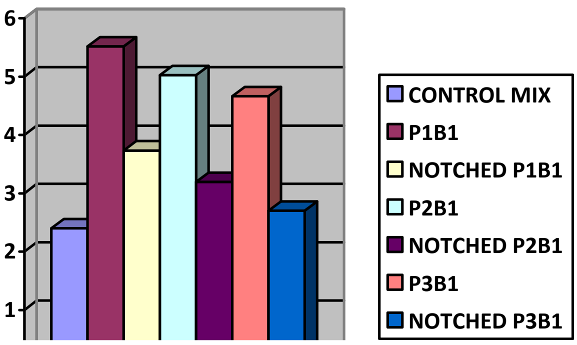

Chart -3: Flexural strength test results at 28 days

4. CONCLUSION

It was concluded that from the results obtained shows that addition of hybrid fibers to the concrete shows that the compressive strength of the specimen is increased to a maximum of 11.15% only for fiber combination of P1B1 than that of plain concrete. The compressive strength increases only for specimen with least fiber proportions. In contrast to compressive strength, the tensile strength of the specimens increases with increase in fiber combinations. The maximum increase in tensile strength is achieved in specimen with maximum fiber combination (i.e. P1B3). The flexural strength test indicated that the specimen with least fiber combination shows maximum increase in flexure strength up to 3.12MPa in case of specimen without notch(P1B1) and up to 1.335 MPa in case of specimen with notch(P1B1N). The flexural strength decreases thereafter as the fiber content was increased. The optimum fiber combination for the specimen with basalt and polypropylene combination as hybrid fiber is 0.3% of volume of specimen in hybrid fiber reinforced concrete specimen as an admixture for better performance. The notched specimens withstand lesser stress than that of specimens without notch

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