EXPERIMENTAL STUDY ON THE COMBINED EFFECTS OF HYBRID FIBERS AND PCE SUPERPLASTICIZER IN STANDARD CONCRETE

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***Abstract*—This research investigates a novel combination of glass fibers, carbon fibers, and Polycarboxylate ether to enhance concrete's mechanical properties. The unique mix design, not previously explored in existing literature, aims to improve strength, durability, and sustainability in construction. The research involved casting concrete specimens incorporating varying proportions of hybrid combinations of glass fibers, carbon fibers, and Polycarboxylate ether as admixtures. Hybrid fiber Reinforced concrete (HFRC), Glass fiber reinforced concrete (GFRC) and Carbon fiber reinforced concrete (CFRC). Fiber combinations A: 0 % GF; B: 1.5 % GF + 0.5 % CF; C: 1 % GF + 1 % CF; D: 0.5 % GF + 1.5 % CF; E: 2 % CF. The PCE-based superplasticizer, used at 0.8 % in all combinations by the weight of cement. combination of glass and carbon fibers at a constant 2 % total fibers. Comprehensive tests were conducted on water absorption (cube), compressive strength (cube), split tensile (cylinder) and flexural behavior (beam) to evaluate performance enhancements over conventional concrete across 7th, 14th, and 28th days. Compressive strength 35.33 MPa, Flexural strength test 9.1 MPa, split tensile 5.60 MPa, and water absorption 6.31 at 28 days, Mix C achieved as compared with different ratios in M25 grade concrete.**

***Index Terms*— Hybrid Fiber Reinforced Concrete (HFRC), Carbon Fibers (CF), Glass Fibers (GF), polycarboxylate ether (PCE)**

I. INTRODUCTION

Concrete is a cementitious component known for being widely commonly utilized construction material in everywhere since its impact strength, flexibility, and long-lasting use. Change in temperature a common problem in day-to-day life in concreting performance. Fiber Reinforced Concrete (FRC) is introduced as a solution to improve the flexural and crushing strength, make it more resistant against cracking, and improve its durability. The focuses on utilization of hybrid fibers (HF), glass and carbon combined with Portland Pozzolana cement (PPC) and Polycarboxylate Ether (PCE) superplasticizer (SP) to make a stronger and more durable concrete mix. Hybrid fibers (HF) are making bonds with concrete ingredient forms of hybrid fiber reinforced concrete (HFRC).

II. LITERATURE REVIEW

Lingala Ajay and M. Anil Kumar, 2020 Investigate regarding mechanical properties about reinforced with fiber, AR glass for 28 days improves strength of compression, tensile, and bending strength. Prasad Bishetti, et al., 2019 The study looked at mechanical futures of GFRC by adding of GF (0 %, 0.03 %, 0.06 % and 0.1 %) or M_{25} grade concrete for 7th, 14th, and 28th days. GF improves the strength in compression, split, and bending. Mr. N. Thirugnanasambantham, et al., 2019 Introduction of glass fibers varied lengths are 6, 12, and 18 mm and percentages 5, 10, and 20 to M_{25} grade concrete. The research aimed to assess the compressive strength, flexural strength, and workability to produced GFRC mixtures. Souvik Das et al., 2020 Study found that,18.36 % increase in splitting tensile strength and a 24.87 % for 28th days. Zhan Guno et al., 2021 Specimens were heated to extreme temperatures the strength in compressive, bending, and fracture strengths were determined. Result shows that Carbon fibers boosted CFRC's flexural .and splitting strengths with a carbon fiber composition of 1.0 wt. percentage and a fiber length of 10 millimeter. Ghanem, Sahar Y. and Bowling, Jonathan, 2020 Chopped CFRC at volume proportions of 0.5%, 1.0%, 1.5%, and 2.0%. The study evaluated the workability, strength in compression, fracture and bending strengths are enhanced steadily as fiber content climbed, with strength efficiency exceeding 18.37% to 132.6% for tensile strength and 3.26% to 13.82% for flexural strength. Trupti Amit Kinjawadekar, et al., 2023 The compressive strength rose by up to 48% for 28 days, improve mechanical characteristics. while the flexural strength exhibited significant improvements as compared to standard concrete. Pradeep Kumar Ram, et al., 2023 This study investigated the mechanical characteristics of concrete that contained several hybrid fiber combinations, such as carbon-steel, steel-polypropylene, and glass-steel, all with a total fiber volume percentage of 0.25%. Samples were cured 28 days during examining. The study showed that hybrid fibers, even at small fiber volume parts, might greatly improve concrete mechanical properties. Mohammed Hadeed et al., 2023 Investigating the effect of mixing GF and polypropylene fibers (PPF) on the mechanical applications of high-strength concrete (HSC). and lightweight concrete (LWC). Various combinations 0.5% GF + 0.5 % PPF for 28 days.

III. METHOLOGY

Cement—As per IS 1489:1991, Portland Pozzolana Cement (PPC) contains ordinary Portland cement and fly ash mixed together to form PPC mass and contains 610 kg cement for testing. The cement was dry, fresh lumps. **Coarse Sand Zone III—**As per IS 383:2016, Zone III sand is available in rivers, and was used as a coarser gradient was used as fine aggregates. The sand was cleaned, well graded, and free from clay and silt. and contains 701.25 kg used for testing. **Aggregate—** As per IS 383, Stone aggregates range between 10 and 20 mm (for 10 mm 912 kg and 448 kg for 20 mm), **Water—**Water is a natural substance that is located on the planet, from the sky or from the ground. The cement water ratio is important to make a cement paste. Potable water, or normal clean water, free from organic impurities and salts, had been used and is used for mixing and curing. As per IS 456:2000, w/c in the cementitious-based material is 0.45 ratio 274.5 kg is used. **Fibers: Glass Fiber (GF) —**As per ASTM C666/C 1666M – 08:2023, The glass fibers were added; the length is 12 mm, alkaline resistance. Improves and makes balance in concrete, improving crack bindings. **Carbon Fiber (GF)—**Short carbon fibers of length 10 mm were added. It improves concrete performance in temperature variations. **PCE Superplasticizer—**The use of PCE (Polycarboxylate Ether) advance version of superplasticizer based on moderate range of water is reduced and utilized to improve workability, 0.8 % is added in a form of white powder.


(a)


(b)


(C)


(d)


(e)

Fig. 1 (a) GF 12 mm length **(b)** GFRC **(c)** CF 12 mm length **(d)** CFRC **(e)** PCE

IV. TESTING PROCEDURES

The six samples are prepared for testing. Five samples contain fiber combinations (Glass and Carbon) + PCE superplasticizer, and one sample contains plain concrete without fibers at a temperature of 27°C presents the testing procedure for CST, STT, FST, and WAT Design mix as per IS 10262, methology for M_{25} grade.

Compressive Strength—CST 150 mm cube is tested using Universal Testing Methods in M_{25} grade of concrete. This test is performed in a sample of cube to determine the strength of compression for plain concrete and fibers. The load was applied until failure, and strength was calculated using formula: σ = P/A Where, P is Maximum load at failure (Newton) and A is Cube section of the area (millimeter square) as per IS: 456 and IS 516 (Part 1, Section 1)

Flexural Strength—FST is conducted on beam specimen of 700 mm in length using four-point loading method by using Universal Testing Methods using 4-point bending. Bending stress is determined to see that fiber ratio is best among compare with plain concrete. According to IS 516:2021 the test specimen for flexural strength testing shall be a beam following to IS 1199 (Part 5). As per IS 516 (Part 1, Section 1), calculated by applying the equation: a > 13.3 mm $f_{CR} = 3PL / 2bd^2$ and a < 20 mm $f_{CR} = PL / bd^2$. a is Break length, P is Maximum load applied to the samples (Newton), L is distance among supports (Millimeter), b is width (Millimeter) d is depth (Millimeter)

Split Tensile Strength—STS done on cylinder samples of 150 mm dia. and 300 mm ht. is tested using UTM. As name suggest split it is used in sample of cylinder type at seven, fourteen, and twenty-eight days the fiber mix or single fiber mix in concrete is improve bending strength as weaker in plain concrete. When cracks are seen, stop the loading and record the load applied as seen in the dial gauge of the machine. Record the maximum load applied at failure. This test is estimated using this equation: $ft = 2P / \pi dl$. P is Maximum stress .at failure (Newton), d is diameter (300 millimeter), L is length (150 millimeter)

Water Absorption—IS: 1199 (Part 2) WAT examination is conducted on a cube sample to determine how much water the concrete absorbs using an oven and a weighing machine. It is often represented as a percentage of weight gained after soaking a dry concrete sample under water for an exact period of duration. IS 516 (Part 1, Section 1) this test is used to measure that how much material absorb water under specific conditions, often used to assess material properties like porosity, durability and resistance to moisture3. Calculating the water absorption percentage using this formula: $WA = \{(W_2 – W_1)/ W_1\} \times 100$. W_1 is original weight (kg), W_2 is Fully Submerged weight (kg).

V. RESULT AND DISCUSSION

Compression Strength Test (CST) Result

Mix	7 days	14 days	28 days	Remarks
Plain Concrete	23.11	28.89	32.44	No PCE
A	24.0	30.22	34.00	2% GF and 0% CF
B	24.67	31.11	34.67	1.5% GF and 0.5% CF
C	25.33	31.78	35.33	1% GF and 1% GF
D	24.67	31.11	34.67	0.5% GF and 1.5% CF
E	23.78	30.00	33.78	0% GF and 2% CF

7, 14 and 28 days curing period and weight applied accordingly. plain concrete 520, 650 and 720 KN respectively. Mix A 540, 680 and 765 KN. Mix B 555, 700 and 780 KN. Mix C 570, 715 and 795 KN, Mix D 555, 700 and 780 KN and Mix E 535, 675 and 760 KN.

Flexural Strength Test (FST) Result

Mix	7 Days	12 Days	28 Days	Remarks
Plain Concrete	3.2	4.3	5.0	No PCE
A	4.4	5.9	7.1	2% GF and 0% CF
B	5.0	6.4	8.0	1.5% GF and 0.5% CF
C	5.3	7.1	9.1	1% GF and 1% GF
D	5.2	6.8	8.7	0.5% GF and 1.5% CF
E	4.8	6.4	8.2	0% GF and 2% CF

7, 14 and 28 days curing period and weight applied accordingly. plain concrete contains at a weight of 18, 24 and 28 KN respectively. Mix A 25, 33 and 40 KN. For Mix B 28, 26 and 45 KN. Mix C 30, 40 and 51 KN, Mix D 29, 38 and 49 KN and Mix E 27, 36 and 46 KN.

Spilt Tensile Test (STT)

Mix	7 days	14 days	28 days	Remarks
Plain Concrete	2.80	3.50	4.00	No PCE
A	3.47	4.01	5.00	2% GF and 0% CF
B	3.60	4.30	5.20	1.5% GF and 0.5% CF
C	3.80	4.60	5.60	1% GF and 1% GF
D	3.60	4.30	5.20	0.5% GF and 1.5% CF
E	3.30	4.10	4.80	0% GF and 2% CF

7, 14 and 28 days curing period and weight applied accordingly. plain concrete contains at a weight of 197.8, 247.3 and 282.6 KN respectively. Mix A 248 and 283.6 KN. For Mix B 555, 700 and 780 KN. Mix C 268.5, 325 and 395.6 KN, Mix D 254.3, 303.8 and 367.4 KN and Mix E 233.1, 289.7 and 339.1 KN.

Water Absorption (WA) Result

Mix	7 days	14 days	28 days	Remarks
Plain Concrete	7.71	7.14	6.50	No PCE
A	7.45	6.70	6.38	2% GF and 0% CF
B	7.43	6.81	6.28	1.5% GF and 0.5% CF
C	7.50	6.89	6.31	1% GF and 1% GF
D	7.57	6.99	6.39	0.5% GF and 1.5% CF
E	7.60	7.10	6.49	0% GF and 2% CF

7, 14 and 28 days curing period and weight applied accordingly. plain concrete contains at a weight of 197.8, 247.3 and 282.6 KN respectively. Mix A 248 and 283.6 KN. For Mix B 555, 700 and 780 KN. Mix C 268.5, 325 and 395.6 KN, Mix D 254.3, 303.8 and 367.4 KN and Mix E 233.1, 289.7 and 339.1 KN.

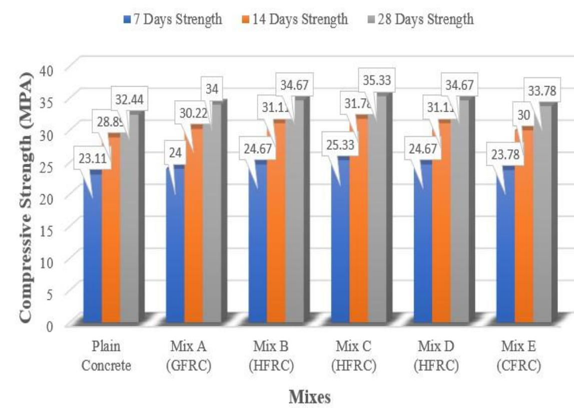

Fig 2: Compressive strength tests for plain and fiber-modified concretes

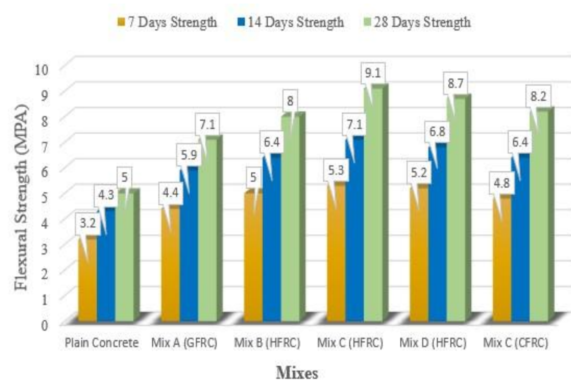

Fig. 3: Flexural strength tests for plain and fiber-modified concretes

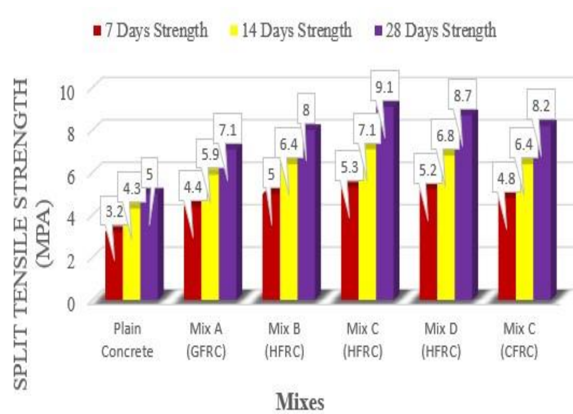

Fig. 4: Split tensile strength tests for plain and fiber-modified concretes

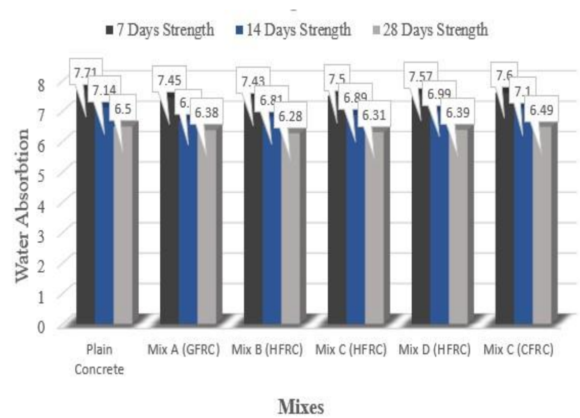

Fig. 5: Water absorption tests for plain and fiber-modified concretes

VI. CONCLUSION

The focus of this study is to keep on improving the mechanical features of concrete by analyzing GF and CF under different loading circumstances.

The key findings from this study are as follows:

1. Superior Strength at Compression—GF and CF resulted in a great modification in the strength in compression, with the highest strength recorded for the mix B featuring both 1 % GF and 1 % CF + 0.8 % PCE superplasticizer. The hybrid fiber mixes also displayed a significant rise in strength in compressive in relation to the plain concrete and other fiber mix, with the finest outcomes gathered by merging GF and CF.

2. Boosted Elastic and Bending Properties—The collaboration of GF and FF, better improves the tensile and bending properties of the concrete matrix at every stage. The hybrid mixes are superior then single fiber mixes, bringing stronger stability against cracking and higher load-bearing capacity. This makes FRC a good match for structures where elastic and bending properties are valuable.

3. Advanced crack protection—The protection of cracks within loading circumstances was heavily upgraded by hybrid fibers. The mixture of GF and CF lower the expansion gap, improved utilization of energy, and expanded overall hardness. These features are especially valuable for structures exposed to changing stresses, such as bridges and tall buildings.

4. Moisture Absorption—Ability of a material to capture water via its gaps is a good predictor for its porousness and overall toughness. Materials that absorb a lot of water are generally more likely to crack, lose strength, and deteriorate over time, especially when exposed to dampness or freeze-thaw cycles. The usage of hybrid fibers, such as glass and carbon (HFRC), and PCE superplasticizer has shown in increased performance in terms of water absorption and total material strength.

4. Optimized Fiber Proportions—In this study examine optimal proportion of fibers for achieving the best mechanical performance was around 1 % CF and 1% GF along with 0.8 % PCE superplasticizers in combination with concrete HFRC. This combination helps to maintain finest balance of strength of compressive, tensile, and flexural performance.

5. Practical Implications—The research results indicate that HFRC may be utilized effectively in current construction projects requiring great strength and durability, especially with structures exposed to fluctuating load scenarios. Its boosted durability against fractures and longevity makes it a good choice for coastal constructions, pavements, and infrastructure that have been exposed to extreme weather conditions.

Future Work

Recommendation of further investigation:

- Examine the long-term toughness of GF and CF reinforced in harsh environments, including high temperatures and chemical attacks.
- Investigate the financial advantages of working with HFRC in large construction projects.
- Analyze performance of HFRC under various fluctuating load factors, such as earthquake and wind forces, to determine its earning capacity for structural services.

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