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Investigating the Strength of Hybrid Fiber Reinforced Concrete through Experimental Analysis

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Abstract: Cementitious materials are among the most commonly used and essential substances in the construction industry. While these materials are initially incorporated into well-established systems and fundamental designs during the construction process, their inherent fragility and susceptibility to cracking under stress necessitate ongoing maintenance or even replacement within a relatively short lifespan. To address this issue, there is a growing need for new concrete-based materials with improved durability characteristics, particularly in terms of crack resistance. Traditional concrete, being a brittle material, has been largely replaced by fiber-reinforced concrete due to its enhanced properties. While using a single type of fiber can have beneficial effects on the mechanical properties of concrete, hybridization offers the opportunity to combine different fiber types to leverage their respective advantages. In this study, the influence of incorporating both glass fiber and polypropylene fiber into concrete mixes is examined to evaluate the mechanical properties of the composite material. Fifteen cubes and fifteen cylinders of glass fiber-reinforced concrete (GFRC) at varying proportions (0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2% by volume of M30 grade concrete) were cast and tested for optimal compressive and tensile strength at 28 days. Additionally, three-dimensional specimens with different proportions of polypropylene fiber were cast, while maintaining the glass fiber content constant, to identify the ideal combination for enhancing mechanical strength. The results indicate that the hybrid fiber-reinforced concrete (HFRC), comprising 1% glass fiber and 0.6% polypropylene fiber, exhibits improved compressive, tensile, flexural, and shear properties compared to conventional concrete.

Key words: Hybrid fiber reinforced concrete (HFRC)**,** Glass fiber, Polypropylene fiber, compressive strength test, Flexural, Split Tensile test, Shear behavior.

INTRODUCTION

Using ACI Board 544, the long-fiber maintained concrete (FRC) is described as a substantial manufactured from water-pushed cements comprising extraordinary or amazing and coarse amounts and harmed distinct strands. Typically, flexible stacking is supported by brittle concrete. Concrete's mechanical properties may be improved with the assistance of support provided by haphazardly positioned, swiftly separated strands that stop and provide initiation, cause, or a combination of breakdowns. FRC can keep track of assisting significant numbers of people at night at routes avoiding essential concrete's smash routes. Fundamentally, socioeconomic class matters since the individual and execution of FRC are both impacted by the fibre material, focus, shape, course, and dissemination. FRC is most likely considered of as a two-level composite material, with fibre filling for the thinking level and considerable filling for the framework level.
The degree period of fibre thinking is the most often utilised limit that is visible with the characteristics of FRC. These include fibre check, fibre express floor area, and fibre dissipation, among other variables. Another helpful mathematical size for representing a fibre is the

perspective degree, which is depicted taking into account how the fibre length is remoted with the help of employing its near distance across. Fiber sorting is most often divided into a number of classes. Asbestos, glass, steel, and carbon are examples of materials with more fundamentally bendable moduli, while cellulose, nylon, and polypropylene are examples of flexible materials with moduli that are less flexible than the bulk structure. Another association, such as metallic, polymeric, or standard, is dependent at the first stage of the fibre material. The estimated composition and characteristics of typical strands are shown in Table 1.

Table 1. Typical Properties of Fibers

Type of Fiber	Tensile Strength (MPa)	Young's Modulus (GPa)	Ultimate Elongation %	Specific Gravity
Acrylic	210-420	2.1	25-45	1.1
Asbestos	560-980	84-140	0.6	3.2
Carbon	1800-2600	230-380	0.5	1.9
Glass	1050-3850	70	1.5-3.5	2.5
Nylon	770-840	4.2	16-20	1.1
Polyester	735-875	8.4	11-13	1.4
Polyethylene	700	0.14-0.42	10	0.9
Polypropylene	560-770	3.5	25	0.9
Rayon	420-630	7	10-25	1.5
Rock Wool	490-770	70-119	0.6	2.7
Steel	280-2800	203	0.5-3.5	7.8

FRC can be utilized in an assortment of ways. For an extensive stretch, asbestos filaments have been utilized in pipes and slim sheet segments. Glass filaments are additionally utilized in the production of slim sheet components and in concrete applications. Steel strands have been used in the development of asphalts, shotcrete, and a scope of different developments. Plastic shrinkage cracks are controlled with polypropylene filaments [2-4]. As new fiber types and FRC fabricating measures are grown, new application regions become open.

LITERATURE REVIEW

KANNAN.S,et al.,(2017) , The discoveries of the exploratory tests showed that adding treated steel, glass, and polypropylene filaments at 1%, 0.75 percent, and 1% separately expanded the strength by 37.45 percent, 39.41 percent, and 27.62 percent in pressure, strain, and flexure following 28 days. When contrasted with a reference blend plan, the conduct of concrete under load was reliably improved. Hence, a framework with volume part hybridization of 1% treated steel, 0.75 percent glass, and 1% polypropylene filaments was resolved to be the ideal blend with synergetic response as far as mechanical qualities.

As indicated by the discoveries of this examination, the compressive, split ductile, and flexural strength of HFRC02 expanded by 37.42, 39.41, and 27.62 percent, individually. By adding 0.75 percent fiber to the volume of cement, the blend (GFR C02) was demonstrated to be effective in pressure, strain, and flexure, with rate increments of 14.12, 17.58, and 4.19, individually. The blend (SSFRC03) with 1% fiber to the volume of concrete was resolved to be ideal in SSFRC, with expansions in pressure, strain, and flexure of 26.57 percent, 28.71 percent, and 17.54 percent, separately.

AvinashThakur, HemantSood et al.,(2017) , This examination gives an outline of the attributes of a few filaments used in underlying applications. What's more, a short outline of distributions on different filaments and the utilization of regular and manufactured strands to further develop concrete attributes is featured. The strength qualities of crossover fiber Sisal/polypropylene supported concrete will be the subject of this examination.

As indicated by the discoveries of this examination, both Sisal and Polypropylene fiber in concrete blend cause a drop in droop esteem, which impacts consistency. The best Sisal fiber measurement for utilization in concrete blend was 1-1.5 percent, while the ideal Polypropylene fiber dose was 0-0.5 percent.

Vineetha V. ,AryaAravind et al.,(2017) At volume parts of 0.5 percent, 0.75 percent, 1%, 1.25 percent, and 1.5 percent, the mixture fiber, a blend of polypropylene and nylon filaments, is utilized to work on the strength of concrete. The mechanical attributes of concrete, like compressive strength, split elasticity, and flexural strength characteristics, are examined, just as the bond strength of the concrete utilizing a pullout test.

According to the findings of this experiment, the compressive strength of concrete with 25% coarse aggregate replaced by recycled concrete aggregate is lower. The addition of nylon and polypropylene fibre to concrete using recycled concrete aggregate increased the concrete's split stiffness, flexural strength, and compressive strength. As the extent of the strands increases up to 1%, then declines after that, the strength of mixed fiber-built concrete with recycled aggregate increases. According to the test data, the example with a 1% fibre content and a 25% and 75% combination of polypropylene and nylon strands produced more common outcomes than the others.

MATERIALS AND METHODOLOGY

By altering the proportion of cement substitution with silica fume and maintaining a fixed percentage of nano aluminium oxide (Al203), an experimental examination has been planned to examine the impact of these materials on concrete. Six concrete mixes, including one nominal mix, were created. Each combination was used to cast 9 cubes, 9 cylinders, and 9 beams, which were then given 3, 7, and 28 days to cure. To determine the changes in concrete strength, tests were conducted on the test specimens.

BASIC TESTS ON MATERIALS:

Fineness of cement:

The rate of hydration and, thus, the rate of strength growth are substantially influenced by cement fineness. The fineness of the cement affects how quickly heat accumulates. A greater surface area for hydration is provided by finer cement, hastening the development of strength. Structures develop fractures as a result of concrete's tendency to shrink as cement's fineness increases.

Observations and calculations:

Trial no.	1	2	3
Weight of cement in gms	100	100	100
Wt. Of residue on sieve in gms.	2.5	2.3	2.4
Amount retained (%)	2.5%	2.3%	2.4%

Fineness of cement = 2.4%

Specific gravity of cement:

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A cement sample's weight and the volume of the liquid it displaces are measured in order to calculate the specific gravity. The liquid that will be utilised has to be neutral in terms of chemical reactions. Additionally, the liquid with a purpose to be utilised ought to be selected in order that it has no bodily interactions with the cement, along with absorption. If polar beverages are employed, their density withinside the regions straight away subsequent to the cement particle floor might be better than the loose liquid's density elsewhere. Additionally, the cement ought to now no longer encompass any aggregated debris with inner voids; otherwise, the density will handiest be assessed on a mean basis.

OPC typically has a specific gravity of 3.15 on average. If a particular cement sample has a specific gravity reading that deviates noticeably from 3.15, the sample's quality could be in question. The cement will have a reduced specific gravity if clays, ground sand, fly ash, and other contaminants were included.

Formula:

$$\text{Specific gravity} = \frac{weight\ of\ cement}{volume\ of\ cement}$$

Observations of specific gravity of cement test.

S. No.	Initial residing	Final reading	Volume Of cement (v)	Specific gravity G=W/V
1	0	19.75	19.75	3.24

Calculations:

Specific gravity of cement = 3.24

Normal consistency of cement:

The cement paste needs to be of a regular consistency so that the Vicat plunger can pierce it up to 5 to 7 mm from the Vicat mould's base. Cement paste stiffens and loses fluidity when water is added, causing it to harden and stiffen.

Observations of consistency of cement test.

% of water	Initial reading	Final reading	Height not penetrated (mm)
26%	50	32	18
28%	50	20	30
30%	50	12	38
32%	50	7	43

Normal consistency of cement =32%

Initial setting time:

The first setting time is the period of time required for the paste to solidify to the point when the vicat needle can no longer pierce it more than 5 millimetres (mm) from the mold's base.

Figure 3.8: vicat apparatus

Observations and calculations:

Weight of cement taken = 300gm.

Weight of water taken = 81.6ml

Where p is the normal consistency.

Table: Observations of initial setting time of cement test.

Time(minutes)	10	20	30	40	50	60
Initial reading	50	50	50	50	50	50
Final reading	0	1	2	2.5	3.5	5
Height not penetrated	50	49	48	47.5	46.5	45

Initial setting time of cement = 60 minutes.

Specific gravity of coarse aggregate:

In concrete technology, the design computation of concrete mixtures uses aggregate specific gravity. Knowing each component's specific gravity allows one to translate their weight into solid volume, which allows one to determine the potential yield of concrete per unit volume. When using the workability data to calculate the compacting factor, the aggregate's specific gravity is also necessary. Similar to how it is necessary to take aggregate specific gravity into account when dealing with light weight and heavy weight concrete. The aggregates' average specific gravity ranges from 2.6 to 2.8.

Formula:

Specific gravity = $\frac{(w2-w1)}{(w2-w1)-(W3-w4)}$

Observations of Specific Gravity of 20 mm coarse aggregate:

	Trial-1	Trial-2
Weight of empty specific gravity bottle(gms)(W1)	460	460
Weight of bottle + aggregate(gms)(W2)	1235	1230
Weight of bottle + aggregate + water(gms)(W3)	1695	1690
Weight of bottle + water(gms)(W4)	1215	1215
Specific gravity	2.627	2.61

Specific gravity of 20mm coarse aggregate = 2.62

Table: Observations of Specific Gravity of 12 mm of coarse aggregate:

	Trial-1	Trial-2
Weight of empty specific gravity bottle(gms)	460	460
Weight of bottle + aggregate(gms)	1220	1210
Weight of bottle + aggregate + water(gms)	1695	1695
Weight of bottle + water(gms)	1215	1215
Specific gravity	2.714	2.77

Specific gravity of 12mm of coarse aggregate =2.74

Specific gravity of fine aggregate:

The weight of mixture on the subject of the burden of an equal quantity of water is referred to as precise gravity. In order to decide the moisture content material and calculate the quantity yield of concrete, calculations related to cement concrete layout paintings normally name for the precise gravity of a mixture. The specific gravity also reveals details about the characteristics and quality of aggregate. The strength and quality of a material are thought to be gauged by the specific gravity of the aggregate. Low specific gravity stones are often more brittle than those with higher specific gravity values.

Table: Observations of Specific gravity of Fine aggregate:

	Trial-1	Trail-2
Weight of empty specific gravity bottle(gms)	460	460
Weight of bottle + aggregate(gms)	1230	1230
Weight of bottle + aggregate + water(gms)	1660	1652
Weight of bottle + water(gms)	1215	1215
Specific gravity	2.37	2.316

Average Specific gravity = (2.37+2.316)/2= 2.343
Specific gravity of fine aggregate = 2.343

Sieve analysis of fine aggregate:

The sum of all possibilities retained on sieves of the present sizes, multiplied by 100, is the fineness modulus of a mixture. It might be thought of as a length of weighted standard sieve on which the material is maintained, with the sieves numbered beginning with the finest (for the reason one hundred fifty micron sieve is taken because the lowest). A grading curve is a graphical representation of the results of sieve evaluation, where the ordinate at the normal scale denotes the proportion passing for each sieve and the abscissa denotes the corresponding sieve establishing plotted on a log scale in a semi-log paper.

Observations and calculations:

S. No.	Sieve sizes Mm	Weight retained	%age weight retained	Cumulative %age of weight retained(F)	%age weight passing	Cumulative %age weight passing
1	4.75	0	0	0	100	100
2	2.36	95	9.5	9.5	90.5	190.5
3	1.18	271	27.1	36.6	63.4	253.9
4	600µ	295	29.5	66.1	33.9	287.8
5	300µ	309	30.9	97	3	290.8
6	150µ	30	3.0	100	0	290.8

The fineness modulus of fine aggregate = 3.09

RESULTS AND ANALYSIS

With Glass fibers
Workability (Slump cone Test)

S. No	% GF	Slump in mm
1	Normal mix	60
2	0.20%	55
3	0.40%	50
4	0.60%	40
5	0.80%	30
6	1%	25
7	1.20%	25

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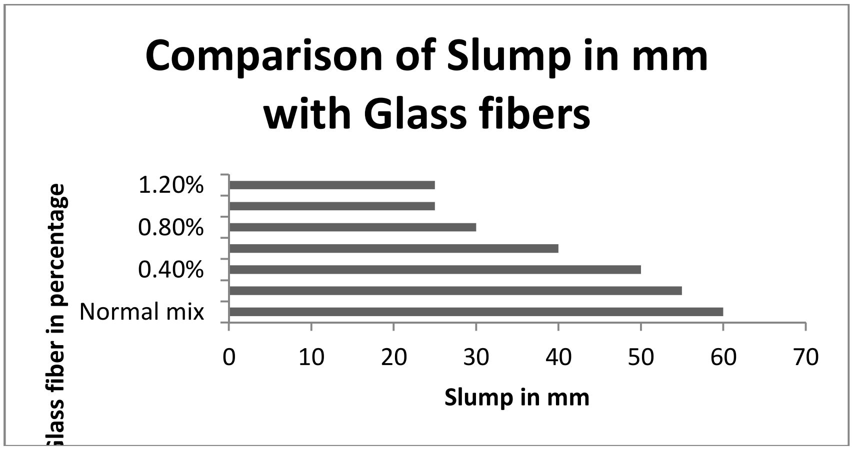
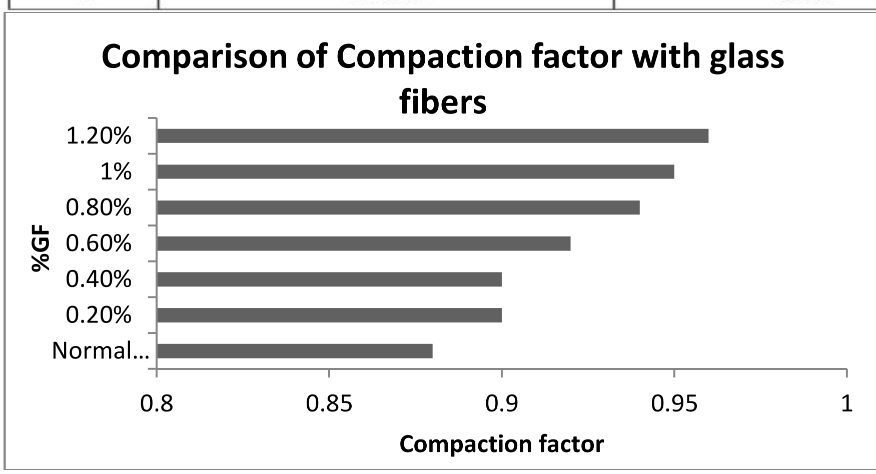


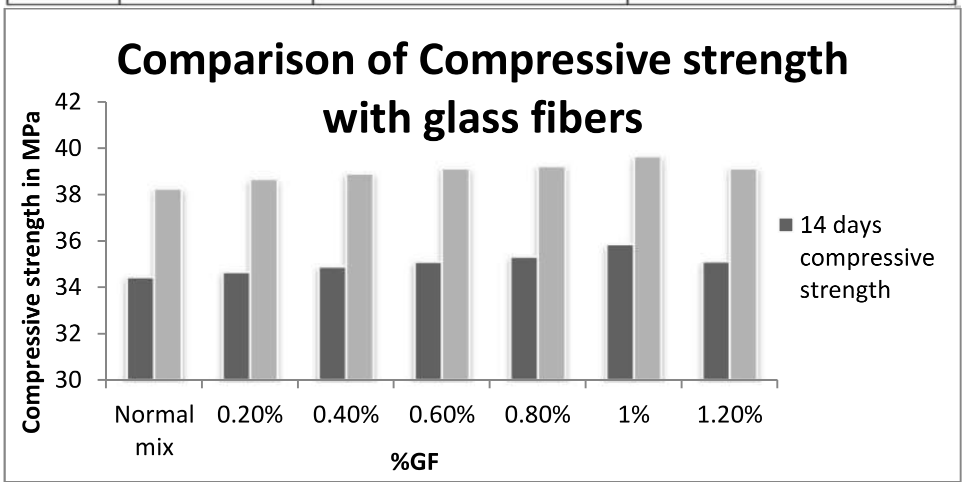
Compaction factor test

S. No	% GF	Compaction factor
1	Normal mix	0.88
2	0.20%	0.9
3	0.40%	0.9
4	0.60%	0.92
5	0.80%	0.94
6	1%	0.95
7	1.20%	0.96



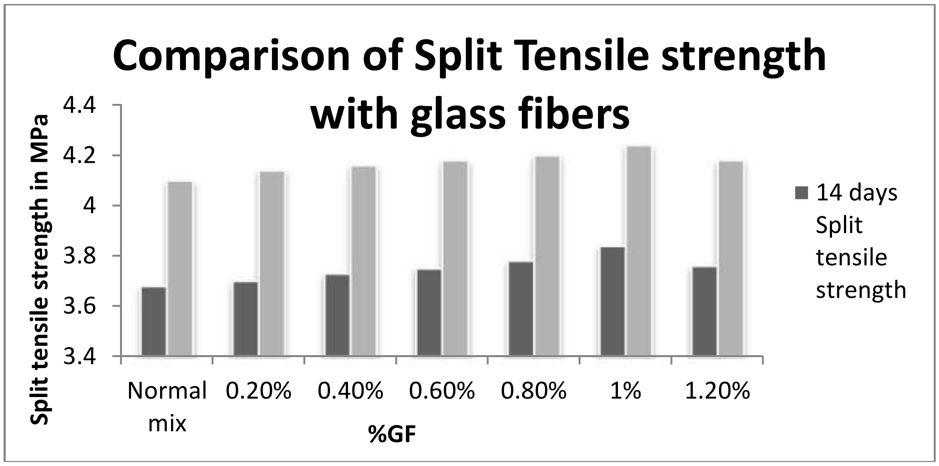
Compressive strength

S. No	% GF	14 days compressive strength	28 days compressive strength
1	Normal mix	34.44	38.25
2	0.20%	34.66	38.66
3	0.40%	34.9	38.9
4	0.60%	35.1	39.12
5	0.80%	35.33	39.22
6	1%	35.86	39.64
7	1.20%	35.12	39.12



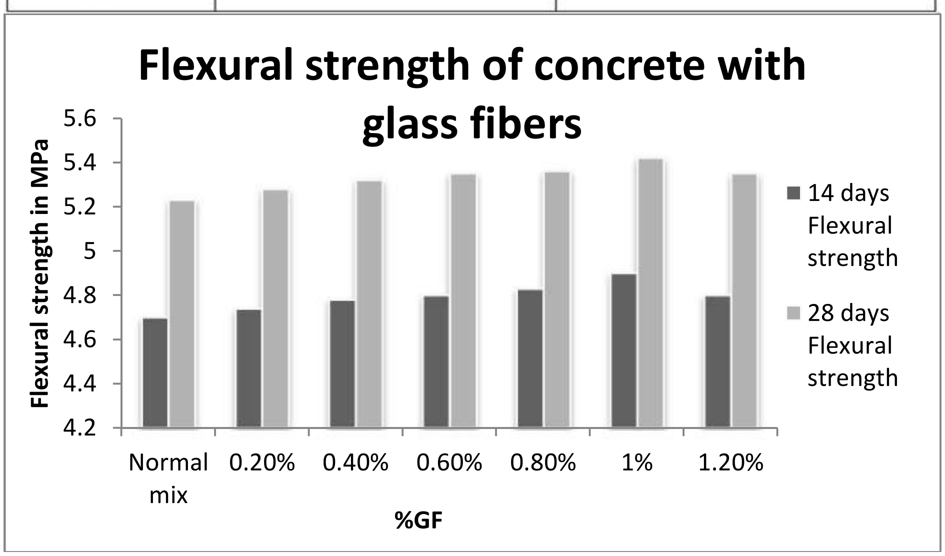
Split tensile strength

S. No	% GF	14 days Split tensile strength	28 days Split tensile strength
1	Normal mix	3.68	4.1
2	0.20%	3.7	4.14
3	0.40%	3.73	4.16
4	0.60%	3.75	4.18
5	0.80%	3.78	4.2
6	1%	3.84	4.24
7	1.20%	3.76	4.18



Flexural strength

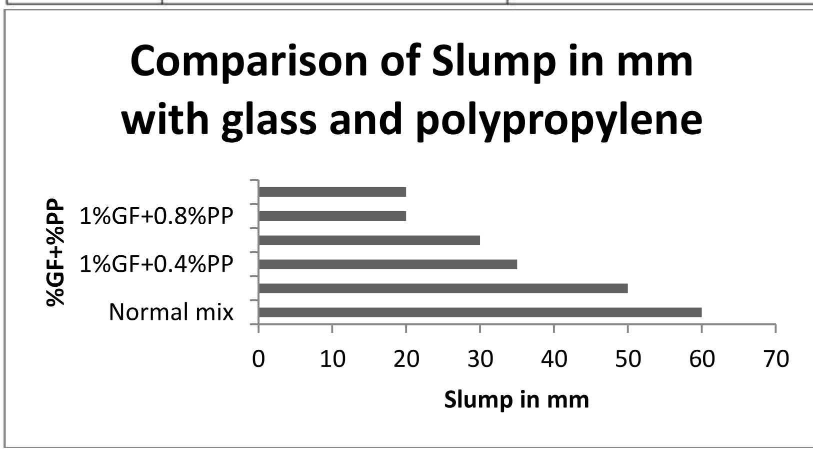
% GF	14 days Flexural strength	28 days Flexural strength
Normal mix	4.7	5.23
0.20%	4.74	5.28
0.40%	4.78	5.32
0.60%	4.8	5.35
0.80%	4.83	5.36
1%	4.9	5.42
1.20%	4.8	5.35



With Glass fibers and Polypropylene

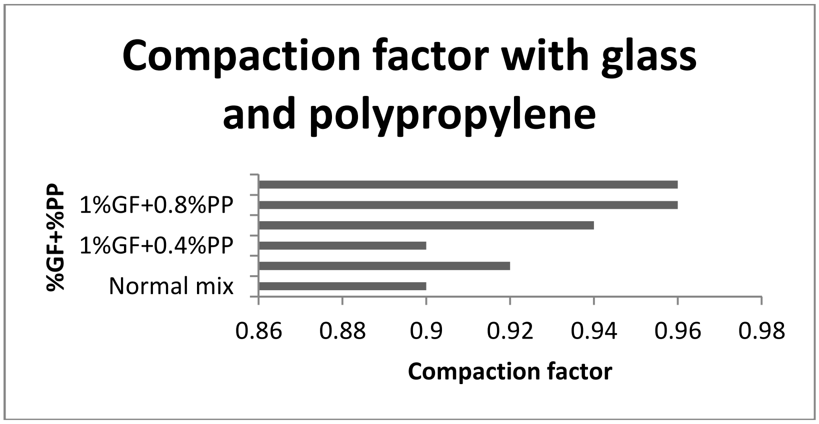
Workability (Slump cone test)

S. No	% GF+%PP	Slump in mm
1	Normal mix	60
2	1%GF+0.2%PP	50
3	1%GF+0.4%PP	35
4	1%GF+0.6%PP	30
5	1%GF+0.8%PP	20
6	1%GF+1%PP	20



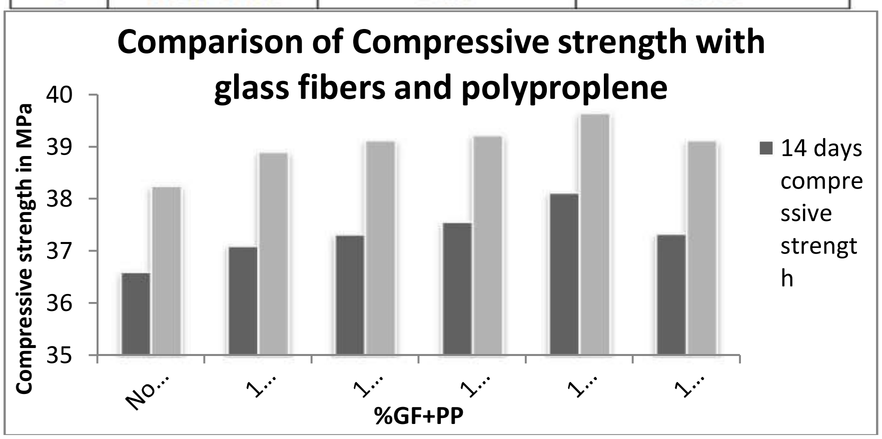
Compaction factor

S. No	% GF+%PP	Compaction factor
1	Normal mix	0.9
2	1%GF+0.2%PP	0.92
3	1%GF+0.4%PP	0.9
4	1%GF+0.6%PP	0.94
5	1%GF+0.8%PP	0.96
6	1%GF+1%PP	0.96



Compressive strength

S. No	% GF+%PP	14 days compressive strength	28 days compressive strength
1	Normal mix	36.6	38.25
2	1%GF+0.2%PP	37.1	38.9
3	1%GF+0.4%PP	37.32	39.12
4	1%GF+0.6%PP	37.56	39.22
5	1%GF+0.8%PP	38.12	39.64
6	1%GF+1%PP	37.33	39.12



Split tensile strength

S. No	% GF+%PP	14 days Split tensile strength	28 days Split tensile strength
1	Normal mix	3.92	4.1
2	1%GF+0.2%PP	3.97	4.16
3	1%GF+0.4%PP	3.99	4.18
4	1%GF+0.6%PP	4.02	4.2
5	1%GF+0.8%PP	4.08	4.24
6	1%GF+1%PP	4	4.18

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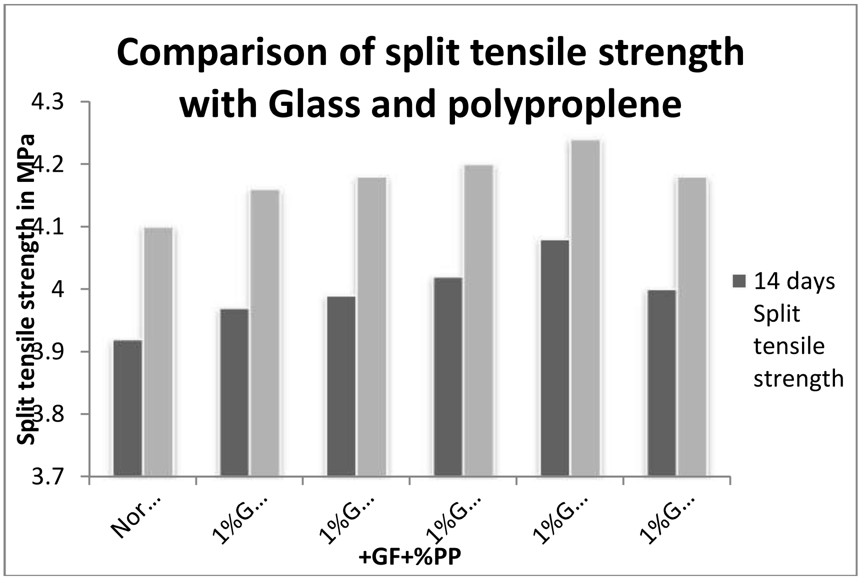
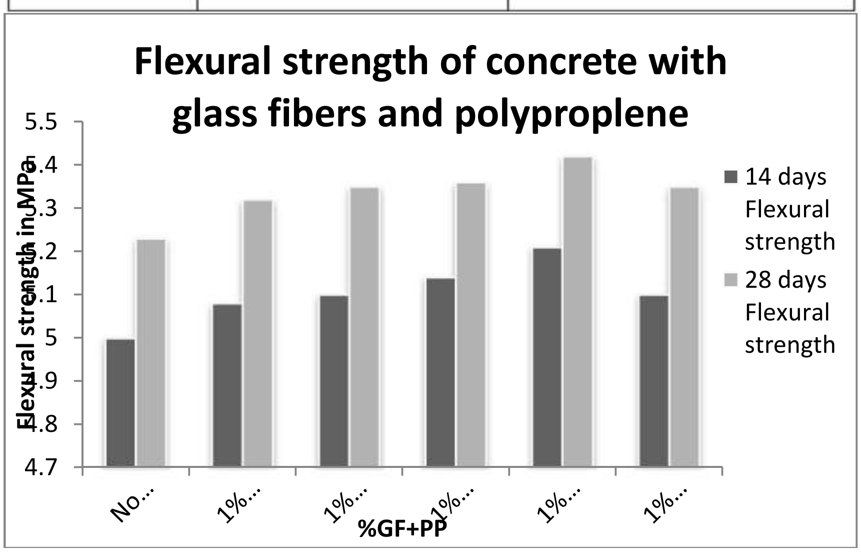


Flexural strength

% GF+%PP	14 days Flexural strength	28 days Flexural strength
Normal mix	5	5.23
1%GF+0.2%PP	5.08	5.32
1%GF+0.4%PP	5.1	5.35
1%GF+0.6%PP	5.14	5.36
1%GF+0.8%PP	5.21	5.42
1%GF+1%PP	5.1	5.35



CONCLUSIONS

If two or more different types of fibres are purposefully combined in a common matrix to create a composite that benefits from each type of fibre and exhibits a synergetic response, the composite is said to be hybrid. FRC may be thought of as a multi-layered composite fabric where fibre serves as the inclusion section and concrete serves as the matrix section. As the percentage of fibres in concrete increases, the stoop cone charge falls. The levels of compaction will rise as the fraction of fibres grows. At 1% glass fibres throughout the whole 14-day and 28-day curing, the most usable values of compressive electricity, cut-up tensile electricity, and flexural electricity are attained. 5. By combining 0.8% polypropylene fibres with 1% glass fibres, the compressive electricity will increase and the best price will be obtained once again.

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