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Recent Advances in Polypropylene Fibre-Reinforced Concrete: A Systematic Review on Mechanical Characteristics and Durability Performance

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Abstract

Polypropylene Fibre-Reinforced Concrete (PPFRC) has gained considerable attention in recent years due to its enhanced mechanical properties, durability, and sustainability. However, existing literature often isolates specific parameters such as compressive strength, flexural behaviour, or fire resistance, making it challenging for researchers to assess the overall performance of PPFRC comprehensively. This review compiles and critically examines the most recent advancements (2022–2025) in PPFRC, focusing on mechanical characteristics, durability performance, and structural applications. By focusing on contemporary studies, the review highlights advancements in fibre dosage optimisation, hybrid fibre reinforcement, and long-term durability. Results indicate that polypropylene fibres can improve compressive strength by 5–30 % and flexural strength by 10–50 %, while ductility and toughness enhancements range from 30% to 160%, contributing significantly to crack resistance. On the durability front, fire resistance is notably improved, with residual strength retention up to 80% at 600°C; freeze-thaw resistance is enhanced by 15–40 %, and sulfate and chloride resistance improve by 20–55 %. Despite these advancements, challenges remain in validating laboratory findings at the field scale and understanding long-term performance beyond a 10-year horizon. Standardisation in mix design and testing procedures is also necessary for broader industry adoption. This review emphasises PPFRC's potential in forming resilient, durable, and sustainable infrastructure and suggests future directions such as AI-based mix optimisation, hybrid fibre systems, and integration with emerging technologies like 3D printing.

Major Findings: *This review carefully studied the recently published articles to highlight the latest improvements in PPFRC. Durability 10-50 % and strength 5-30 % have improved significantly. The study also shows Fire resistance up to 80% at 6000. Machine learning models are used to optimise mix design and predict performance.*

Keywords: *Durability Performance, Hybrid Fibre Reinforcement, Mechanical Properties, Polypropylene Fibre-Reinforced Concrete, Structural Applications*

1.0 Introduction

Concrete is one of the most consumable materials in the construction industry. Although concrete has numerous advantages, it still suffers from several disadvantages, including brittleness and sensitivity to cracking, which affect its long-term durability. Fibre-reinforced concrete is investigated to overcome these problems. Out of several types of fibres, polypropylene fibres attracted attention due to their low cost, corrosion resistance, and ability to raise tensile strength. Studies show that adding 0.1% to 2% polypropylene fibres can improve flexural strength by 10–50 %, also fracture width by 53.3%. Additionally, it increases toughness and fire resistance. Due to these

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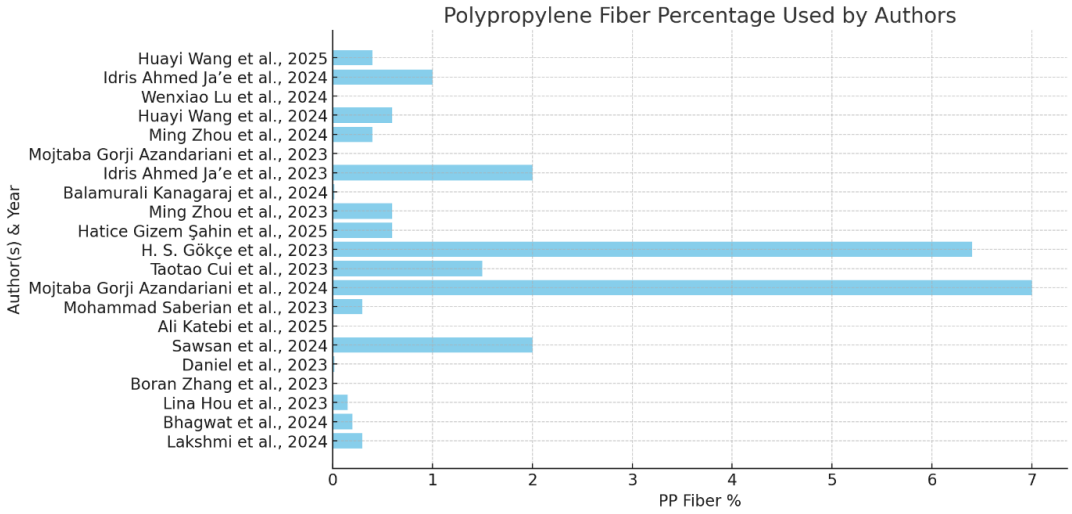


Figure 1. Polypropylene Fiber percentage used by Authors

advantages, PPFRC (Polypropylene Fibre-Reinforced Concrete) is particularly well-suited for uses including pavements, bridges, tunnels, and marine constructions.

Research on PPFRC has been somewhat fragmented, with many studies focusing narrowly on individual aspects such as compressive strength, flexural behaviour, or fire resistance. Earlier investigations often overlooked the combined use of different fibre types and lacked the application of AI-driven optimisation techniques. However, recent studies have started to explore hybrid fibre reinforcement—particularly combinations of steel and polypropylene fibres—which have demonstrated significant benefits. For instance, hybrid systems have been shown to enhance fracture energy by up to 200% and increase energy dissipation capacity by 105% under cyclic loading conditions.

Long-term performance validation study is still a challenge for researchers. Hence, it is significantly necessary to study the latest development and research on PPFRC. So, in the current review primary focus is given to research carried out between 2022 and 2025.

This paper compiles the most recent data about mechanical qualities, machine learning usage, durability performance, and structural applications. The research on Polypropylene Fibre-Reinforced Concrete (PPFRC) is roughly divided into two areas based on a thorough analysis of current literature: mechanical characteristics and durability performance. While some researchers have concentrated on PPFRC's mechanical properties, such as strength, hardness, and structural applications, others have investigated the material's endurance under

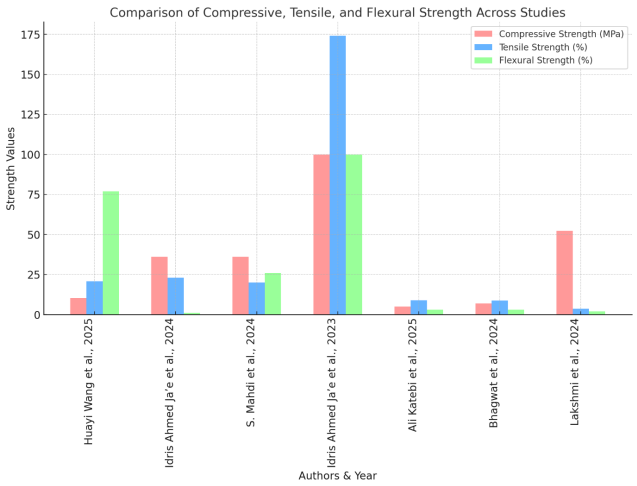


Figure 2. Comparison of compressive, Tensile and Flexural Strength

varied environmental conditions. Mechanical Properties of PPFRC – Graph 1 indicates different authors and their polypropylene usage percentage for research work. Graph 2 shows different tests carried out by different researchers.

2.0 Study of Mechanical Characteristics

Table 1 provides a consolidated overview of key studies on the mechanical properties of Polypropylene Fibre-Reinforced Concrete (PPFRC), highlighting the influence of varying fibre dosages on parameters such as compressive

Table 1. Mechanical Properties of Polypropylene Fibre-Reinforced Concrete (PPFRC)

Author(s)	Fiber Dosage	Major Findings
Huayi Wang *et al*[1].	0 %, 0.2 %, 0.4 %	Increased load capacity by 10.4–36.6 %, deflection by 20.9–50.6 %, ductility by up to 153.9 %.
Žiga Unuk *et al*[2].	Not specified	PP fibres improved ductility at high loads; minor effect under moderate loads.
Idris Ahmed Ja'e *et al*[3].	0 %, 0.5 %, 0.75 %, 1.0 %	Toughness indices improved by up to 570 %, and residual strength by 55.4 %.
S. Mahdi *et al*[4].	Recycled PP fibres	Reduced strengths by 20–36 %, but performance is acceptable for low-load elements.
Wenxiao Lu *et al*[5].	0.3 % PPF + 9 % EXP	Enhanced ductility, crack resistance; full-scale tests confirmed shrinkage control.
Amirhesam Mashayekhi *et al*[6].	PPL, PVA, Hybrid	Shear capacity ↑ by 12–20 %, peak deflection ↓ 13–28 %, hybrid > mono fibre.
Huayi Wang *et al*[7]. (FE model)	0.2 %, 0.4 %, 0.6 %	Fracture energy ↑ by up to 88.7 %, flexural/tensile strength ↑ up to 21.9 %.
Jalota& M. Suthar[8]	Various PPF %	ANN models outperformed SVMs for predicting Marshall stability.
Idris Ahmed Ja'e *et al*[9]. (KPPFRC)	0.5–2 %	1.5 % optimal dosage improved compressive strength by 100 %, tensile by 174 %.
Mashayekhi *et al*[10]. (Hybrid)	TPPL/PVA, PPS/PVA	Energy dissipation ↑ up to 664 %, crack resistance enhanced.
Ming Zhou *et al*[11].	0 %, 0.2 %, 0.4 %, 0.6 %	Tensile strength ↑ up to 21.8 %; too much fibre (0.6 %) reduced strength due to porosity.
H. S. Gökçe *et al*[12].	1.6–6.4 %	Ultimate stress ↑ from 1 MPa to 16 MPa; RSM optimised toughness.
Taotao Cui *et al*[13].	Steel + PP hybrid	Axial tensile behaviour improved; new tensile stress-strain model proposed.
Ali Raza *et al*[15].	Structural PPF	SSFPC had higher axial strength (↑21.9 %), and GSFPC had higher ductility (↑27.4 %).
Ayman Mansour *et al*[14]. (review)	Various	Review of anchorage performance with SFRC, relevant to structural behaviour.
Ali Katebi *et al*[16].	1 % PPF	Compressive strength ↓ by 5 %, but sustainability and fresh properties improved.
Sawsan *et al*[17].	0–2 % PPF	Strength ↑ from 47.6 MPa to 56.43 MPa; energy absorption increased.
Daniel *et al*[18].	2 % PPF	LCA showed reduced environmental impact; optimal pozzolan combo enhances performance.

strength, flexural performance, ductility, toughness, and energy absorption across different experimental setups. Huayi Wang *et al.*[1] conducted an experimental study to assess the flexural behaviour of Polypropylene Fiber-Reinforced Concrete (PPFRC) beams reinforced with Basalt Fiber Reinforced Polymer (BFRP) bars. By varying the percentage of polypropylene and basalt fibre influence on cracking behaviour and flexure capacity using four-point bending tests. PP fibre volume ratios (0%, 0.2%, and 0.4%) and BFRP reinforcement ratios (0.96%, 1.39%, and 1.90%). Results show that ultimate load capacity increased by 10.4 % to 36.6 %, and ultimate deflection improved by 20.9% to 50.6%. Ductility increased by 76.9% to 153.9%. The study proposed new formulas for crack spacing and width. The accuracy proved to be better than ACI 440.1R-06 and GB 50608–2020.

Žiga Unuk *et al.*[2] conducted an experimental and numerical study on the transverse compressive behaviour of steel tubes infilled with concrete. The research showed that they compared three configurations: empty steel tubes, plain concrete-infilled tubes, and PPFRC-infilled tubes under compressive loading perpendicular to the tube axis. The experiments were performed using displacement-controlled loading. The results were

analysed through simplified beam theory models and nonlinear finite element analysis. Through their study, it is proved that empty tubes have load-bearing capacity and stiffness notably less as compared concrete-infilled steel tubes. Overall, the research highlights that while PP fibres may not significantly influence structural performance under moderate loads. But it can improve ductility at higher loads, making them even beneficial for applications requiring greater toughness and energy absorption.

Idris Ahmed Ja *et al.*[3] showed an experimental and numerical study on the structural performance of lightweight polypropylene fibre-reinforced concrete using Lightweight Expanded Clay Aggregate (LECA). The study investigated using the following PP fibre percentages (0%, 0.5%, 0.75%, and 1.0%) and a constant 10% micro-silica. To check the effect on mechanical properties, flexural toughness, impact energy absorption, and crack resistance. Experimental data was used to develop prediction models. The study found that increasing PP fibre content enhanced toughness, impact energy absorption, and crack resistance. Toughness indices I5 and I10 increased by 300% and 570%, while residual strength improved by 55.4% at 1% PPF. The study developed new predictive models for crack resistance as well as impact energy absorption. The validation was done through ANOVA analysis. This shows strong correlations between flexural toughness, impact energy, and crack resistance.

S. Mahdi *et al.*[4] examined the flexural behaviour and post-cracking performance of polypropylene fibre-reinforced Waste Cardboard Blended Concrete (WCBC). The study aimed to explore the structural feasibility of repurposing waste cardboard and recycled polypropylene (PP) macro-fibres in concrete. The research assessed key mechanical properties (compressive strength, flexural strength, modulus of rupture, modulus of elasticity, and tensile strength) at 7 and 28 days. In addition to that, Crack Mouth Open Displacement (CMOD) tests and four-point bending tests on retaining wall beams were conducted. To analyse post-cracking behaviour. From the Results, they concluded that adding waste cardboard reduced compressive, flexural, and tensile strengths by 36 %, 26 %, and 20 %, respectively, while the modulus of elasticity decreased by 23 %. But the mechanical properties remained within the acceptable range for structural applications. The study determined that waste cardboard and PP fibres can be effectively integrated into sustainable concrete applications. Especially in low-load-bearing structural elements.

Wenxiao Lu *et al.*[5] investigated the mechanical properties and cracking resistance of shrinkage-compensating concrete reinforced with Expansive Agents (EXP) and Polypropylene Fibres (PPF). The study was carried out to address shrinkage-induced cracking in concrete sidewalls by optimising EXP and PPF content. While conducting the study, Laboratory tests were also conducted, including slump, compressive strength, flexural strength, X-Ray Diffraction (XRD), and Scanning Electron Microscopy (SEM). In addition to that, along with full-scale sidewall monitoring and numerical simulations to analyse stress, strain, and crack propagation. Results showed that EXP reduced early-age strength but had minimal impact on long-term strength. PP fibres improved ductility and crack resistance. The optimum mix was found to be 9 % EXP with 0.3 % PPF. The full-scale monitoring showed that internal temperature variations reached 40°C during curing. The EXP effectively controlled shrinkage and microcrack formation. Also, Numerical simulations confirmed that EXP and PPF improved ductility and prevented crack propagation.

Amirhesam Mashayekhi *et al.*[6] investigated the cyclic performance of GFRP-reinforced Seawater Sea-Sand (SWSS) concrete culverts incorporating synthetic fibres. They tested five full-scale inverted U-shaped culverts with different fibre reinforcements: Macro-Polypropylene (PPL), Micro-Polyvinyl Alcohol (PVA), and hybrid PPL/PVA fibres. In addition to these two control culverts, a steel-reinforced Freshwater Normal-Sand (FWNS) concrete culvert and a GFRP-reinforced FWNS culvert were tested for comparison. Important parameters evaluated included load-deflection response, ultimate shear capacity, energy dissipation, hysteretic damping, strength degradation, and self-resetting capacity under cyclic loading. The results showed that incorporating PPL and PVA fibres improved shear capacity by 12–20 % and reduced peak deflection by 13–28 %, enhancing ductility and energy dissipation. Hybrid fibres performed better than mono-fibre reinforcement, providing higher damping and greater energy absorption at low deflections. Steel-reinforced concrete culverts exhibited 17% lower peak deflection than GFRP-reinforced ones. The study also validated AASHTO shear capacity equations.

Huayi Wang *et al.*[7] investigated the tensile fracture behaviour of Polypropylene Fiber-Reinforced Concrete

(PFRC) using a microscale finite element model. The study observed PFRC as a three-phase heterogeneous material consisting of aggregates, mortar (with embedded PP fibres), and the Interfacial Transition Zone (ITZ). Three-point bending and splitting tensile tests were conducted on mortar and composite specimens with PP fibre volume fractions of 0.2 %, 0.4 %, and 0.6 % to analyse their influence on crack resistance and fracture properties. The results showed that PP fibres improved flexural and tensile strength by 9.6–15.0 % and 9.5–21.9 %, respectively, with fracture energy increasing by up to 88.7 %.

Jalota and M. Suthar[8] investigated the prediction of Marshall stability in polypropylene fibre-reinforced asphalt concrete using machine learning models. They compared Support Vector Machine (SVM) models with different kernel functions, SVM-Normalised Polynomial, SVM-RBF, SVM-Polynomial, and SVM-PU, against an Artificial Neural Network (ANN) model. From the literature dataset of 138 experimental values were collected and split into 70% training and 30% testing data. The input parameters included Polypropylene Fibre Length (LPPF), polypropylene fibre percentage (PPF% %), Bitumen Content (BC), and Bitumen Grade (BG). The ANN model outperformed all SVM models, achieving the highest correlation coefficient (CC = 0.8935), Nash-Sutcliffe efficiency (NSE = 0.7975), and the lowest RMSE (1.8303) and MAE (1.3298), indicating superior predictive accuracy. The study concludes that ANN-based prediction models can efficiently replace time-consuming laboratory tests.

Idris Ahmed Ja *et al.*[9] studied the mechanical properties of Kenaf-Polypropylene Fibre-Reinforced Concrete (KPPFRC) using experimental and predictive modelling techniques. The research aim was to optimise fibre volume fractions (0.5% to 2%) using Response Surface Methodology (RSM) and evaluate their effects on compressive, split tensile, and flexural strength. Tests were conducted on grade 35 concrete, and regression models were developed to predict mechanical responses. Results showed that optimal fibre content (1.5%) significantly improved mechanical properties, increasing compressive strength by 100 %, split tensile strength by 174%, and flexural strength by 100% compared to control samples.

Amirhesam Mashayekhi *et al.*[10] investigated the cyclic flexural performance of fibre-reinforced seawater sea-sand concrete (FR-SWSSC) with hybrid fibres to improve durability in marine and coastal structures. During the study, they examined the effects of Polypropylene (PPL, TPPL), Polyvinyl Alcohol (PVA), and Basalt (BF) fibres under four-point cyclic bending tests to assess energy dissipation, strength degradation, and damage resistance. Results showed that hybrid fibre reinforcement significantly improved cyclic performance. The TPPL/PVA hybrids achieve 105% and 664% higher energy dissipation than mono TPPL and PVA fibres, respectively. Similarly, PPS/PVA hybrids displayed 79 % and 112 % increases in hysteretic damping ratio compared to mono PVA and PPS fibres. Hybridisation enhanced crack resistance, reduced peak deflections.

Ming Zhou *et al.*[11] conducted a mesoscale modelling study to predict the splitting tensile behaviour of Polypropylene Fibre-Reinforced Concrete (PFRC) using the Discrete Element Method (DEM). The study investigated the effects of polypropylene fibre content (0% to 0.6%) and aggregate type (limestone and granite) on Interfacial Transition Zone (ITZ) properties. A multi-phase DEM model was developed in PFC3D software. Experimental results showed that 0.2 % and 0.4 % PP fibres increased tensile strength by 17.6% and 21.8%, respectively, while 0.6 % fibre content reduced strength by 8 % due to excessive porosity. The ITZ tensile strength decreased by 34.4 % to 47.3 % in limestone-based samples. The study shows that DEM is a powerful tool for PFRC failure analysis and optimisation.

H. S. Gökçe *et al.*[12] investigated the toughness behaviour of Polypropylene Fibre-Reinforced Foam Concrete (PFRC) under uniaxial and triaxial compression loads. The study evaluated the effect of varying fibre content (1.6%, 3.2%, 4.8%, and 6.4%) on the mechanical performance. A Response Surface Methodology (RSM) was used to optimise fibre dosage for toughness enhancement. Results showed that fibre reinforcement improved strain capacity, with ultimate compression stress increasing from 1 MPa to 16 MPa as foam density increased. Also, strain-hardening was observed in low-density foam concrete. And high-density specimens exhibited strain-softening. The optimum fibre contents for low, medium, and high-density foam concrete were 3.9%, 4.6%, and 6.4%, respectively.

Taotao Cui *et al.*[13] investigated the axial tensile behaviour of Hybrid Steel-Polypropylene Fibre-Reinforced High-Strength Lightweight Concrete (HFR-HSLC). The objective of the study was to enhance

the tensile properties of HSLC, which typically suffers from brittle failure. Direct Tensile Tests (DTT) and Digital Image Correlation (DIC) measurements were conducted to analyse tensile stress-strain behaviour, toughness, and crack propagation. The conclusions showed that hybrid fibres improved tensile performance at both micro and macro levels. A new axial tensile stress-strain equation was developed, which is useful for practical design reference.

Ayman Mansour *et al.*[14] conducted a state-of-the-art review on the load-bearing behaviour of anchors in Fibre-Reinforced Concrete (FRC), and the focus was on Steel Fibre Reinforced Concrete (SFRC) and its influence on anchorage performance. The study analysed 916 tests, critically reviewing how fibre content, fibre type, distribution, and embedment depth impact tensile and shear strength of anchors.

Ali Raza *et al.*[15] investigated the axial performance of polypropylene Structural Fibre-Reinforced Plastic Waste Aggregate Concrete (SFPC) reinforced with GFRP rebars (GSFPC). Its performance compared with steel-reinforced SFPC (SSFPC) under different loading conditions. During the research, testing was carried out on 18 circular specimens. Whose (300 mm diameter, 1200 mm height) is under concentric and eccentric loads. To find axial strength, ductility, and Finite Element (FE) modelling accuracy. Findings revealed that SSFPC components had 21.9 % higher axial strength than GSFPC but 27.4 % lower ductility. The study concludes that GSFPC offers a sustainable and corrosion-resistant alternative.

Ali Katebi *et al.*[16] explored urban environmental challenges by incorporating 7 % treated rubber powder, 1 % polypropylene fibres, and wash water into Self-Compacting Concrete (SCC). Twelve mix designs were prepared and then tested with cement contents of 400 and 440 kg/m^3 and water-to-cement ratios (0.36 and 0.5). Workability, mechanical properties, and durability were found. The author concludes that treated rubber powder improved fresh concrete properties compared to untreated rubber. SCC with fibres, rubber powder, and wash water exhibited a 5% slump flow reduction, 30% increase in T50cm time, 10 % lower J-ring passing ability, 20% higher V-funnel duration, and 5% reduced fillability. Compressive strength dropped by 5% in fibre-reinforced mixes. The study proves that SCC with rubber powder, fibres, and wash water can enhance sustainability and mechanical performance.

Sawsan *et al.*[17] discovers the structural performance of Steel-Concrete-Steel (SCS) composite sections incorporating Polypropylene Fibres (PPF) and ground Granulated Blast-Furnace Slag (GGBS) as an eco-friendly alternative to conventional concrete. The research analysed seven SCS specimens. Push-out monotonic loading is given to evaluate ductility and ultimate strength. Also finds failure modes and energy absorption. They found compressive strength increased from 47.6 MPa to 56.43 MPa as PPF content rose from 0% to 2%. Also, the energy absorption was higher in PPF-filled SCS specimens compared to the control sample.

Daniel *et al.*[18] evaluate the life cycle performance of polypropylene fibre-reinforced pozzolanic concrete using a database-driven approach. Linear regression analysis was done. And through the experimental study, the optimum fibre content was identified as 2%, while 30% fly ash, 15% slag, and 7.5% silica fume were found to be the ideal pozzolanic replacements. A Life Cycle Assessment (LCA) using a cradle-to-gate approach showed that incorporating PP fibres with pozzolans significantly reduced environmental impact indices.

3.0 Durability Performance of PPFRC

Table 2 summarises recent research on the durability performance of Polypropylene Fibre-Reinforced Concrete (PPFRC), showcasing the effects of fibre content on fire resistance, sulfate and chloride attack, shrinkage, thermal stability, and overall resistance to aggressive environmental conditions.

Mojtaba Gorji Azandariani *et al.*[19] Perform experimental study of mechanical and durability properties of polyolefin and polypropylene fibre-reinforced concrete. Compressive strength, resistance against sulfates, acid resistance, penetration of chloride ions, also abrasion resistance were investigated using cubic and cylindrical specimens. Plain concrete specimens were compared with the concrete adding 1 % volume of polyolefin and polypropylene fibres. Findings showed that polyolefin fibres significantly improved compressive strength (by 30.47%), whereas polypropylene fibres provided a smaller increase (9.67%). In acid resistance tests, polyolefin fibres enhanced strength by 35%, whereas polypropylene fibres showed a 19% increase. They found

Table 2. Durability Performance of PPFRC

Author(s)	Fiber Dosage	Major Findings
Mojtaba Gorji Azandariani *et al*[19]	1 %	Polyolefin > PPF; acid resistance ↑ by 19 %, sulfate resistance ↑, and compressive strength ↑ by 9.67 %.
Santosh Mishra *et al*[20].	Not specified	Strength ↓ from 70.7 MPa to 50.1 MPa with temperature ↑; better ductility at low temperatures.
Balamurali Kanagaraj *et al*[21].	2 % each fibre	Strength degradation 40–80 % post-fire; steel fibres best, PPF moderate fire durability.
Boran Zhang *et al*[25].	Not specified	Acid rain reduced UHPPFRC strength; sulfate is more damaging than the heating rate.
Hatice Gizem Şahin *et al*[23].	0.2 %, 0.4 %, 0.6 %	Compressive strength ↓ 34–56 % at 900°C; fibre type/orientation affected durability.
Mojtaba Gorji Azandariani *et al*[24]	1–7 %	Compressive strength ↑ by up to 34.36 % with polyolefin fibres; chloride/acid resistance improved.
Boran Zhang *et al.*[22] (fire model)	Not specified	Fibre orientation critical for tensile strength under fire; enhanced safety in UHPPFRC.
Bhagwat *et al*[26].	0 %	Shrinkage ↓ by 40%, permeability ↓ by 33%, improved resistance to acid and surface cracking.
Lakshmi *et al*[27].	0.1–0.3 %	Split tensile ↑ 6.4%, flexural ↑ up to 8.2%, compressive strength steady; crack resistance improved.

that, compared to other fibres, polyolefin fibre-reinforced concrete had the greatest sulfate resistance and the highest compressive strengths. These results highlight that polyolefin fibres outperform polypropylene fibres in improving concrete durability and mechanical strength.

Santosh Mishra *et al.*[20] used the Lattice Discrete Particle Model (LDPM) and its fibre-extended version (LDPM-F) to numerically study the behaviour of Polypropylene Fibre-Reinforced Concrete (PFRC) under moderate temperature changes (-30°C to 60 °C)[2]. The mechanical property changes, formation of cracks, and flexural behaviour by TPB (three-point bending) and compression tests were studied. Experimental findings showed that compressive strength decreased from 70.7 MPa at -30°C to 50.1 MPa at 60°C, while elastic modulus peaked at 0°C (32,151 MPa) and declined at higher temperatures. The study concluded that moderate temperature variations significantly influence PFRC performance, with negative temperatures improving strength and ductility. Whereas positive temperatures reduce overall structural integrity.

Balamurali Kanagaraj *et al.*[21] investigated the thermal and mechanical performance of natural and synthetic fibre-reinforced Recycled Aggregate Concrete (RAC) under fire exposure. The study incorporated steel, polypropylene, and coconut fibres (each at 2%) to improve the rheological, hardened, and post-fire properties of RAC. Without fibres exhibited the highest porosity (20–32 %), leading to significant strength degradation (40–50 % at 821°C, increasing to 74–80 % at 1029°C). Out of all fibre-reinforced mixes, steel fibres provided the best fire resistance and limited mass loss. The study also developed predictive models to correlate porosity and mass loss, aiding fire-resistant concrete design.

Boran Zhang *et al.*[22] studied the deterioration of fire resistance in Ultra-High-Performance Polypropylene Fibre-Reinforced Concrete (UHPPFRC) due to long-term acid rain exposure. The research developed a coupled chemo-thermal-mechanical model to analyse sulfate penetration, internal stress buildup. The study investigated the effects of sulfate concentration, heating rate, and fibre dosage. Findings showed that acid rain-induced sulfate attack compromised UHPPFRC strength by reducing porosity and increasing internal expansive stress., The study also found that fire resistance was more sensitive to sulfate concentration than heating rate.

Hatice Gizem Şahin *et al.*[23] investigated the degradation of mechanical properties in 3D fibre-reinforced Printed Concrete (3DPC) mixtures exposed to elevated temperatures. The study evaluated three fibre types (steel, basalt, polyamide) at 0.2%, 0.4%, and 0.6%

volume fractions, with exposure to 300°C, 600°C, and 900°C. Key tests included compressive strength, flexural strength (in parallel, perpendicular, and lateral loading), weight loss, water absorption, and microstructural analysis. Results showed that 3DPC durability significantly declined with increased temperature exposure. At 900°C, compressive strength loss ranged from 34% to 56%, while flexural strength loss varied between 28% and 73%, depending on fibre type and orientation. These findings prove the importance of fibre selection for high-temperature applications in 3DPC.

Mojtaba Gorji Azandarian *et al.*[24] investigated the durability and compressive strength of composite Polyolefin Fibre-Reinforced Recycled Aggregate Concrete (PFRRAC) under chloride and acidic environments. The study evaluated 150 cubic concrete specimens (100 × 100 × 100 mm) with varying polyolefin fibre contents (1%, 3%, 5%, and 7%) and recycled aggregate replacements (10%, 30%, 50%, and 70%). Results showed that adding polyolefin fibres improved compressive strength by up to 34.36% at 5 % fibre content, whereas increasing recycled aggregate content reduced strength by 21.12 % to 43.85 % (at 70% replacement).

Boran Zhang *et al.*[25] investigates the fire resistance and internal stress behaviour of Ultra-High-Performance Polypropylene Fibre-Reinforced Concrete (UHPPFRC) panels used in cladding systems. A coupled hygro-thermal-mechanical model was developed to predict internal stress, temperature distribution, and porosity changes during fire exposure. The study highlights that fibre orientation significantly influences tensile strength variations and overall fire resistance.

The findings emphasise the importance of fibre distribution and dosage optimisation for enhancing the durability and safety of UHPPFRC cladding in fire-prone environments.

This study by Bhagwat *et al.*[26] explores the effects of M-sand and polypropylene fibres on the strength and durability of Self-Compacting Concrete (SCC). The research highlights that M-sand improves both fresh and hardened properties of SCC compared to natural sand. Due addition of polypropylene fibres slightly reduces the workability of SCC. 0.15% polypropylene fibre was found to be the optimal dosage. They found a 6.97% increase in compressive strength, an 8.68% increase in split tensile strength, and a 3% increase in flexural strength. Durability improvements were significant, with a 40% reduction in drying shrinkage, 30 % lower water absorption, and 33.33% less permeability. The study also reported enhanced resistance to acid attack and surface crack initiation.

The study by Lakshmi *et al.*[27] evaluates the performance of low-volume synthetic polypropylene fibres in pozzolanic cement concrete (M40 grade). The research investigates the effects of 0.1%, 0.2%, and 0.3% fibre dosages in Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC) concrete. The results indicate that compressive strength decreases with increasing fibre content, with 0.2% fibre dosage in OPC and PPC achieving 52.24 MPa and 47.7 MPa, respectively, close to the control mix. Split tensile strength improved by 3.7% in OPC and 6.4% in PPC at 0.3% fibre dosage. Flexural strength showed marginal improvement up to 2% in OPC and 8.2% in PPC for the same dosage. Overall, incorporating polypropylene fibres with OPC and PPC provides durable, crack-resistant, and structurally sound concrete.

4.0 Research Gaps and Future Scope

Despite significant advancements in polypropylene fibre-reinforced concrete (PPFRC), several research gaps remain. The long-term durability under harsh environmental conditions, including freeze-thaw cycles, sulfate attack, and chloride penetration, requires further investigation. Optimising fibre dosage for achieving the best balance between mechanical properties, durability, and cost-effectiveness is still not well established. Numerical modelling and AI-based predictive analytics can enhance performance estimation and mix design optimisation. Large-scale field studies validating laboratory findings are limited, restricting practical applications.

5.0 Conclusion

Enhanced Mechanical and Durability Properties – Research from 2022–2025 confirms that PPFRC improves flexural strength, tensile resistance, and crack control, with fibre dosages optimising toughness and impact absorption. Studies also highlight increased fire resistance, freeze-thaw durability, and sulfate/chloride resistance, making PPFRC suitable for harsh

environments. Potential in Sustainable Infrastructure. The incorporation of PP fibres in pavements, bridges, marine structures, and tunnels contributes to longer service life, reduced maintenance costs, and enhanced sustainability. Hybrid reinforcement with steel or basalt fibres further expands its structural applications. Future Research & Technological Advancements – AI-driven predictive models, 3D printing technology, and smart self-healing materials can further optimise PPFRC for next-generation infrastructure. Future studies should focus on long-term performance, recyclability, and economic feasibility to promote its wider adoption.

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