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Performance Evaluation Of Hybrid Fiber Reinforced Concrete

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Abstract: This study concentrates in determining the optimum fiber content in the Hybrid fiber reinforced concrete with glass and polypropylene fibers. Specimens for five mixes with varying total volume of fiber were casted. The percentages of fibers used are 0, 0.5, 1, 1.5, 2 by weight of cement using Glass fiber of 60% and Polypropylene fiber of 40% in the total fiber volume. The specimens were tested in compression, modulus of elasticity and modulus of rupture. The M1.0G60P40 showed increase in strength about 24.2%, 33.7% and 13.1% in compression, modulus of elasticity and modulus of rupture.

Index Terms: Aspect-ratio, Crack, Fiber, HFRC, Hybrid, Glass fiber, Polypropylene fiber, Workability.

1. INTRODUCTION

Infrastructure is the key to a country's economic growth and social development. Concrete is the simplest and versatile construction material compared to other construction materials. It is the most utilized construction material which results in better strength, flexural structure, better workability and durability [1]. However, Reinforced concrete (RC) shows more brittleness, also weak in tension and has lower shatter resistance, thus disappointments normally happen when exposed to impact loading. To overcome and increase the structural integrity, Fiber- reinforced concrete (FRC) which contains fibrous material which are consistently distributed and randomly arranged is utilized. Fibers improve penetration resistance, decline cavity sizes, control crack development, reduce damaged area, and improve the ductility of RC targets (e.g. beams and slabs), likewise the impact resistance of plain and reinforced concrete targets is comparatively. The character of FRC varies as per the type of concrete, fibers used and its geometries, distribution, orientation, and densities. Fiber-reinforced concrete (FRC) demonstrates significantly better engineering properties in elasticity, flexural strength, fracture toughness, and resistance to fatigue and impact [1, 2, 6]. Cement major component of concrete is a major contributor in environmental pollution since the cement industry emits huge volumes of CO_2. Thus the cement cannot be eliminated from concrete yet addition of fiber induces increase in strength characteristics in small grade of concrete which not only reduces the weight of elements but also increases the tensile strength of concrete. An appropriate combination of fibers produces better composite concrete than the individual fibers. FRC can be mostly set into two kinds (i) Mono fiber reinforced concrete(MFRC) (ii) Hybrid fiber strengthened concrete(HFRC). Single or Mono fiber reinforced contain just a single sort of fiber, it enhances the properties of FRC to a constrained dimension and is compelling just in strain and crack opening [1, 4]. Though, Hybrid fiber reinforced concrete can be characterized as the reinforced concrete mixture that has at least two fibers alongside alternate constituents of concrete. The presence of one fiber enables the more efficient utilization of the potential properties of the other fiber and thus enhancing engineering properties.

Results demonstrate that the geometrical properties of fibers are more influential than the material properties in improving the impact resistance of the hybrid-fiber reinforced slabs. The concept behind the hybrid fibers with two or more fiber types and sizes is that they could deliver synergistic effects through their diverse elastic properties and/or various sizes since micro-fibers can control the growth of micro-cracks, while large fibers restrain the growth of larger cracks [1, 5]. HFRC in contrast with MFRC distinctively exhibits higher/more compressive and tensile strength and stronger energy dissipation ability [3]. Fibers can be categorized into high modulus and high strength fibers like carbon, polyvinyl alcohol, steel, asbestos and glass fibers which can efficiently increases the strength of concrete but does not improve ductility. Low strength fibers like polypropylene, nylon and acrylic fibers improve ductility and reduce cracking [4].

2 SPECIMEN PREPARARTION

2.1 Materials

The PPC cement used is from Chettinad brand. The Fine aggregate used is M sand of specific gravity 2.57 and fineness modulus 3.7. Fig 1 shows Glass fiber of 12mm length brought from Sri Teja Enterprises, Chennai. Fig 2 shows Polypropylene fiber of 12mm brought from Kalyani polymers, Bengaluru. The properties of the fiber are listed in the table 1.

2.2 Mix proportions and mixing method

The design of concrete compositions for each mix is given in table 2. The total fiber volume is kept as 0%, 0.5%, 1.0%, 1.5% and 2% of cement weight. For each mix the in the total volume of fiber 60% of it is glass fiber and 40% is polypropylene fiber. The proportion of cement, M sand, coarse aggregate and water cement ratio 0.45 is kept as constant in all mixes. The mix was made with 400 kg/m3 of cement, 576 kg/m3 of M Sand, 516 kg/m3 of 10mm aggregate and 516 kg/m3 of 20mm aggregate. The fiber proportion used in each mix is listed in table 2. Each batch of mix is hand mixed. Initially the cement, M sand and coarse aggregate is thoroughly mixed and then the fiber is added and mixed again as shown in fig 3. At last the water is added and the mix is thoroughly mixed as shown in fig 4. Cubes of 150mm x 150mm x 150mm, Cylinders of diameter 150mm and 300mm

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height and Prisms of 500mm x 100mm x 100mm were casted. The compaction and curing was done in accordance with IS 516-1959.

Figure 1 *12mm Glass fiber*

Figure 2 *12mm Polypropylene fiber*

Table 1 *Properties of fiber*

PROPERTY	GF	PPF
Aspect Ratio	400	600
Diameter (mm)	0.03	0.02
Elongation%	4.8	-
Length(mm)	12	12
Melting Point(ºC)	165	-
Tensile Strength(MPa)	500	3450

Figure 3 *Mix before adding water*

Figure 4 Mix after adding water

***Table 2** Percentage of Fiber in mix*

MIX NAME	CEMENT (kg/m^3)	M SAND (kg/m^3)	CA 10mm (kg/m^3)	CA 20mm (kg/m^3)	TOTAL FIBER %	GF %	GF (kg/m^3)	PPF %	PPF (kg/m^3)	WATER (l/m^3)
M0G0P0	400	576	516	516	-	-	-		-	180
M0.5G60P40	400	576	516	516	0.5	0.3	1.2	0.2	0.8	180
M1.0G60P40	400	576	516	516	1	0.6	2.4	0.4	1.6	180
M1.5G60P40	400	576	516	516	1.5	0.9	3.6	0.6	2.4	180
M2.0G60P40	400	576	516	516	2	1.2	4.8	0.8	3.2	180

(a) Slump test (b) Compressive test

(c) Split tensile test (d) Flexural test

Figure 5

***Table 3** Slump value*

MIX	SLUMP (mm)	TYPE OF SLUMP	DEGREE OF WORKABILITY AS PER IS 456:2000
M0G0P0	100	True slump	Medium
M0.5G60P40	90	True slump	Medium
M1.0G60P40	83	True slump	Medium
M1.5G60P40	75	True slump	Medium
M2.0G60P40	69	True slump	Medium

3 TESTING

The workability of the fresh concrete of the mixes in table 2 was determined by slump cone test as per IS 1199- 1959 as shown in Figure 5(a). The slump value was found by determining the difference between the height of the mould and the highest point of the specimen being tested. As shown in figure 5(b), 5(c) and 5(d) for all the cube, cylinder and prism specimens 7th, 14th and 28th day strengths in compression, split tensile and flexural was determined in accordance with IS 516 – 1959, IS 5816- 1999 and IS 516- 1959 respectively.

4 RESULTS AND DISCUSSION

4.1 Effects of fiber in workability

The results from the slump cone test for the mixes are shown in table 3. It is found that the addition of the fibers resulted in less workability of the mix. As the fiber volume increased the workability of the mix decreased. An average reduction of 20.75mm in slump value was observed. Also during casting, the increase in the balling of fibers was witnessed as the volume of the fiber increased.

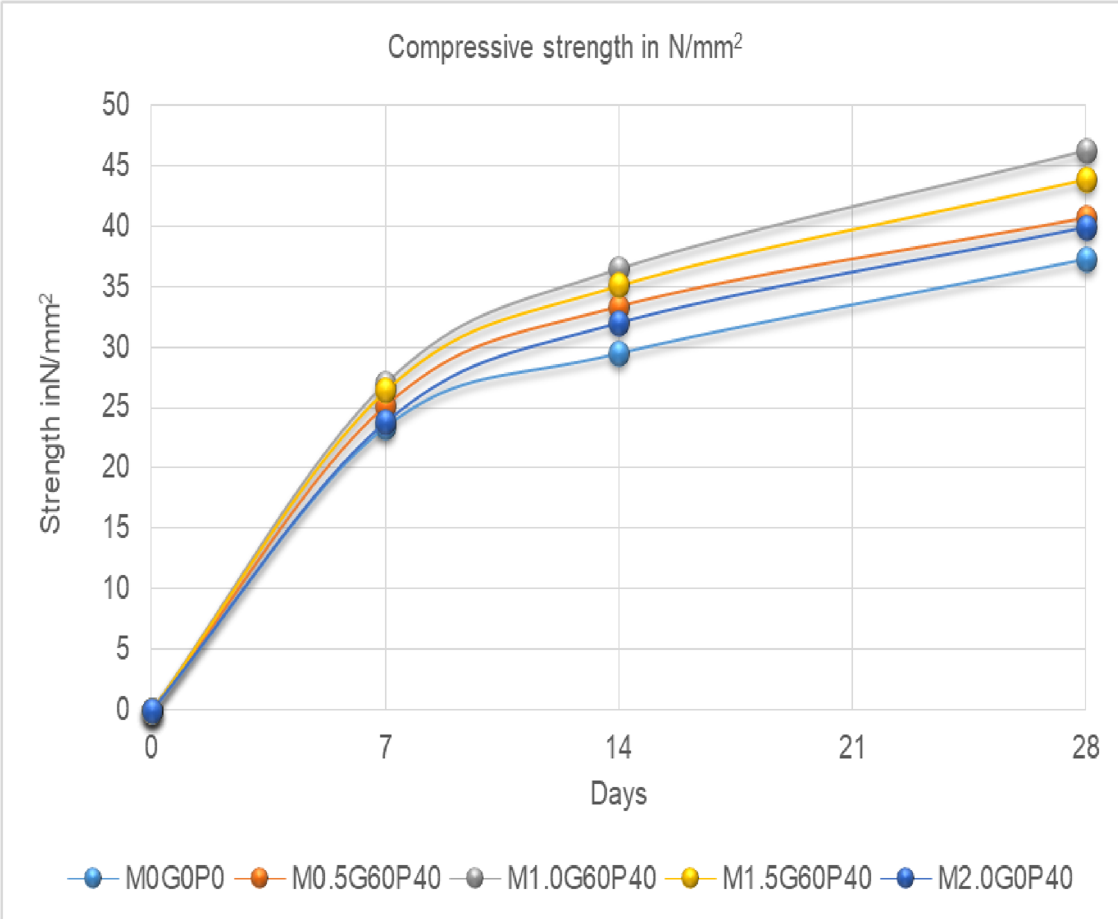

Fig 6 *Compressive strength*

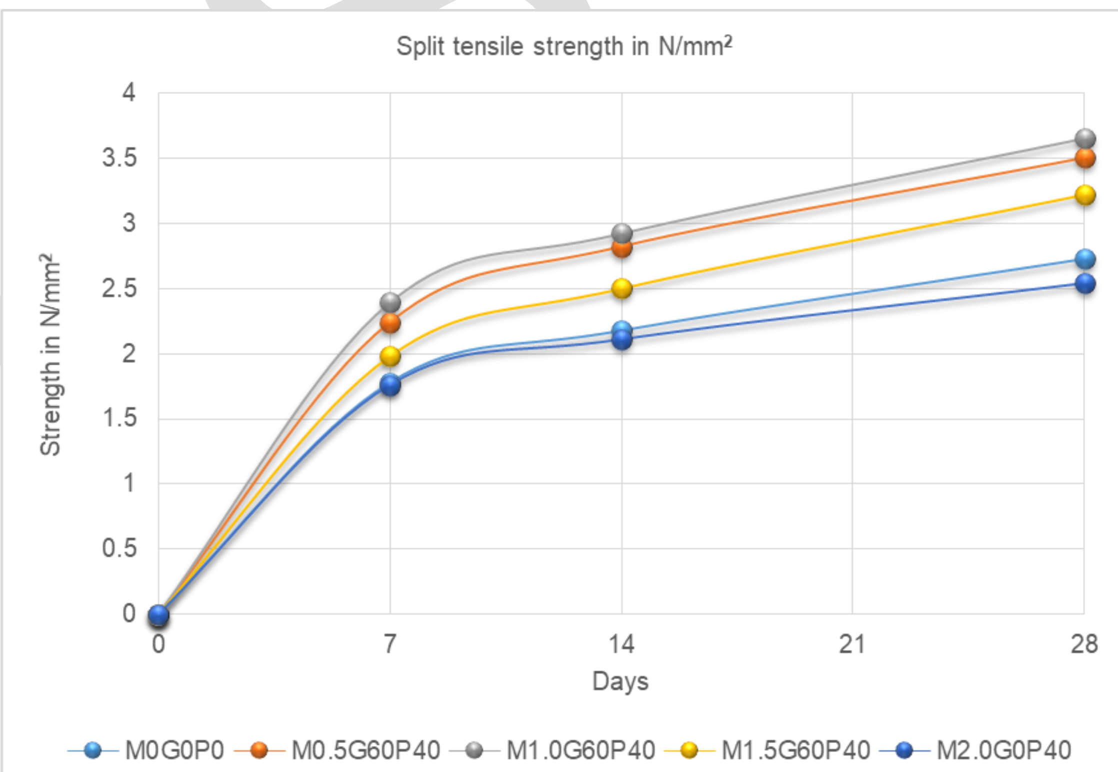

Fig 7 *Split tensile strength*

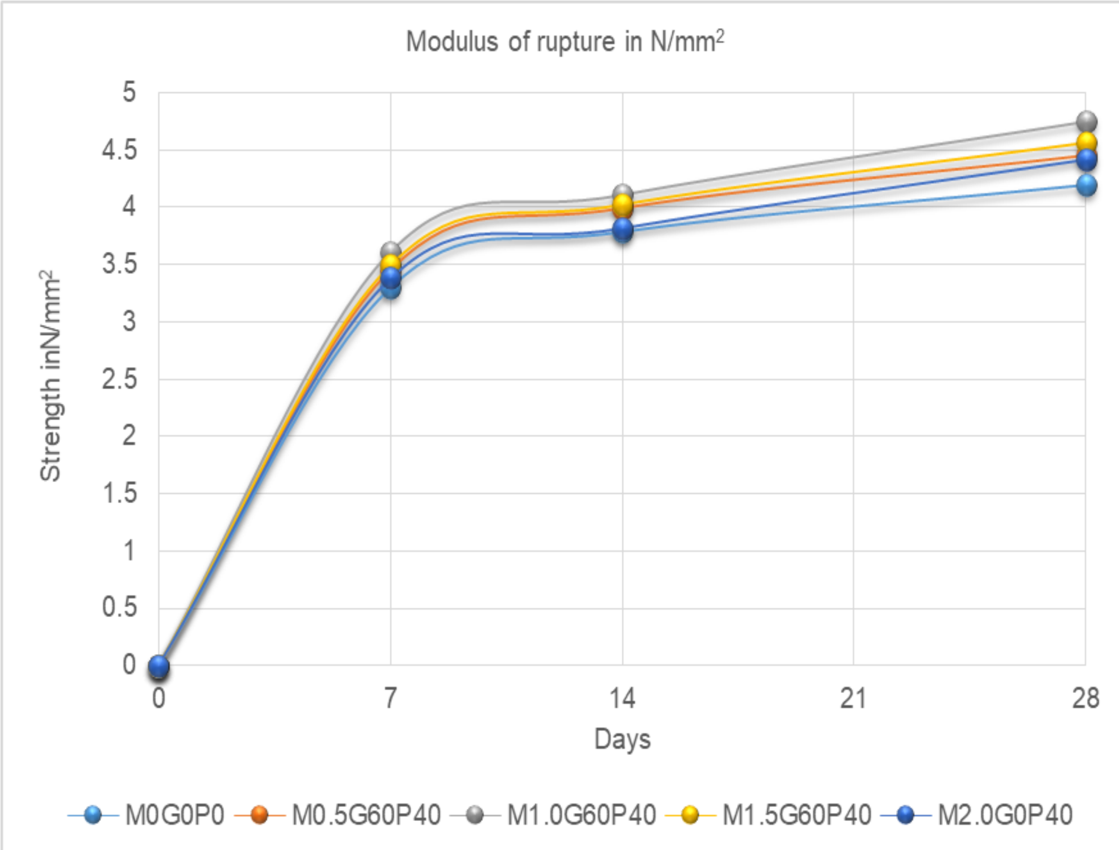

Fig 8 *Modulus of rupture*

MIX	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)		
	7th DAY	14th DAY	28th DAY
M0G0P0	23.37	29.45	37.21
M0.5G60P40	25.14	33.34	40.65
M1.0G60P40	26.98	36.44	46.2
M1.5G60P40	26.4	35.11	43.92
M2.0G60P40	23.7	32	39.89

4.2 Compressive strength

The results of the compressive strength are shown in table 4. The fig 6 shows the increase the compressive strength as the fiber volume increases. However, when the total fiber volume is increased more than 1% the reduced in strength was observed. The Mix M1.0G60P40 showed an increase in strength about 24.2% than the controlled mix. The compressive strength of M1.5G60P40 mix decreased gradually about 5.2% compared to the mix M1.0G60P40.

Table 4 *Compressive strength of Mixes*

4.3 Split tensile strength

Table 5 shows the strength in split tensile test. The fig 6 shows the increase the compressive strength as the fiber volume increases The Mix M1.0G60P40 showed an increase in strength about 33.7% than the controlled mix. The splitting tensile strength of M1.5G60P40 mix decreased gradually about 13.4% compared to the mix M1.0G60P40.

Table 5 *Split tensile strength of Mixes*

MIX	AVERAGE SPLIT TENSILE STRENGTH (N/mm^2)		
	7th DAY	14th DAY	28th DAY
M0G0P0	1.78	2.18	2.73
M0.5G60P40	2.24	2.82	3.5
M1.0G60P40	2.39	2.92	3.65
M1.5G60P40	1.98	2.5	3.22

M2.0G60P40	1.76	2.11	2.54

4.4 Flexural strength

The average flexural strength is shown in table 6. The fig 6 shows the increase the compressive strength as the fiber volume increases. The Mix M1.0G60P40 showed an increase in strength about 13.1% than the controlled mix. The splitting tensile strength of M1.5G60P40 mix decreased gradually about 4.2% compared to the mix M1.0G60P40.

Table 6 *Flexural strength of Mixes*

`MIX	AVERAGE FLEXURAL STRENGTH (N/mm2)		
	7th DAY	14th DAY	28th DAY
M0G0P0	3.3	3.79	4.2
M0.5G60P40	3.45	3.99	4.45
M1.0G60P40	3.61	4.11	4.75
M1.5G60P40	3.49	4.02	4.56
M2.0G60P40	3.38	3.82	4.42

(a)

(b)

Fig 9 *Crack after testing*

5 CONCLUSION

- A good bonding between the fiber and the concrete was found after testing. It may be due to the random orientation of the fibers which prevented the crack propagation in the concrete.
- The hybrid fiber mixes shows higher strength in compression, modulus of elasticity and modulus of rupture compared to the controlled mix.
- It is found that the strength of the mixes increases with the increase in the fiber dosage.
- However, the hybrid mixes show higher strength than the controlled mixes compression, modulus of elasticity and modulus of rupture. Thus the addition of fiber increased the strength properties of the mix.
- The reduction in strength at the increase of fiber volume may be due to the jamming of fiber in the bonding of concrete.
- The hybrid fiber mixes showed smaller crack pattern than the controlled specimen.
- The fig 9 (a) and (b) shows that the fiber helps in bridging the crack.

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