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Strength and Durability Assessment of Fiber-Reinforced High-Performance Concrete

Meeravali Karumanchi[1], Mohammed Ziad Farooqui[2], Akash V[3], Shaik Daggu Fayaz[4], Thagaram Raju[5], Kovuru Niranjan[6], shaik nayab Rasool[7]
[1,7]*Assistant Professor, ABR College of engineering and Technology, China irlapadu, Kanigiri, Prakasam, A. P-523254.*
[2,3,4,5,6]*B. Tech Students, Civil department, ABR College of engineering and Technology, China irlapadu, Kanigiri, Prakasam, A. P-523254*

Abstract— **This study presents an experimental investigation on the strength and durability characteristics of Fiber-Reinforced High-Performance Concrete (FRHPC) incorporating steel and polypropylene fibers. High Performance Concrete (HPC) is known for its superior strength, durability, and low permeability; however, its brittleness and crack-prone nature under tensile and flexural stresses necessitate further enhancement. To address this, six concrete mixes were designed with varying fiber contents: a control mix (M0), individual fiber mixes, and hybrid fiber combinations. Ground Granulated Blast Furnace Slag (GGBFS) was used as a partial replacement for cement to improve durability and sustainability, while a polycarboxylate-based superplasticizer ensured required workability. The performance of each mix was evaluated through a series of standardized tests including slump cone test, compressive strength, split tensile strength, flexural strength, static modulus of elasticity, and Rapid Chloride Penetration Test (RCPT). The results revealed that the inclusion of fibers, particularly in hybrid form, significantly improved the mechanical properties and reduced chloride permeability. Mix M3, containing 1.0% steel and 0.3% polypropylene fibers, demonstrated the best overall performance with enhanced strength, ductility, stiffness, and durability. While fiber addition slightly reduced workability, it remained within acceptable limits due to the use of high-range water-reducing admixtures. The findings confirm that the combined use of steel and synthetic fibers in HPC not only enhances its structural performance but also greatly improves resistance to environmental degradation. This study supports the application of FRHPC in demanding infrastructure projects where high strength and long-term durability are essential.**

Index Terms— **Fiber-Reinforced High-Performance Concrete (FRHPC); Steel fibers; Workability; Mechanical properties; Durability studies.**

I. INTRODUCTION

Concrete is universally recognized as the most extensively used construction material, forming the structural core of infrastructures such as buildings, bridges, highways, dams, and tunnels. Its widespread use is primarily due to its versatility, ease of availability, and cost-effectiveness. However, despite its remarkable compressive strength and adaptability, conventional concrete suffers from several inherent limitations. These include low tensile strength, brittle behavior, vulnerability to microcracking, and reduced durability under adverse environmental conditions. As civil engineering continues to evolve with growing infrastructural demands and exposure to aggressive environments, the need for advanced materials capable of addressing these shortcomings has become increasingly essential [1,2].

To meet the modern-day requirements of sustainable and long-lasting infrastructure, significant advancements have been made in the development of concrete technology. One such advancement is High Performance Concrete (HPC), which is a special class of concrete designed to achieve enhanced strength, superior durability, and improved performance under both mechanical and environmental stresses [3]. Unlike traditional concrete, HPC is characterized by its carefully engineered mix design, the use of mineral admixtures like silica fume and fly ash, and the incorporation of chemical admixtures such as superplasticizers and retarders. These ingredients work together to reduce water-to-binder ratios, improve workability, control setting time, and minimize shrinkage. The result is a dense, high-strength material that performs well even in the most challenging service conditions [4].

Nevertheless, even with all the enhancements provided by HPC, the problem of cracking due to tensile stresses, drying shrinkage, thermal expansion, and external loading persists. Such cracks not only affect the structural performance but also accelerate the ingress of harmful substances like chlorides, sulfates, and carbon dioxide, ultimately leading to deterioration. To address this critical issue, the integration of fiber reinforcement into concrete has gained prominence in recent years. The addition of randomly distributed, discontinuous fibers significantly improves the post-cracking behavior of concrete by providing crack-bridging capacity, enhancing toughness, and increasing resistance to impact and fatigue. This integration of fibers with HPC has led to the development of Fiber-Reinforced High-Performance Concrete (FRHPC), a material that combines the compressive strength and durability of HPC with the tensile enhancement and crack resistance offered by fibers [5,6].

Fiber-reinforced concrete is a composite material that consists of a cementitious matrix and a dispersion of fibers that work synergistically to arrest crack growth and distribute stresses more evenly. Various types of fibers have been utilized in concrete based on the intended performance requirements and environmental exposure. Steel fibers, known for their high tensile strength and stiffness, are widely used to improve flexural and impact resistance. Polypropylene fibers are particularly effective in reducing plastic shrinkage cracking and improving freeze-thaw resistance [7]. Glass fibers, when treated for alkali resistance, contribute to enhanced tensile properties and resistance to chemical attack. More advanced fibers such as basalt and carbon are used in specialized applications for their high strength-to-weight ratios and excellent corrosion resistance, although they tend to be more expensive. The specific type, length, aspect ratio, and volume fraction of fibers used in the mix can significantly influence the overall performance of the concrete [8].

In the current era, the construction industry is gradually shifting from traditional strength-based design approaches to performance-based engineering. This means that beyond achieving adequate strength, the focus now includes ensuring long-term serviceability, resistance to environmental degradation, and minimization of life-cycle costs. In this context, both strength and durability parameters assume great importance [9-11]. Compressive strength, tensile strength, and flexural strength remain essential benchmarks for load-bearing capacity and structural stability. At the same time, durability parameters such as water absorption, permeability, resistance to chemical attack, and behavior under cyclic freezing and thawing are critical for ensuring the longevity and cost-effectiveness of structures [10].

The combination of fibers and HPC has the potential to meet both these performance goals. The fiber network within the HPC matrix acts as a crack control mechanism, reducing the width and frequency of cracks and thereby minimizing pathways for moisture and aggressive chemicals. This contributes to the concrete's ability to resist deterioration due to environmental effects such as carbonation, chloride ingress, sulfate attack, and alkali-silica reaction. In critical infrastructure such as marine structures, bridges exposed to de-icing salts, and industrial facilities with chemical exposure, FRHPC offers a material solution that ensures both mechanical reliability and extended durability [12,13].

Although the benefits of fiber reinforcement in conventional concrete are well documented, there remains a lack of comprehensive experimental data that specifically examines the performance of fiber-reinforced systems within high performance concrete matrices [14]. Most studies tend to focus on individual aspects such as compressive strength or crack control, without providing a holistic assessment of both strength and durability across different fiber types and dosages. Furthermore, the interaction between fibers and the dense microstructure of HPC is complex and requires systematic study to understand the synergies and limitations [15].

II. RESEARCH SIGNIFICANCE

This research is motivated by the need to investigate, through laboratory experimentation, how the inclusion of fibers affects the overall performance of High-Performance Concrete. The study aims to evaluate a series of concrete mixes containing different types and dosages of fibers, and to assess their mechanical properties such as compressive strength, split tensile strength, and flexural strength. In addition to strength, the durability characteristics such as water absorption, resistance to acidic environments, and chloride penetration resistance are also examined to determine the potential benefits of fiber reinforcement in hostile service conditions. A comparison with non-fiber-reinforced HPC mixes will be conducted to quantify the performance improvements attributable to fibers. Microstructural analyses may also be included to provide insights into crack propagation behavior and the interaction between fibers and the cementitious matrix.

The importance of this study lies in its ability to provide engineers, researchers, and construction professionals with practical data and insights for the design and implementation of FRHPC in real-world applications. From a structural engineering perspective, the research can contribute to optimizing mix designs for demanding applications where durability and mechanical strength are equally important. For the broader construction industry, the adoption of FRHPC can translate to lower maintenance costs, fewer repairs, and improved sustainability through extended service life. In addition, the findings can support the development of performance-based specifications and contribute to the formulation of national and international standards related to fiber-reinforced concrete.

By systematically evaluating the effects of fiber incorporation in high-performance concrete, this experimental study aims to fill a significant knowledge gap in modern concrete technology. It highlights the importance of material innovation in achieving the goals of structural resilience, cost-efficiency, and sustainability in construction. The integration of fiber reinforcement with HPC has the potential to redefine concrete design in the 21st century, and this research seeks to contribute meaningfully to that advancement.

III. MATERIALS AND METHODS

3.1 Materials and mix proportions

In this study, the production of FRHPC involved the use of carefully selected materials to ensure the desired levels of strength, durability, and performance. The selection of constituent materials was guided by standard specifications and performance requirements associated with high-grade concrete. The materials used in the mix included Ordinary Portland Cement (OPC), fine and coarse aggregates, a mineral admixture in the form of Ground Granulated Blast Furnace Slag (GGBFS), a chemical admixture (superplasticizer), potable water, and two types of fibers steel fibers and polypropylene fibers. Each of these components was procured, stored, and processed under controlled conditions to maintain uniformity and quality throughout the experimental program.

OPC of 53 grade was used as the primary binding material. It conforms to IS 12269:2013 [24] and was chosen for its superior early strength development, which is crucial in the context of High-Performance Concrete. The cement was obtained from a single batch and stored in moisture-free conditions to prevent pre-hydration or lump formation. Fine aggregate used in the study consisted of clean, well-graded natural river sand, conforming to Zone II requirements as per IS 383:2016 [23]. The sand was free from organic impurities and clay content, and it was sieved through a 4.75 mm IS sieve before use. Its specific gravity was approximately 2.65, and it had suitable fineness modulus and gradation to contribute to the packing density and flowability of the mix.

The coarse aggregate comprised crushed angular granite stones with a nominal maximum size of 12.5 mm. These aggregates also conformed to IS 383:2016 [23] standards and were chosen for their high strength and compatibility with dense concrete matrices. The aggregates were free from flaky particles, dust, and other deleterious materials. Their specific gravity was around 2.7, and they were used in surface-dry conditions to maintain accurate water-cement ratios. Clean potable water, conforming to IS 456:2000 [22], was used for both mixing and curing of the concrete. The water was free from salts, acids, and other harmful contaminants that could adversely affect cement hydration or the durability of concrete.

GGBFS was used as a mineral admixture to partially replace cement. GGBFS is an industrial by-product obtained during the manufacture of iron in blast furnaces and is rich in amorphous silica and alumina. In concrete, GGBFS acts as a latent hydraulic binder and contributes significantly to strength and durability development through secondary hydration reactions. Its fine particle size enhances the packing density, reduces permeability, and contributes to improved resistance against chemical attacks such as sulfate and chloride ingress. In this study, GGBFS was added as a partial replacement of cement at a dosage of 30% by weight, and it complied with the specifications of IS 16714:2018 [25]. The use of GGBFS not only improves the microstructure and durability but also promotes sustainability by utilizing industrial waste.

A polycarboxylate ether (PCE)-based superplasticizer was employed to enhance the workability of the concrete without increasing the water content. This high-range water reducer helped achieve the required flowability and compaction without segregation or bleeding. The superplasticizer dosage ranged between 0.8% to 1.2% of the total binder weight, determined through trial mixes to attain the optimum slump and strength performance. It complied with IS 9103:2019 [26] and was compatible with both cement and GGBFS.

To further enhance the performance, two types of fibers were used: steel fibers and polypropylene fibers. Hooked-end steel fibers were incorporated to improve the tensile strength, ductility, and energy absorption capacity of the concrete. These fibers were 30 mm in length and 0.5 mm in diameter, with an aspect ratio of 60. They complied with ASTM A820 [32] standards and were rust-free, clean, and uniformly dispersed during mixing. Steel fibers were added at a volume fraction of 1.0% of the total concrete volume. Their primary role was to bridge microcracks, control crack widening, and improve the post-cracking behavior of the matrix.

In addition to steel fibers, monofilament polypropylene fibers were used to control early-age cracking due to plastic shrinkage and to improve the durability performance, especially in environments prone to freeze-thaw and chemical exposure. These fibers were 12 mm in length with a diameter of approximately 18 microns. They were chemically inert, hydrophobic, non-corrosive, and complied with ASTM C1116/C1116M [33]. Polypropylene fibers were added at 0.3% by volume of concrete. Their fine dimensions helped arrest microcracks during the plastic and early hardening stages, thus contributing to the long-term integrity of the concrete matrix. Fig.1 presents the steel and polypropylene fibers used in this study.

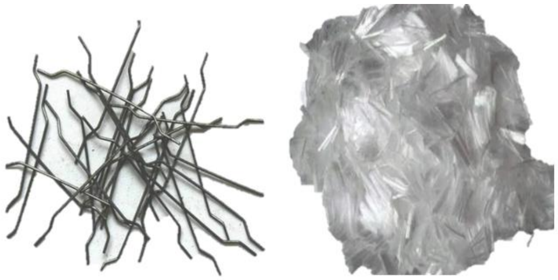

Fig.1: Steel and polypropylene fibers

All materials were procured from local suppliers and tested for compliance with relevant codes before use. Cement, GGBFS, and chemical admixtures were stored in sealed containers in a dry, shaded environment. Aggregates were stored on clean, impermeable surfaces and covered to prevent contamination. Fibers were stored indoors in sealed packaging to maintain their condition. During the mixing process, the dry ingredients, including fibers, were thoroughly mixed in a pan mixer to ensure even dispersion. Wet ingredients were added gradually, and mixing continued until a uniform, homogeneous mix was obtained. The mixing process followed IS 516 guidelines, and fresh concrete properties such as workability and consistency were assessed before casting.

Table 1: Mix proportions of HPC in kg/m^3

Mix ID	Description	OPC	GGBFS	Steel Fibers	PP Fibers	Fine Agg.	Coarse Agg.	Super plasticizer	Water
M0	Control HPC	350	150	0	0	650	1150	5	150
M1	HPC + 1% SF	350	150	78.5	0	650	1150	5	150
M2	HPC + 0.3% PPF	350	150	0	2.7	650	1150	5	150
M3	HPC + 1% SF + 0.3% PPF	350	150	78.5	2.7	650	1150	5	150
M4	HPC + 0.5% SF + 0.3% PPF	350	150	39.25	2.7	650	1150	5	150
M5	HPC + 1% SF + 0.15% PPF	350	150	78.5	1.35	650	1150	5	150

Table 1 presents six concrete mixes designed to study the impact of fiber reinforcement on the strength and durability of HPC. All mixes share a consistent base composition, characterized by a low water–binder ratio of 0.30 and a total binder content of 500 kg/m³, comprising 70% OPC and 30% GGBFS. Fine and coarse aggregates are fixed at 650 kg/m³ and 1150 kg/m³, respectively, with 150 kg/m³ of water and 1% superplasticizer (5.0 kg/m³) used to maintain workability.

The control mix (M0) contains no fibers. Mixes M1 to M5 incorporate different types and dosages of fibers. M1 includes 1% steel fibers, M2 has 0.3% polypropylene fibers, while M3 combines both (1% SF + 0.3% PPF). M4 uses 0.5% steel with 0.3% PP fibers, and M5 uses 1% steel and a reduced 0.15% PP fiber content. These variations aim to evaluate how fiber type and dosage influence the mechanical and durability performance of HPC, with the base mix kept constant to ensure reliable comparison.

3.2 Test methods

To assess the workability of fresh concrete, the slump cone test was performed as per IS 1199:1959 [27]. The concrete was filled in a standard slump cone (300 mm height, bottom diameter 200 mm, and top diameter 100 mm) in three equal layers. Each layer was tamped 25 times with a standard tamping rod. After the cone was lifted vertically, the slump was measured as the difference in height between the cone and the settled concrete [17]. This test helped evaluate the flowability of the HPC, particularly important when fibers are added, as they tend to reduce workability.

The compressive strength of concrete was determined as per IS 516:2013 [28] using cube specimens of size 150 mm × 150 mm × 150 mm. The specimens were cast, compacted in layers, and cured in water at 27 ± 2°C for 7, 28, and 56 days. At each age, the cubes were removed, surface dried, and tested in a compression testing machine with a uniform loading rate of 140 kg/cm²/min until failure. The maximum load applied divided by the cross-sectional area provides the compressive strength.

Split tensile strength was evaluated using IS 5816:1999 [30] on cylindrical specimens of size 150 mm diameter and 300 mm height. The specimens were cured and tested at 28 days. Each cylinder was placed horizontally in the testing machine, and load was applied uniformly along the diameter until the specimen split into two halves.

Flexural strength was determined using IS 516:2013 [28] guidelines on beam specimens of size 100 mm × 100 mm × 500 mm under two-point loading. The beams were tested after 28 days of curing using a universal testing machine. The load was applied at two points equidistant from the center, and the flexural strength (modulus of rupture) was calculated.

The static modulus of elasticity was determined on 150 mm × 300 mm cylindrical specimens as per IS 516 (Part 5/Sec 1):2018 [29]. After 28 days of curing, the specimens were tested using a compression testing machine equipped with a dial gauge and extensometers. The specimen was loaded gradually up to 40% of its ultimate strength, and the corresponding stress and strain values were recorded. The modulus of elasticity was calculated from the slope of the stress-strain curve in the linear elastic range.

Durability in terms of resistance to chloride ion penetration was assessed using ASTM C1202 [31] – Rapid Chloride Permeability Test. Disc-shaped specimens (100 mm diameter × 50 mm thick) were cut from 150 mm diameter × 300 mm height cylinders after 28 days of curing. The specimens were vacuum-saturated and placed in an RCPT cell, where one side of the specimen was exposed to a 3% NaCl solution and the other to a 0.3 N NaOH solution. A DC voltage of 60 V was applied for 6 hours, and the total charge passed (in Coulombs) was measured. Lower charge values indicated better resistance to chloride penetration and hence higher durability.

IV. RESULTS AND DISCUSSION

4.1 Workability

The slump test was conducted to evaluate the workability of all six concrete mixes, and it was observed that the control mix (M0) recorded the highest slump value of 195 mm, indicating excellent flowability. The introduction of fibers, particularly steel fibers, led to a noticeable reduction in slump values. Mix M1, which contained 1.0% steel fibers, showed a slump of 137 mm, reflecting the stiffening effect due to the interlocking of rigid steel fibers that resist free movement of the concrete matrix. Similarly, M4 and M5, which had combined fibers, also exhibited lower slump values of 98 mm and 95 mm respectively. On the other hand, mixes containing only polypropylene fibers, such as M2 (0.3% PP fibers), showed a moderate slump of 120 mm, indicating a relatively lesser impact on workability due to the finer size and flexible nature of the fibers. Among all, the hybrid mix M3 recorded the lowest slump due to the combined effect of both fiber types, indicating increased internal friction and reduced flow. Although fiber addition slightly reduced workability, all mixes remained within acceptable limits for HPC applications [17-19]. The use of superplasticizer ensured that even with fiber inclusion, a workable mix suitable for compaction and placement was achieved. These results emphasize the need to optimize superplasticizer dosage when using fibers in HPC to maintain desired workability. Fig.2 presents the workability values of freshly prepared HPC.

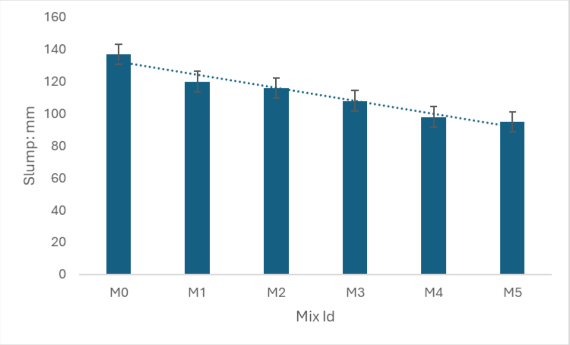

Fig.2: Slump cone values of freshly prepared HPC

4.2 Compressive strength

The compressive strength results across 7, 28, and 56 days revealed a consistent improvement with fiber incorporation when compared to the control mix. At 28 days, the control mix (M0) achieved a strength of 68.4 MPa, while M1 (with 1.0% steel fibers) and M2 (with 0.3% polypropylene fibers) exhibited enhanced strengths of 74.2 MPa and 71.0 MPa, respectively. The highest 28-day strength of 76.9 MPa was recorded for M3, which contained a combination of both steel and polypropylene fibers. This synergistic effect suggests that while steel fibers provide crack-bridging and improved stress transfer, polypropylene fibers effectively control early-age microcracks and plastic shrinkage, leading to better overall matrix integrity. The continued strength gain at 56 days, particularly in fiber mixes, is also attributed to the pozzolanic reaction of GGBFS, which contributes to long-term strength development. Mixes M4 and M5, which had adjusted dosages of steel and polypropylene fibers, also performed better than the control, indicating that even reduced fiber volumes can enhance compressive behavior if properly balanced. The inclusion of fibers contributed to greater crack control, delayed failure, and improved energy absorption during loading, all of which translate to increased compressive strength [20]. These results confirm that fiber reinforcement, especially in hybrid form, effectively enhances the compressive behavior of HPC. Fig.3 illustrates the compressive strength of HPC under 7, 28 and 56 days of curing.

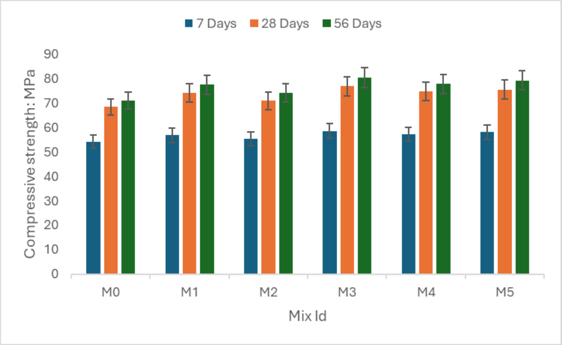

Fig.3: Compressive strength of HPC under 7, 28 and 56 days of curing

4.3 Split tensile strength

Split tensile strength is critical in assessing the tensile performance and crack resistance of concrete, which is typically a brittle material under tensile stress. The test results demonstrated that all fiber-reinforced mixes showed significant improvements in tensile strength compared to the control mix. At 28 days, the control mix (M0) achieved a tensile strength of 4.1 MPa, while M1 and M2 recorded values of 5.2 MPa and 4.8 MPa respectively. This indicates that both steel and polypropylene fibers contribute positively to resisting tensile failure. The highest split tensile strength of 5.6 MPa was observed in M3, confirming the effectiveness of using both fiber types in combination. The fibers work by bridging cracks, transferring tensile stress, and preventing the sudden propagation of microcracks. Steel fibers, due to their stiffness and strength, are particularly effective in this regard, whereas polypropylene fibers help in restraining early microcracking and shrinkage. Mixes M4 and M5, though slightly lower than M3, also showed notable improvements over the control, reaching values above 5.4 MPa. These results highlight that hybrid fiber systems offer a comprehensive mechanism for enhancing tensile capacity, combining the benefits of both fiber types. The test results strongly support the use of fiber reinforcement in HPC for applications where tensile resistance and crack control are critical [20,21]. Fig.4 presents the split tensile strength of HPC under 28 days of traditional water curing.

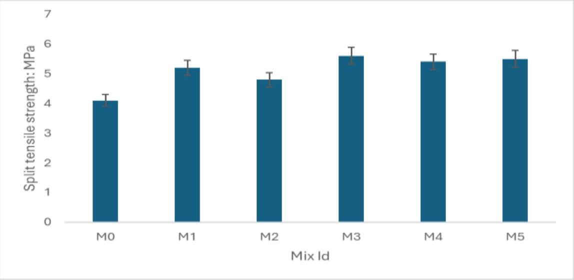

Fig.4: Split tensile strength of HPC

4.4 Flexural strength

Flexural strength results provided further insight into the crack resistance and load-carrying capacity of fiber-reinforced concrete under bending. The control mix (M0) recorded a 28-day flexural strength of 6.8 MPa, whereas the inclusion of steel fibers in M1 raised the strength to 8.3 MPa. Polypropylene fiber in M2 also improved flexural behavior, resulting in a strength of 7.5 MPa. The highest flexural strength was achieved by M3 (9.0 MPa), which contained both 1.0% steel and 0.3% polypropylene fibers. This demonstrates the clear advantage of hybrid fiber systems, where the steel fibers enhance the post-cracking load resistance while the polypropylene fibers contribute to reducing initial microcrack formation. The fibers help delay the propagation of cracks, distribute stress more uniformly, and increase energy absorption, leading to a tougher material. M4 and M5 also showed strong performance, reaching flexural strengths of 8.7 MPa and 8.8 MPa respectively. These results reinforce the idea that even with slightly reduced fiber content (as in M4 and M5), the composite behavior of concrete under flexural loading improves significantly. Such enhancements make FRHPC ideal for structural components like beams, pavements, and slabs, where flexural performance is crucial. Fiber inclusion especially in hybrid form proved highly effective in improving flexural strength. Fig.5 presents the flexural strength of HPC under 28 days of traditional water curing.

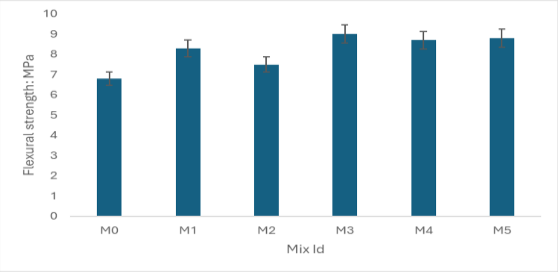

Fig.5: Flexural strength of HPC

4.5 Modulus of elasticity

The modulus of elasticity is an important indicator of a material's stiffness and deformation characteristics under load. The test results showed that the control mix (M0) had a modulus of 34.5 GPa at 28 days, which increased with the inclusion of fibers. Mix M1, containing 1.0% steel fibers, recorded a modulus of 36.1 GPa, while M2 with 0.3% polypropylene fibers achieved 35.4 GPa. The hybrid mix M3 recorded the highest value of 37.0 GPa, indicating improved resistance to elastic deformation. This increase in stiffness can be attributed to the presence of steel fibers that contribute significantly to the load-bearing capacity, particularly in the elastic phase before cracking. Polypropylene fibers also enhance matrix integrity, though their effect on stiffness is less pronounced due to their lower modulus. Mixes M4 and M5, with reduced fiber content, also showed improved values (36.3 and 36.6 GPa), confirming that even moderate fiber addition enhances the modulus of elasticity. These results suggest that fiber-reinforced HPC not only performs better under high loads but also deforms less, maintaining structural shape and serviceability. The increase in elastic modulus further supports the application of FRHPC in load-bearing and deflection-sensitive elements such as columns and prestressed members. Fig.6 presents the modulus of elasticity of HPC under 28 days of traditional water curing.

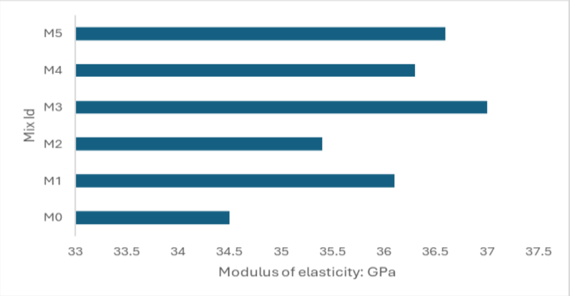

Fig.6: Modulus of elasticity of HPC under 28 days of curing

4.6 RCPT

The RCPT results provide critical insights into the durability and resistance of concrete against chloride ingress, which is a primary cause of corrosion in reinforced structures. The control mix (M0) exhibited a charge passed of 1280 Coulombs, categorized under "moderate" chloride permeability. The incorporation of steel fibers in M1 reduced this value to 970

Coulombs, while M2 with polypropylene fibers showed 1050 Coulombs, both falling into the “low” permeability range. The hybrid mix M3 recorded the lowest charge passed, 890 Coulombs, placing it in the “very low” permeability category. This significant reduction highlights the combined effect of improved microstructure due to GGBFS and enhanced crack control provided by fibers. The steel fibers help reduce crack widths, while polypropylene fibers effectively prevent the formation of microcracks during early curing. Mixes M4 and M5 also exhibited excellent durability, with RCPT values of 920 and 910 Coulombs respectively. These results clearly indicate that fiber-reinforced HPC offers superior resistance to chloride penetration, making it highly suitable for marine structures, bridges, and other aggressive environments where durability is paramount. The synergy between low w/b ratio, mineral admixtures, and fiber reinforcement plays a vital role in achieving such high durability performance. Table 2 shows the RCPT test results in coulombs.

Table 2: RCPT test results of HPC

Mix ID	Charge Passed (Coulombs)	Chloride Permeability Rating
M0	1280	Moderate
M1	970	Low
M2	1050	Low
M3	890	Very Low
M4	920	Very Low
M5	910	Very Low

V. CONCLUSIONS

Based on the experimental investigation carried out on FRHPC, it can be concluded that the inclusion of fibers both steel and polypropylene significantly enhance the mechanical and durability properties of concrete. The addition of fibers slightly reduced the workability of the mix, especially with steel fibers due to their rigidity and interlocking behavior; however, the use of a superplasticizer effectively maintained workable consistency across all mixes. Among the six mixes studied, the hybrid combination in Mix M3 (1.0% steel + 0.3% polypropylene fibers) consistently showed superior performance in compressive strength, split tensile strength, flexural strength, and modulus of elasticity. This indicates a synergistic effect of hybrid fibers in improving load resistance, crack control, and post-cracking behavior, thereby enhancing both strength and ductility.

From a durability perspective, the RCPT results revealed that fiber-reinforced mixes demonstrated lower chloride permeability compared to the control mix, with Mix M3 again showing the best resistance. The combined action of GGBFS in densifying the concrete matrix and fibers in minimizing crack widths played a key role in reducing the ingress of harmful ions. Even with reduced fiber contents in Mixes M4 and M5, the performance remained significantly better than the control mix, confirming that optimized dosages of fibers can yield durable and structurally reliable concrete. Overall, the study validates the effectiveness of using steel and polypropylene fibers in high-performance concrete, especially in environments requiring enhanced mechanical strength and long-term durability. These results support the practical application of FRHPC in infrastructure projects such as bridges, marine structures, pavements, and high-rise buildings where both performance and service life are critical.

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Declarations

The authors declared that there is no conflict-of-interest statement to publish this paper.

Conflicts Of Interest

The authors declare that there is no conflict of interest.

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