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Experimental Investigation of Strength in Hybrid Fiber-Reinforced Concrete

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ABSTRACT

This experimental investigation into hybrid fiber-reinforced concrete (HFRC) has highlighted the significant improvements in mechanical properties achievable through the strategic combination of different fiber types. The results demonstrate that incorporating both steel and polypropylene fibers into the concrete matrix enhances its compressive strength, tensile strength, and toughness compared to conventional concrete mixes. The optimal blend of fibers not only improves load-bearing capacity but also increases ductility and resistance to cracking, making HFRC a viable option for various structural applications.

The study indicates that the synergistic effect of hybrid fibers contributes to a more uniform stress distribution within the concrete, which is crucial for enhancing durability and performance under dynamic loading conditions. Specifically, the incorporation of steel fibers improves the concrete's ability to resist tensile forces, while polypropylene fibers provide effective control over plastic shrinkage and enhance post-cracking behavior.

These findings advocate for the adoption of hybrid fiber reinforcement in concrete technology as a means to produce more resilient and durable structures. The successful integration of different fiber types presents a promising avenue for developing high-performance concrete that meets the demands of modern construction practices.

Future research should focus on investigating the long-term performance of HFRC in various environmental conditions and exploring the cost-effectiveness of using hybrid fiber reinforcement in large-scale applications. Overall, this study contributes valuable insights into the potential of hybrid fiber-reinforced concrete as a sustainable solution for enhancing the strength and durability of concrete structures.

I.INTRODUCTION

1.1 General

The construction industry continually seeks innovative materials and methods to enhance the performance and durability of concrete structures. Among the various advancements in concrete technology, fiber reinforcement has emerged as a promising solution to address the inherent weaknesses of conventional concrete, particularly its low tensile strength and susceptibility to cracking. While traditional reinforcement methods, such as steel bars, have been widely used, the incorporation of fibers into concrete mixes offers significant advantages, including improved toughness, ductility, and impact resistance.

Hybrid fiber-reinforced concrete (HFRC), which combines two or more types of fibers, has gained increasing attention due to its ability to leverage the strengths of different fiber materials. Steel fibers are renowned for their high tensile strength and ability to improve the load-carrying capacity of concrete, while polypropylene fibers provide excellent resistance to plastic shrinkage cracking and enhance post-cracking behavior. The strategic combination of these fibers can create a composite material that exhibits superior mechanical properties compared to conventional concrete or those reinforced with a single fiber type.

This study aims to investigate the effects of hybrid fiber reinforcement on the strength characteristics of concrete. By varying the proportions of steel and polypropylene fibers, the research seeks to identify the optimal mix design that maximizes mechanical performance. Comprehensive testing, including compressive strength, tensile strength, and flexural strength assessments, will provide valuable insights into the effectiveness of hybrid fiber reinforcement in improving the overall durability and resilience of concrete structures.

The findings of this investigation will contribute to the growing body of knowledge on fiber-reinforced concrete, offering practical implications for the design and construction of high-performance concrete structures. As the construction industry increasingly emphasizes sustainability and performance, this research aligns with the goal of developing innovative materials that enhance the longevity and reliability of infrastructure while reducing environmental impact.

Table 1. Typical Properties of Fibers

Types of fiber	Tensile Strength(MPa)	Young's Modulus(GPa)	Ultimate Blongation(%)	Specific Gravity
Acrylic	210-420	2.1	25-45	1.1
Asbestos	560-980	84-140	0.6	3.2
Glass	1050-3850	70	1.5-3.5	2.5
Polyester	735-875	8.4	11-13	1.4
Polypropylene	560-770	3.5	25	0.9
polyethylene	700	0.14-0.42	10	0.9
Steel	280-2800	203	0.5-3.5	7.8

II.MAERIALS AND MIX DESIGN

2.1 MATERIALS USED

2.1.1. CEMENT

Calcareous materials like limestone or chalk, just as argillaceous minerals like shale or mud, are utilized to make Portland cement. There are two sorts of cycles: wet and dry cycles, which contrast dependent on whether the crude materials are blended and ground wet or dry. Lime, silica, alumina, and iron oxide are the most widely recognized fundamental fixings utilized in cement creation. At high temperatures in the oven, these oxides join with each other to create more unpredictable mixtures.

Hydration of cement alludes to the chemical cooperations that happen among cement and water. Cement hydration can be addressed twoly. The first is an answer system, wherein cement disintegrates to create a very soaked arrangement from which hydrated items hasten. Second, water harms cement compounds after some time, beginning at the surface and advancing to within.

Figure 2.1: OPC 53 grade cement

2.1.2. AGGREGATES:

Aggregates are a vital part of concrete. They give concrete body, decline shrinkage, and set aside cash. Aggregates are inactive granular materials like sand, rock, or squashed stone that are created from their own essential fixings. They are additionally the crude fixings utilized in the creation of concrete. Aggregates should be perfect, firm, and solid particles that are liberated from ingested chemicals or coatings of mud and other fine components that may make cement break down.

Aggregates are divided into two categories from the consideration of size.

i).Coarse aggregate ii). Fine aggregate

2.1.2.1. COARSE AGGREGATE

Coarse aggregates are particles with a width of more than 4.75mm yet frequently going from 9.5mm to 37.5mm. They can emerge out of one or the other essential, optional, or reused materials. Essential or virgin aggregates can be found ashore or in the ocean. Rock is a coarse, land-won aggregate that comes from the ocean. Rock and squashed stone are instances of coarse aggregates. Rock make up the heft of coarse aggregate in concrete, with squashed stone representing most of the rest.

In this study coarse aggregate of nominal sizes of 20mm, 12mm are used.

Figure 2.2: 20mm coarse aggregates

Figure 2.3: 12mm coarse aggregates

2.1.2.2. FINE AGGREGATE:

Coarse aggregates are particles with a width of more than 4.75mm yet every now and again going from 9.5mm to 37.5mm. They can arise out of either fundamental, discretionary, or reused materials. Fundamental or virgin aggregates can be found ashore or in the sea. Rock is a coarse, land-won aggregate that comes from the sea. Rock and squashed stone are examples of coarse aggregates. Rock make up the weight of coarse aggregate in concrete, with squashed stone addressing a large portion of the rest.

Figure 2.4: Fine aggregate

2.2..WATER:

Water is a significant segment of concrete since it assumes a functioning part in the chemical connection among cement and water. Since it helps in the development of the strength-giving cement gel, the amount and nature of water should be painstakingly thought of. C3S requires 24% water by weight, while C2S requires 21%. It's additionally been determined that a chemical response with Portland cement compounds needs on normal 23% water by weight of cement. Since this 23% of water ties chemically with cement, it is alluded to as bound water. It's additionally been determined that generally 15% of the heaviness of cement is expected to fill the gel-pores.

Thus, for the whole chemical response and to consume the space inside gel-pores, a sum of 38% water by weight of cement is required. Since the immaculateness and nature of water affect strength, we must examine the virtue and nature of water. The general guideline for deciding whether water is reasonable for blending concrete is that in the event that it is fitting for drinking, it is likewise appropriate for blending concrete. The setting season of cement is influenced by sodium and potassium carbonates and bicarbonates. Manganese, Tin, Zinc, Copper, and Lead salts fundamentally lessen the strength of concrete. A turbidity breaking point of 2000 sections for every million has been proposed. Locally accessible consumable new water which is liberated from groupings of help and natural substances has been utilized in this exploratory program for blending and relieving.

2. 2.1. Glass fibers

Different strands, like polymers and carbon fiber, have mechanical qualities that are by and large comparable to glass fiber. Albeit not as hard as carbon fiber, when utilized in composites, it is undeniably more affordable and fragile. Thus, glass strands are utilized as a supporting specialist in numerous polymer products, bringing about the glass-built up plastic (GRP), otherwise called "fiberglass," which is an amazingly solid and similarly lightweight fiber-built up polymer (FRP) composite material. This substance is more thick than glass fleece, contains practically no air or gas, and is an essentially more unfortunate warm protector.

FIG.2.5.Glass fibers

Polypropylene fibers

Polypropylene strands were at first proposed as a concrete added substance in 1965 by the US Corps of Engineers for the development of impact safe constructions. The fiber has since been created, and it is presently used either as a short broken fibrillated material for fiber supported concrete or as a ceaseless mat for slender sheet segment make. From that point forward, the use of these strands in the building of designs has soar since adding filaments to concrete improves its sturdiness, flexural strength, rigidity, sway strength, and disappointment mode. Polypropylene twine is modest, bounteously accessible, and like all artificial strands of a steady quality.

FIG.2.6Polypropylene fibers

2.3. BASIC TESTS ON MATERIALS

FINENESS OF CEMENT:

The fineness of cement essentially affects the speed of hydration and, therefore, the pace of strength increment. Cement fineness raises the pace of warmth move. Better cement has a bigger surface region for hydration thus creates strength all the more rapidly. As the fineness of cement rises, so does the shrinkage of concrete, bringing about cracks in buildings.

Method:

Gauge 100 gms of the provided cement and filter it continually on I.S.Sieve No.9 (90) for 15 minutes. Fingers can be utilized to separate air set irregularities, however nothing ought to be scoured on the sifters.

After the sieving is finished, search for the buildup on the strainer and record the worth as a level of the first example gathered.

Observations and calculations:

Table 2.3.1: Observations of fineness of cement test.

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%

Amount retained $= \frac{2.5+2.3+2.4}{3*100} * 100 = 2.4\%$

Fineness of cement = 2.4%

SPECIFIC GRAVITY OF CEMENT:

The heaviness of a cement test and the measure of the fluid dislodged by the cement test are utilized to ascertain explicit gravity. The fluid that will be used ought to be liberated from chemical responses. Likewise, the fluid used ought to have no actual connections with the cement, like retention. In the event that polar fluids are used, their thickness at the cement molecule surface will be higher than the thickness of the free fluid away from the molecule surface. Additionally, no agglomerated particles with inside spaces ought to be available in the cement; in any case, simply the normal evident thickness would be evaluated.

OPC's ordinary explicit gravity is as a rule about 3.15. On the off chance that the particular gravity of a specific example of cement is impressively unique in relation to 3.15, the example's quality might be addressed. On the off chance that dirts, ground sand, fly ash, and different contaminations are added to the cement, it's anything but a diminished explicit gravity.

Procedure: Fill the jar with lamp fuel to a point on the stem that is between the zero and 1ml imprint. After the carafe has been lowered in a water shower, the main perusing ought to be taken. Then, at that point, in a little sum, a weighted amount of cement (about 64g of Portland cement) ought to be added at a similar temperature as the fluid. A vibrating gadget can be utilized to accelerate the cement's entrance into the carafe and keep it from holding fast to the neck. The plug ought to be placed in the cup after the entirety of the cement has been added. **Formula:**

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

Observations:

Type of cement = OPC 53 grade
Liquid used = kerosene
Density of liquid = 13.6 gr/cc
Weight of cement taken w = 64 gm

Table 2.3.2.: 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	20.32	3.15

Calculations:

$$\text{Specific gravity} = \frac{\text{weight of cement}}{\text{volume of cement}} = \frac{64}{20.32} = 3.15$$

Specific gravity of cement = 3.24

2.4. NORMAL CONSISTENCY OF CEMENT:

The rate water expected of the cement glue is characterized as the thickness of which permits the Vicatunclogger to enter to a certain degree 5 to 7mm from the Vicat shape's base. At the point when water is added to cement, the resultant glue solidifies and gains strength while losing consistency simultaneously.

Procedure: Set up a glue by consolidating a weighted measure of cement with a weighted measure of water, remembering that the blending period ought to be somewhere in the range of 3 and 5 minutes, and the work ought to be done before any side effects of setting show up. The time frame for checking starts when water is added to the dry cement and finishes when the form is filled. Fill the Vicat form with the glue, putting it on a non-permeable plate, and afterward smooth the glue's surface to make it level with the highest point of the shape. Spot the test block in the form close to the non-permeable resting plate underneath the unclogger pole. Lower the unclogger cautiously to the test square's surface, then, at that point quickly discharge it to empower it to sink into the glue. The activity should be performed before long the form has been occupied and at room temperature. Set up a preliminary glue with various measures of water and test it as expressed above, estimating the needle infiltration. This test ought to be rehashed until the ideal entrance is accomplished.

Observations and calculations:

Weight of cement taken = 300gm.

Table 2.4.1.: 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%

2.4.1. INITIAL SETTING TIME:

The primary setting time is characterized as the time it takes for the glue to solidify to the moment that the vicat needle can't go down through the glue inside 5mm of the shape's base.

Procedure:

Make a smooth cement glue utilizing 0.85 occasions the measure of water expected to get the ideal consistency. Start the stopwatch when the water is added. Fill the vicat's shape totally with the previously mentioned glue and smooth the top, the form sitting on a non-permeable plate. Spot the test block underneath the needle-bearing pole. Lower the needle cautiously to the test square's surface and quickly discharge it, empowering it to enter the square. Rehash this strategy until the needle neglects to penetrate the test block for 5+0.5mm estimated from the lower part of the form when carried into contact with it. The primary setting time is the time since water was added.

Figure 4.8: vicat apparatus

Observations and calculations:

Weight of cement taken = 300gm.

Weight of water taken

= 0.85 P*300gm =0.85*$\frac{32}{100}$*300 = 81.6ml

Where p is the normal consistency.

Table 2.4.2.: Observations of initial setting time of cement test.

Time(minutes)	10	20	30	40	50	60
Initial resding	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.

III.EXPERIMENTAL INVESTIGATION

1.1. TESTS ON CONCRETE

TESTS ON FRESH CONCRETE

Workability

Workability is one of the actual properties of concrete that impacts its strength and durability, just as the work cost and last look. Workability is the measure of energy needed to defeat grating when compacting, and it is an attribute of concrete that influences the measure of usable inner work needed to accomplish full compaction. The general straightforwardness with which concrete might be blended, conveyed, formed, and compacted is likewise determined.

At the point when concrete is basically poured and compacted consistently, without draining or isolation, it is viewed as functional. Impossible concrete requires more exertion to pack in situ, and honeycombs might be evident in the eventual outcome.

The measure of usable interior exertion important to completely smaller the concrete without draining or isolation in the finished item, as shown by the measure of helpful inner work needed to completely reduced the concrete without draining or isolation in the completed item.

SLUMP CONE TEST

Workability is one of the actual properties of concrete that impacts its strength and durability, just as the work cost and last look. Workability is the measure of energy needed to defeat rubbing when compacting, and it is a trait of concrete that influences the measure of usable inside work needed to accomplish full compaction. The general straightforwardness with which concrete might be blended, conveyed, shaped, and compacted is additionally determined.

At the point when concrete is just poured and compacted consistently, without draining or isolation, it is viewed as serviceable. Impossible concrete requires more exertion to pack in situ, and honeycombs might be clear in the eventual outcome.

The measure of usable interior exertion important to completely conservative the concrete without draining or isolation in the finished item, as demonstrated by the measure of valuable inside work needed to completely smaller the concrete without draining or isolation in the completed item.

Fig4.1: Slump cone test

1.2. COMPACTION FACTOR TEST

The compacting element of new concrete is utilized to survey the workability of the material as indicated by IS: 1199 – 1959. The compacting factor test depends on evaluating the level of compaction achieved by doing a standard measure of work and permitting the concrete to fall through a predefined stature. The thickness apportion is utilized to decide the level of compaction, otherwise called the compacting factor. The proportion of the thickness accomplished in the test to the thickness of completely compacted concrete.

The concrete example to be inspected is filled to the edge in the top container. Concrete falls into the base container once the secret entryway is opened. The base container's secret entryway is then opened, permitting the concrete to fall into the chamber. Then, at that point gauge the chamber, which is alluded to as "weight of somewhat compacted concrete." The chamber is exhausted and afterward filled in three equivalent levels with concrete from a similar example. To accomplish total compaction, the layers are seriously pushed. This is alluded to as the "heaviness of somewhat compacted concrete." The proportion of "weight of mostly compacted concrete" to "weight of in part compacted concrete" is known as the compacting factor.

$$\text{Compaction factor} = \frac{(\text{Weight of partially compacted concrete})}{(\text{Weight of fully compacted concrete})}$$

Fig.3.1.: compaction factor test

MIXING OF CONCRETE

A shifting sort concrete blender was utilized to blend the concrete. The coarse material was put first, then, at that point the fine aggregate, lastly the cement into the blender by hand. Water was added to the fixings inside the blender while it was turning. The pivot was continued going for a few minutes. The concrete was unloaded one clean stage after the blender was shifted.

CASTING OF SPECIMENS

Projecting is an assembling method wherein concrete is filled a shape with an empty opening in the ideal structure and permitted to solidify. To complete the cycle, the hardened part, otherwise called a projecting, is removed or broken out of the form. A metal base plate with a level surface is incorporated with each form. The base plate ought to be adequately huge to hold the shape without spilling during the filling interaction, and it ought to be associated with the form by springs or screws. To ensure that no water avoids during the filling, the joints between the pieces of the form are meagerly covered with shape oil, and a comparable covering of shape oil is put between the contact surface of the lower part of the form and the base plate. To keep away from concrete grip, the internal surface of the built shape should likewise be gently covered with form oil.

The test examples' workability and flexural strength were evaluated in this investigation. The M30 configuration blend's fixings. Standard Portland cement (OPC) with a grade of 53 was used. Squashed stone passing IS 20mm sifter, held on IS 10mm strainer, and passing IS 10mm strainer, held on IS 4.75mm sifter were used as coarse aggregate. Waterway sand adjusting to zone II and created sand as indicated by zone II of IS 383-1970 were used as fine aggregate. The molds are set on a level surface. Vibration utilizing a table vibrator fills the molds with very much blended concrete. Overabundance concrete was scooped away, and the top surface was cleaned level and smooth as per IS: 516-1959. Figure 4.3 portrays the projecting of test examples.

To get a homogenous blend, the cement, coarse aggregate, and produced sand are totally joined. Roughly 25% of the required water is added and painstakingly blended to get a homogeneous blend. From that point forward, the excess 75% of water was added and overwhelmingly mixed until the blend was homogenous. The combination is then used to make examples.

CASTING OF PRISMS

For each group of concrete blend, 9 crystals estimating 500mm x 100mm x 100mm were shaped to test the split elasticity. Oil was utilized to cover the crystal molds, which were then loaded up with concrete. The concrete-filled crystal molds were vibrated briefly utilizing a table vibrator. Overabundance concrete was taken out with a scoop whenever compaction was done, and the top surface was smoothed.

Fig3.2.: casting of specimens

CURING OF SPECIMENS

Curing is the way toward directing the speed and level of dampness misfortune from concrete after it has been put and finished in its last situation to keep up with persistent hydration of Portland cement. Curing additionally guarantees that the temperature of the concrete is kept up with at a proper level in its beginning phases, since this straightforwardly affects the speed of cement hydration. For concrete to arrive at its proposed strength and durability, it should be restored as quickly as time permits after establishment and completing, and it should be proceeded for a considerable lot of time according to the fitting prerequisites. To limit warm shrinkage cracks, a steady temperature ought to be kept up with all through the concrete depthTo keep away from plastic shrinkage breaks, endeavors to restrict dampness misfortune from the concrete surface are additionally vital.

In the wake of projecting, the examples are left undisturbed at room temperature for approximately 24 hours. The examples are then taken from the molds and quickly positioned to a curing lake containing perfect and new water, where they are relieved for the proper measure of time as per IS:516-1959.

Following 24 hours of projecting, the crystals were demolded. In a water tank, these examples were restored. The examples were eliminated from the water subsequent to being restored for 7, 14, and 28 days and left to dry in the shade.

3.3.Testing

3.3.1 Compressive strength test

This test was driven according to ([9] IS516-1959). The compressive strength of cement was settled using rigid conditions of standard design 150x150x150mm. Models were put on a CTM bearing surface with a cap of 200T, no irregularities, and an anticipated stacking rate joined until the solid shape was puzzled. The compressive consistency ([21] AS Alnuaimi,) was resolved after the most outrageous weight was noted. IS516-1959 show for compressive strength testing.

Figure 3.3. Casting of cubes

Placing the Specimen in the Testing Machine

The bearing surface of the surveying design will be washed, and any free sand or other substance that may come into contact with the crushing variable platens will be taken out. Thinking about the 3D plans, the models will be managed into the processor so the pile will be bound to two talk sides of the 3D development, instead of the top and base. The model's center point will be deliberately concurred with the circularly found platen's drive. Between the substances of the test model and the steel platen of the surveying unit, no smashing can be utilized. The adaptable domain will be gently turned as the circularly arranged square is empowered pass on the framework.

Figure 3.4. Compressive strength testing machine

The store will be joined without shock and reached out at a predictable speed of about 140kg/cm2/min before the manual for raise hell segregates and no more enormous weight can be added. The best strain related with the model will be enlisted at that stage, similarly as the presence of the solid and any unusual highlights in the kind of disappointment.

Computation: The purposeful compressive consistency of the model will be dictated by isolating as far as possible strain related with the model during the evaluation cross–sectional district, which will be settled from the segment's mean parts and imparted to the nearest kg/cm2. The certifiable collection isn't more than 15% of the regular of three characteristics taken as the delegate of the pack. In explicit cases, a recurrent inquiry would be done.

The compressive strength of cube = $(\frac{P}{A})$ N/mm^2

Where,

P is load at failure in N,

A is area of cube/contact in mm^2.

3.3.2. Split Tensile Strength Test

The test was acted in consistence with IS516-1959. The concrete substance was settled using workplaces of typical size 150mmx300mm. Models are put on a CTM bearing surface with a constraint of 200T without unconventionality, and an anticipated stacking rate is kept up until the chamber is cleansed. The most outrageous weight was perceived, and the idea of the weight was resolved. Flexibility check in two fragments The IS5816-1999 method is according to the accompanying: Placing the Measuring Machine for example:

The testing machine's bearing surface similarly as the stacking strips would be cleaned.

Masterminding: The investigation would be purposely arranged in the concentrating with pressing strips and stacking parts around the left, top, and lower a piece of the stacking model's plane.

The dance will be mounted in the PC determined to search for a model in the center. The heap will be associated on the outlined faces on account of the cubic model, so a break strategy will cross the scoop driven surface. The upper platen would be relating to the lower platen by virtue of traffic circle and void plates.

RATE OF LOADING

The store can be related without falter and loosened up at an evident speed of 1.2 N/mm/min to 2.4 N/mm/min inside. IS 5816 (1999)) ([14] IS 5816 (1999)) ([15] IS 5816 (1999) keep up the speed before dissatisfaction one really worked machines when disappointment is pushed toward the stacking rate would diminish; at this stage, the controls will be sorted out some way to remain mindful of the predefined stacking rate as eagerly as could be anticipated. The most outrageous weight related will be represented at that stage. Strong will be recorded, similarly as any sporadic highlights in the sort bafflement.

Calculation:

The split versatility is resolved as stacking condition so much that the store is applied on top and lower part of the chamber on its sidelong surface, to the locale comparable to the even surface zone of the chamber.

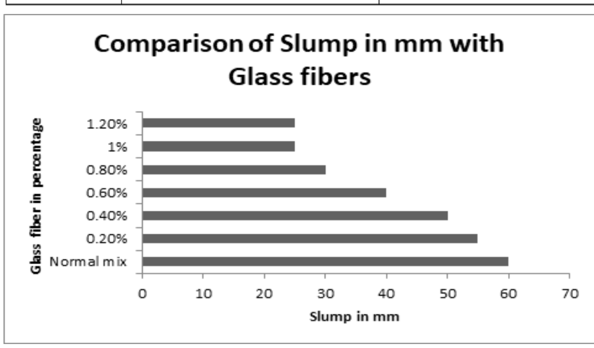
The split tensile strength = $(\frac{2P}{\pi dl})$ N/mm^2

IV. RESULTS AND ANALYSIS

With Glass fibers

Workability (Slump cone Test)

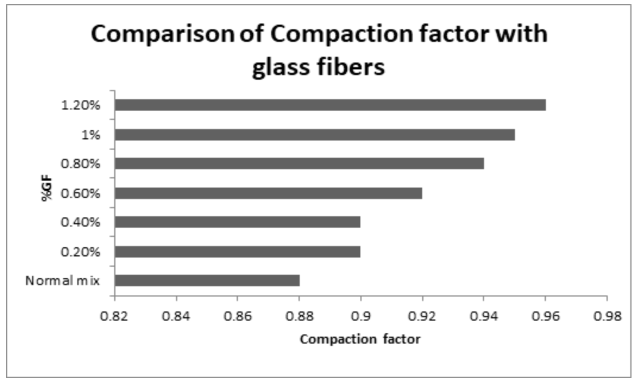
S. No	% GF	Slump in mm
1	Normal mix	60
2	0.20%	55
3	0.40%	50
4	0.60%	40
5	0.80%	30
6	1%	25
7	1.20%	25



Comparison of Slump in mm with Glass fibers

Compaction factor test

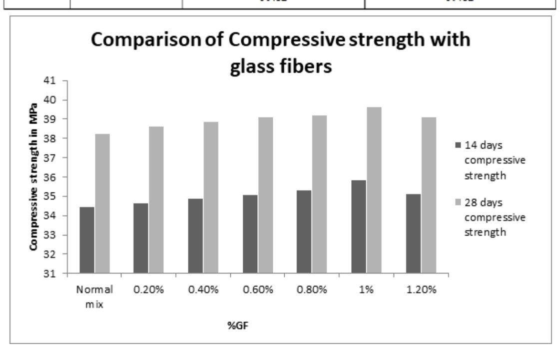
S. No	% GF	Compaction factor
1	Normal mix	0.88
2	0.20%	0.9
3	0.40%	0.9
4	0.60%	0.92
5	0.80%	0.94
6	1%	0.95
7	1.20%	0.96



Comparison of Compaction factor with glass fibers

Compressive strength

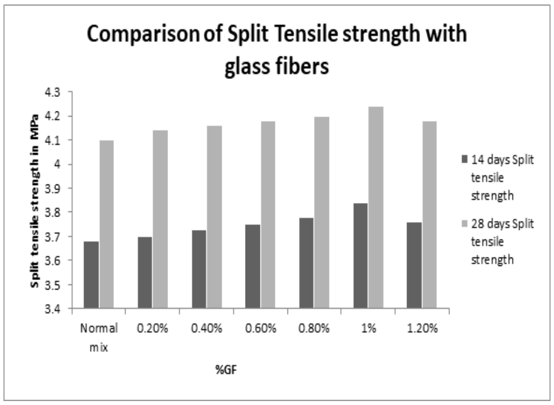
S. No	% GF	14 days compressive strength	28 days compressive strength
1	Normal mix	34.44	38.25
2	0.20%	34.66	38.66
3	0.40%	34.9	38.9
4	0.60%	35.1	39.12
5	0.80%	35.33	39.22
6	1%	35.86	39.64
7	1.20%	35.12	39.12



Comparison of Compressive strength with glass fibers

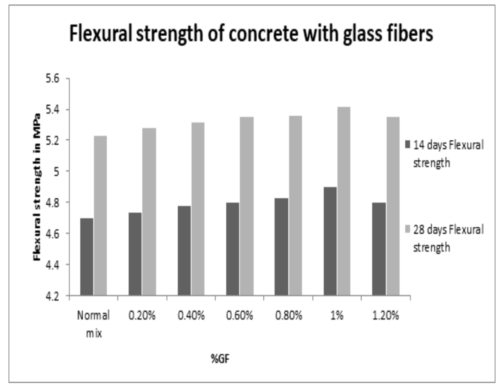
Split tensile strength

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



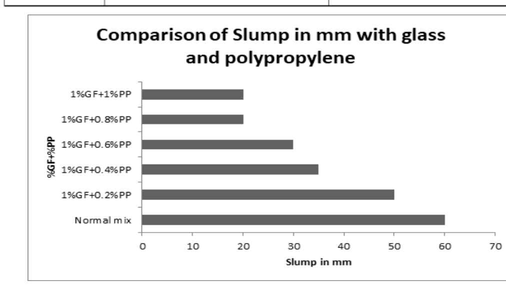
Flexural strength

% 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



V. CONCLUSIONS

This study has successfully demonstrated the benefits of incorporating hybrid fiber reinforcement in concrete, revealing significant enhancements in mechanical properties compared to traditional concrete mixes. The experimental results indicate that the strategic combination of steel and polypropylene fibers leads to improved compressive strength, tensile strength, and flexural performance. Specifically, the hybridization of these fibers effectively leverages their distinct properties—steel fibers enhance the load-bearing capacity and tensile resistance, while polypropylene fibers mitigate plastic shrinkage cracking and improve ductility.

The optimal mix design identified in this investigation showcases how hybrid fiber reinforcement can create a more resilient concrete matrix, making it particularly suitable for applications in high-stress environments, such as pavements, bridges, and industrial floors. The findings suggest that HFRC not only meets but exceeds the performance standards of conventional concrete, offering a viable solution to the challenges of durability and structural integrity in modern construction.

Furthermore, the integration of hybrid fibers aligns with the construction industry's ongoing efforts to develop sustainable building materials. By enhancing the durability and longevity of concrete structures, hybrid fiber-reinforced concrete contributes to reduced maintenance costs and resource consumption over time.

Future research should explore the long-term performance of HFRC under various environmental conditions and loading scenarios to fully understand its potential in real-world applications. Additionally, investigating cost-effective methods for fiber integration and assessing the environmental impact of these materials will be essential for promoting the widespread adoption of hybrid fiber-reinforced concrete in the construction sector. Overall, this study highlights the transformative potential of hybrid fiber reinforcement, paving the way for more durable and efficient concrete solutions in infrastructure development.

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