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Study on Polypropylene Fiber: A Review

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Abstract:

Polypropylene fibre (PPF) works as a reinforcement material, similar to incorporating strong fibres inside concrete matrices to boost structural stability. Widely employed in different fields such as automotive engineering, textile, geotextile and environmental conservation, PPF delivers great advantages due to its essential properties, including its lightweight nature, high strength and resistance to corrosion. The molecular arrangement of PPF, defined by combined propylene monomers forming linear chains, underlying its remarkable flexibility and tensile strength, rendering it significant in numerous applications. Nonetheless, gaps exist in our expertise, particularly concerning the study of higher thresholds: polypropylene fibre integration in concrete, workability reduction with increasing polypropylene fibre concentration, and the eco-friendliness of PPF. Further academic inquiry is important to construct sector-specific models for forecasting and maximising PPF concentrations in concrete compositions. These efforts show possibilities not simply for strengthening infrastructure but also for improving environmentally friendly materials science practices. This finding underscores the crucial relevance of further investigation in material utilizing scientific methods to fully use the capabilities of PPF in increasing structural resilience and environmental sustainability. Additionally, the review article provides insight into the present status of research on PPF, its manufacturing process and its uses in many sectors.

Keywords: *Polypropylene fiber; Mechanical characteristics; Thermal characteristics; Reinforcement of Concrete; Textile; Geotextile; Automotive industry; Environmental protection*

1. Introduction

Polypropylene (PP) has emerged as a popular thermoplastic polymer(a thermoplastic polymer is a form of plastic substance that can be heated and moulded repeatedly without permanently changing) in recent decades because of its exceptional characteristics, economic feasibility, and ease of processing [1]. Over time, major improvements have been made in the manufacture and application of PP, leading to its broad use across different sectors. This review seeks to provide a thorough examination of research conducted on PP and its wide-ranging applications, as well as its potential prospects.

PPF is a synthetic fibre made up of linear polymer chains created by the polymerization of propylene molecules, giving it a unique flexibility. This distinct molecular structure, including monomers of propylene connected in a straight chain, has several advantages, including better chemical resistance, lower density, higher crystallinity, and adequate mechanical strength [2]. PPF have benefits like low weight, high strength, toughness, and corrosion resistance, making them appropriate for a variety of applications in automotive, chemical, clothing, and environmental protection sectors. In addition to its uses in the automotive, chemical, and apparel sectors, polypropylene fibres are also used in construction and concrete applications to enhance the functionality and mechanical characteristics of concrete.PPF overcome certain drawbacks in conventional cement used in construction, such as deformation resistance, fracture resistance, and tensile strength. As a result, the use of PPF increases the overall longevity and structural integrity of concrete constructions.

In the most recent years, scholars focused on improving the strength of masonry walls by using PPF. Masonry walls, though known for their ability to sustain vertical static compressive loads from a building's weight and applied loads, are susceptible to cracking caused by settlement, thermal expansion and contraction, or structural movement. Despite their ability to withstand vertical forces, brick walls lack adequate resistance to lateral stresses [3]. A masonry wall reinforced with polypropylene mortar plastic demonstrated greater in-plane lateral strength than an unreinforced wall, reported Yardim and Lalaj [4]. Furthermore, current improvements in polypropylene fibre technology are creating new prospects in fields like as nanotechnology, biodegradable composites, and sustainable materials. G.R. Koerner et al. reported that PP is unique among geosynthetics because of its affordability and unique characteristics in contrast to PE [5]. These characteristics may include high tensile strength, resistance to chemical and biological degradation, and adaptability in a variety of environmental conditions. As a commercially relevant polymer, PP's broad use in a variety of applications is primarily due to its low cost. [6].

Thus, the review article focuses comprehensively on studies on polypropylene fibre, including its properties, objectives, research gaps, applications and future potential. This paper is expected to encourage more invention and improve the current understanding of polypropylene's role in developing materials that combine technology and science.

2. Backdrop

Mujeeb Latifi et.al (2022) [7] highlights the importance of polypropylene fibres in increasing the strength and durability of concrete, despite early workability difficulties. These fibres have several benefits, including greater tensile and flexural strength, resistance to environmental stresses such as high temperatures, abrasion, impact, and freeze-thaw cycles, and reduced shrinkage-induced length fluctuations, which result in improved stability. This cost-effective method efficiently solves the constraints of concrete, making polypropylene fibres a favoured construction material. Ongoing research is expected to produce significant advances in concrete technology.

Enea Mustafaraj et.al (2019) [8] described the use of 12 mm polypropylene fibres for shear reinforcement, highlighting its function in improving concrete's structural integrity and resistance to shear strain. With their bigger diameter, these fibres provide extra reinforcement inside the concrete matrix, allowing for more effective force distribution. Their flexibility and simplicity of application make them ideal for shear reinforcement in a variety of building procedures. Researchers acknowledge that using 12 mm polypropylene fibres is an efficient and impactful way to improve the structural integrity of concrete structures.

According to **Najaf et al (2022)** [9] incorporation of polypropylene fibre into concrete constructions can promote environmentally beneficial activities. The research study also investigates green options for lowering CO2 emissions (which are mostly caused by human activities such as fossil fuel combustion and industrial operations). The study looks at how polypropylene fibres might increase the compressive strength of lightweight concrete, giving sustainable alternatives to traditional additives and reducing the environmental effect of concrete manufacturing processes.

Han C et.al (2021) [10] investigated the effect of introducing polypropylene fibres with various content percentages (from 0% to 1.5%) and a constant fibre length of 12 mm on the capacity for shear of clay soil. Using direct shear testing, the researchers hope to determine the best mix of fibre content and length, offering vital insights into the link between these parameters and soil stability. The purpose of this research is to help improve the mechanical characteristics of clay soil by investigating the impact of polypropylene fibres on soil behaviour, providing useful information for soil stabilization procedures.

Swarnalata Sahoo et.al (2020) [11] investigate how automakers are reacting to climate change concerns by creating innovative components that reduce vehicle fuel use. The review emphasizes the relevance of biocomposites (materials made up of two or more separate components, at least one of which is generated from renewable biological resources such as plants or animals) in promoting sustainability, with an emphasis on cellulose nanofiber-reinforced composites. Polypropylene (PP) is a vital material in automotive applications, resulting in substantial research interest in PP-based products. These initiatives show potential in tackling environmental issues and lowering the environmental effects of car production. Recent improvements emphasize strategic ways to increase fuel efficiency, emphasizing the relevance of biocomposites, notably the usage of polypropylene.

Wu H et.al (2020) [12] conducted studies primarily on the application of polypropylene in geotextiles. Geotextiles serve an important role in a variety of geotechnical applications and are largely made of polymers such as polypropylene, which cause environmental issues owing to their non-biodegradability. Geotextiles have critical roles in infiltration, drainage, strengthening, separation and erosion prevention in geotechnical engineering. However, the increasing demand for geotextiles, which exceeds 1.4 billion square meters per year, raises worries about environmental deterioration. Recent research initiatives have concentrated on producing new geotextiles, with a special emphasis on eco-friendly solutions that integrate natural fibres such as polypropylene. The use of polypropylene fibres in geotextiles is a significant step in promoting.

Hossain MT et.al (2024) [13], Polypropylene (PP), a highly versatile polymer, has seen significant developments in recent years, owing in large part to the growing need for innovative products. Current research focuses on increasing the characteristics of PP by incorporating polypropylene fibres, particularly for more complex applications. Because of its exceptional properties, PP is widely utilized in an abundance of sectors, including biomedical, automobile, aerospace, and filtration. Challenges like as UV resistance limits and bonding difficulties are being addressed using novel approaches. The incorporation of PPFs has broadened the field of PP applications, providing improved performance and adaptability across a wide range of industries.

Wioletta Raczkiewicz (2021) [14] carried out investigations into utilizing polypropylene fibres to increase concrete's resistance to reinforcing corrosion, particularly chloride-induced corrosion. These fibres improve cohesiveness by reducing large pores and shrinkage cracks, acting as micro-reinforcements to prevent plastic shrinkage and fracture development. While their effect on concrete absorbability varies, they typically improve durability by minimizing microcracks and enhancing frost resistance. However, their presence may reduce workability, causing mix changes. Nonetheless, their ability to reduce chloride-induced corrosion emphasizes its importance in increasing structural longevity.

Marco Corradi et.al (2020) [15] investigated the use of polypropylene fibres and mesh to reinforce masonry structures against seismic stresses. His study focused on the usefulness of different fibre lengths, particularly 12 mm fibres, and their absorption into the cementitious matrix. Corradi's research revealed considerable improvements in the in-plane load capacity of reinforced masonry walls, particularly when polypropylene fibres are used. However, he found difficulties in repairing broken walls with polypropylene fibres, citing bonding and compatibility of materials limitations. Corradi's research emphasizes the significance of maximizing bonding characteristics and resolving compatibility difficulties to assure the efficiency of masonry retrofitting solutions against seismic occurrences.

2.1 Manufacturing of Polypropylene Fiber:

In the manufacturing process of PPF, commercial production generally involves standard melt-spinning processes. Figure 1 depicts the process of melt spinning. This includes heating polypropylene resin particles until they reach a molten condition. The molten material is then extruded through tiny perforations in a spinneret, generating continuous threads. These filaments are rapidly chilled and solidified, commonly by passing them through a cooling chamber or by direct contact with a cooling liquid. The formed fibres are then stretched to align the polymer chains and improve mechanical characteristics. Finally, the stretched filaments are wrapped onto spools or bobbins for storage or further processing. This melt-spinning technique provides for the efficient and high-volume manufacture of polypropylene fibres with constant quality and performance characteristics.

2.1.1 Processing of Polypropylene Fiber

Understanding the melting point of polypropylene (PP) is critical in the processing industry since it typically remains around 170°C but can fall lower for PP variations such as the ProFax 7-series polymers due to variances in their crystal structures. Injection moulding generally runs at temperatures ranging from 220°C to 250°C, with mould temperatures determining the PP cooling rate and, consequently, final qualities. Extrusion, on the other hand, typically uses temperatures between 200°C and 230°C, however, greater temperatures are required to produce films and fibres. Striking the proper temperature balance is critical; extremely high temperatures might cause deterioration, while too low temperatures result in unrealistic PP viscosity. In 1982, Roberts [16] suggested an intriguing option, arguing for lower melt temperatures of about 177°C in PP filament extrusion.

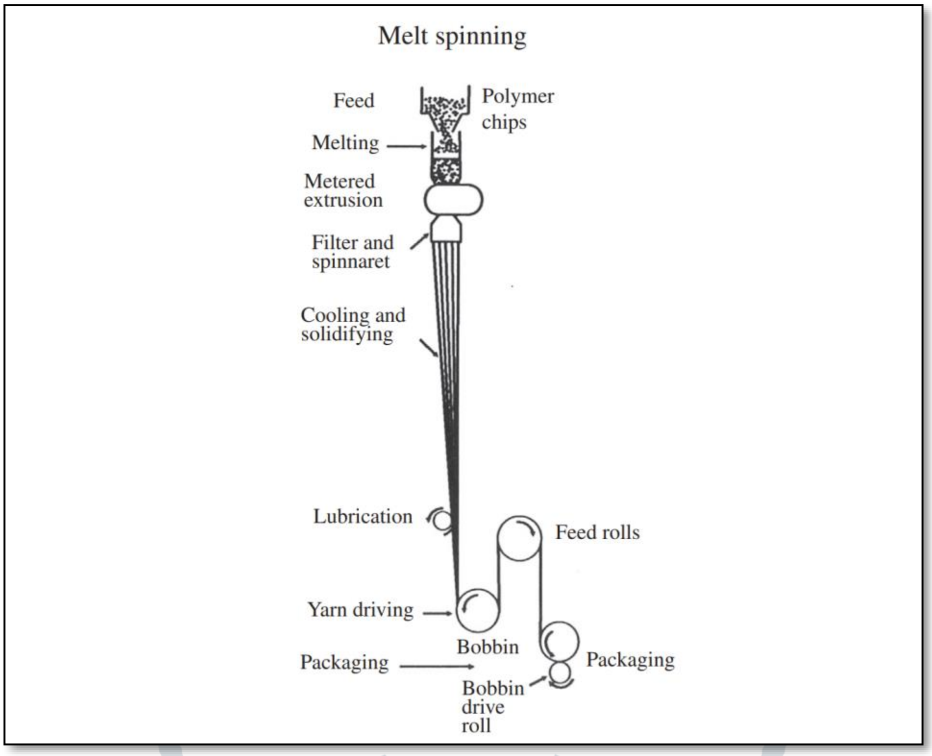

Figure 1- Schematic figure of melt spinning [17]

2.1.2 Melt Spinning Process

Melt spinning is a widely recognized technique utilized to produce thin strips of amorphous metallic material and metallic crystalline alloys, which are referred to as ribbons. Since its inception in 1960 by Duwez et al. [18], this methodology has played a pivotal role in the production of various ternary, binary, and multicomponent amorphous and metallic crystalline alloys within the previous five decades. In the procedure of melt spinning, a metal alloy in a molten state experiences fast cooling rates of up to 10°K/s. A complete review article may be found elsewhere that provides further insights into the creation of amorphous and metallic glasses utilizing the melt-spinning approach [19].

In the usual melt-spinning technique, a specific quantity (varying from 5 to 100 grams) of tiny alloy pieces is kept in a crucible, normally consisting of glass made from quartz or, in certain circumstances, boron nitride for applications requiring higher temperatures. This crucible is ringed by an induction coil, as indicated in Figure 1. The use of a strong electrical current causes the alloy within the crucible to heat up and finally melt. Subsequently, the droplets of molten metallic are driven via Ar-pressurization via a fine nozzle onto a fast revolving wheel made from copper, generally spinning at rates between 5,000 and 7,000 revolutions per minute (rpm). This quick rotation helps the accomplishment of solidification rates (ranging from 10^5 to 10^6 Kelvin per second) essential for changing the liquid state/phase(molten metal) into a solid amorphous phase/state. It is notable that melt spinning of molten metallic systems not only leads to the generation of metallic glassy and amorphous alloys but also stimulates the formation of additional non-equilibrium phases, including nanocrystalline structures[20], quasi-crystalline phases [21], and supersaturated solid solutions[22]. The schematic design in Figure 2 depicts the essential concepts of melt-spinning (a-c) and casting (e-g) processes, generally applied to create ribbon-shaped (d) and rod-shaped (h) metallic glass materials. These samples were created by the author using a melt-spinner device, the PA 500, developed by Edmund Bu¨hler in Germany. The equipment was placed in the

Nanotechnology Laboratory at the Energy and Building Research Center(EBRC) of the Kuwait Institute for Scientific Research(KISR) [23].

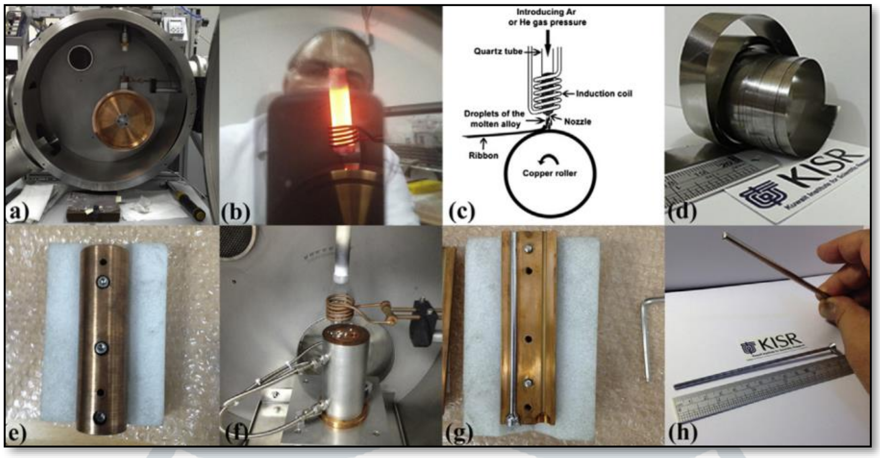

Figure 2- Schematic diagram of a typical melt-spinning process [23]

3. Properties of Polypropylene

PPF, a well-established fibre, is used extensively in a variety of sectors, including automotive, chemical, apparel, and environmental protection. Polypropylene fibres are used not solely in the automotive, chemical, and garment industries, but also in construction and concrete. [24,25]. Polypropylene fibre has several advantageous features, including mechanical, thermal, and morphological characteristics.

3.1 Mechanical Properties

The mechanical characteristics of PPFs are critical to understanding their behaviour and appropriateness for a variety of applications. Here are some important mechanical characteristics of polypropylene fibres. Researchers have extensively researched composites made up of both natural and synthetic fibres, which are often divided into two groups based on their source [26,27]. The key physical characteristics of PPF are given in the Table 1 below:

Table 1: Mechanical characteristics of PPF [28]

Properties	Typical Results
Elongation at Break	45%
Melting Point	160°C
Modulus of Elasticity	400 N/mm^2
Specific Surface Area of Fibers	250 m^2/kg
Thermal Conductivity	Low
Tensile Strength	300-400N/mm^2

3.1.1 Tensile Strengths

The greatest stress a substance can bear before breaking when permitted to be stretched or pulled is tensile strength. Adding PPF as a matrix material can significantly enhance the strength of composite material. Previous studies show that the incorporation of PPF increases the tensile strength. Hoque M et al. [29] performed tensile strength for the PP/fabric and matrix of PP combinations. The Tensile values for the PP/fabric and PP matrix blends are shown in Table 2. The PP sheet's tensile modulus, tensile strength, elongation at break and tensile modulus were to be 363 MPa, 29.5 MPa, 79.75% and 92.3 MPa, 61.15 MPa, 23.98%, respectively. The tensile strength of PP composites made of cotton, l, jute fibre and pineapple leaf increased by 107%. Additionally, it was shown to be 156% better than the m-material matrix PP. The data were analyzed, and it was discovered that the 30% PP/fabric combination had better physical; qualities. However, Eb% was significantly lower than PP in the matrix PP[29,30].

Zhang X. et al.[31] found that when the fibre concentration is more than 0.0 kg/m^3, the dragged PPFs may be noticed on the fracture surface, and pulled polypropylene fibres are visible when the fibre concentration is more than 0.9 kg/m3. Figure 3, illustrates the variation in strength of concrete TS with PPF concentration. The tensile strength of plain concrete increases by 17, 27, 43, 38, and 29 per cent respectively, when the content of fibre is 0.3 kg/m^3,0.6 kg/m^3,0.9 kg/m^3,1.2 kg/m^3 and 1.5 kg/m^3. The TS of concrete increases first and gradually falls as the fibre content increases. The concrete's tensile strength improves most clearly when the fibre content is 0.9 kg/m^3.

Table 2: Tensile Properties of PP and Fabric/PP composites [29].

Materials	Tensile Strength(MPa)	Tensile Strength(MPa)	Elongation at Break(%)
PP	29.5	363	79.75
Fabric/PP	61.15	923	23.98

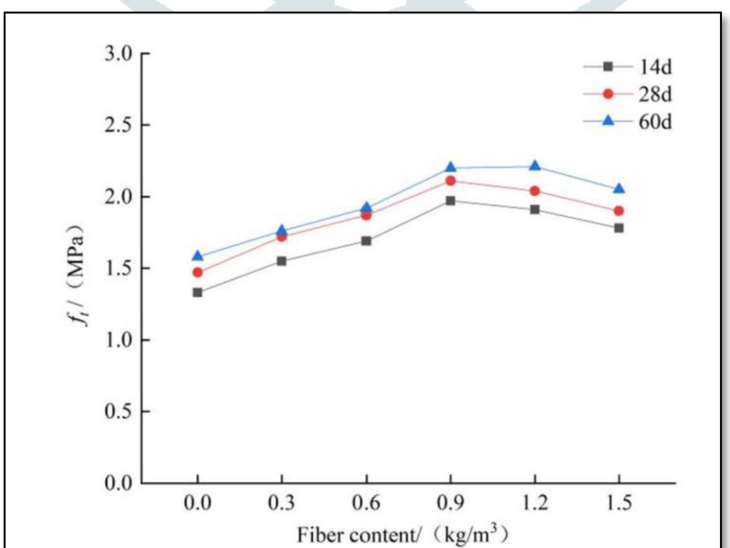

Figure 3- Polypropylene fiber content effect on tensile strength [31]

3.1.2 Flexural Strength

PPFs have high flexural strength, meaning they can sustain bending or flexing pressures without breaking. Flexural stress in a material might be created by a mixture of tensile and compressive stresses, based on where it is across the axis of applied force. Despite encouraging results, polypropylene composites often have lesser flexural strength than other composite materials [32]. However, Khan M et al. [33]found that shorter E-glass fibre and jute fibre reinforce polypropylene combinations(20% fibre wt.) showed improvement in flexural strength which is shown in Table 3. The composite made of short jute fibre and PP exhibited a significant gain in flexural strength, reaching 38 ± 0.3 MPa, an approximate 35% increase over the pure PP matrix. In contrast, the flexural capacity of the short PP composite/E-glass fibre was 36 ± 0.8 MPa, which was 30% greater than the matrix of PP. This improvement shows that both kinds of fibres are effectively reinforced within the PP matrix. Furthermore, compared to the PP /E-glass fibre combinations, the flexural strength of the jute-based composite was found to be 5% greater. This increase in flexural strength demonstrates how much the jute fibres add to the composite material's mechanical performance.

Table 3: Flexural Properties of PP combinations and PP [33,35]

Materials	**Strength (MPa)**
PP	28 ± 1.2
PP combination /Shorter Jute Fiber	38.3
PP Combination/Shorter E-glass Fiber	36.8

Rahman N et al. [34] experimented on flexural rigidity or strength and hybrid nanocomposite modulus which is presented in Figure 4. In Figure 4, the flexural rigidity or strength and hybrid nanocomposite modulus, which include glass fibre (GF) composites and polypropylene (PP) matrix with and without 6 parts per hundred resins (phr) clay are investigated. The results show that adding clay improves flexural capabilities; for all fibre-weight fractions, PP/GF/NC composites consistently outperform PP/GF composites. For instance, flexural strength rises by 23% from 42.3 MPa (PP/G15) to 52.1 MPa((PP/G15)/NC6) and by 10% from 37.3 MPa(PP) to 40.8 MPa (PP/NC6). This shows the strengthening properties of clay, which are particularly apparent in composites with lower fibre weight percentages[33,35].

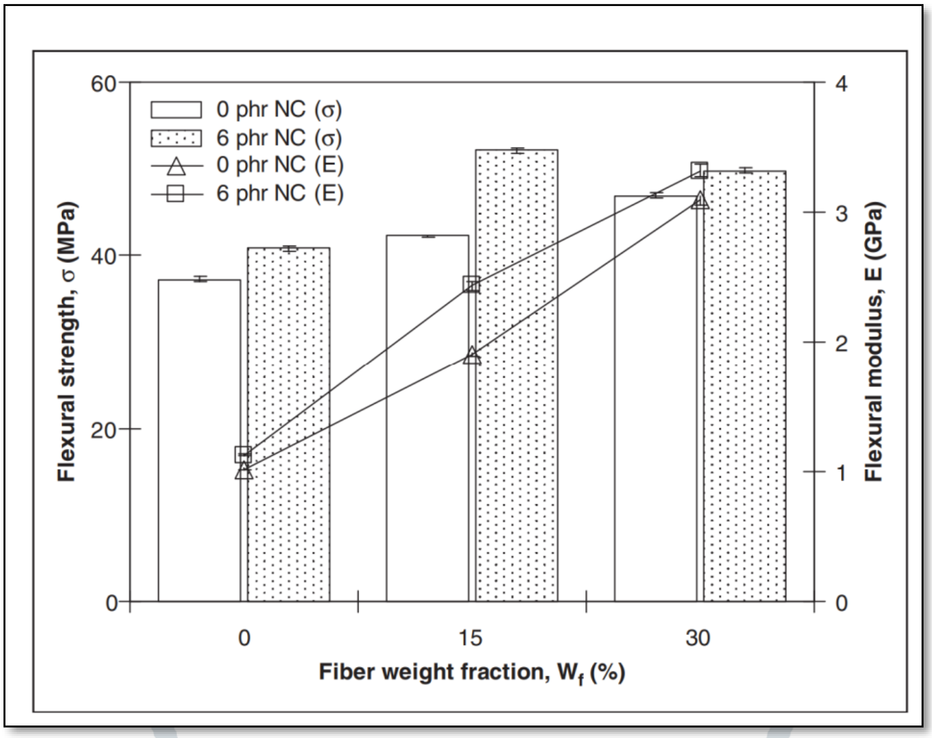

Figure 4 - Flexural modulus and flexural strength of GF/PP and GF/PP/NC hybrid composites [36]

3.2 Thermal Properties

The thermal properties of PPF allow it to be used in a wide range of sectors. To understand the behaviour of the material at various temperatures, these properties are frequently compared and studied. For convenience, values for properties like melting point [37], thermal conductivity[38], and burning point [39] from earlier research are shown in Table 4. The key thermal characteristics of polypropylene fibre (PPF) are listed below:

Table 4: Thermal Properties of PPF[37,38,39]

Properties	Typical Results
Melting point	160°C
TC	0.13 W/m/K
Burning Point	590°C
Fibres Specific Surface Area	250 m^2/kg
Melting Point	160°C

3.2.1. Melting Point

The temperature at which a material, such as PPF, transforms from a solid state to a liquid state is called its melting point. As seen in Table 5, previous studies have found a range of melting points for PPF, including 175°C [40], 160°C [41], and 165°C [42]. It is essential to consider this in a variety of applications, especially those that involve heat processing or exposure to increased temperatures, as this property makes it prone to melting when subjected to high temperatures. Previous studies have provided significant knowledge on PPF's thermal behaviour, which helped in comprehending its functionality and applicability.

Table 5: Melting temperature of polypropylene [40,41,42]

Sample	Polypropylene
1	175°C
2	160°C
3	165°C

3.2.2 Thermal Conductivity

The term "thermal conductivity" defines a material's capacity to transmit heat. ‘k’ is the symbol used to symbolize it most often. Polypropylene fibres have poorer thermal conductivity than metals and other synthetic fibres, making them less effective at heat transfer. This feature is useful in situations where insulation or heat retention is needed.

A few researchers have been investigating the thermal conductivity of PPF. At 25°C, the reported thermal conductivity values for Polypropylene fibres have a notable turning point at about 80°C in Thermal Mechanical Analysis experiments, when expansion slows but a changeover occurs [43]. Patti A et al. [44] state that chemical composition, crystallinity, molecular weight, bond strength, defects or structural faults, side pendent groups, processing circumstances, and temperature are some of the factors that affect a polymer's TC. Han et al.[45],Goswami et al.[46], Maier et al. [47], and Guo et al. [45]discovered that PPF's TC values were 0.11, 0.12-0.17, 0.17-0.22, and 0.22; these values are included in Table 6. Figure 5 demonstrates the TC of PPF concrete conductivity of pp reduced with a rise in the concentration of fibre. It is clear that in comparison to plain concrete (BM), the addition of ppfs raised its thermal conductivity. The thermal conductivity and fibre concentration were found to be linearly related, with coefficients of determination higher than 0.9 suggesting a perfect match [48]. Zhang et al. [49] study additionally investigated the thermal characteristics of PPF concrete, with the same0.3 water/cement ratio and fibres measuring 6mm in length and 17 µm diameter. After the addition of 0.8 % fibre to conventional concrete, they observed a 2.8% drop in heat conductivity. Khaliq et al. [50] also observed this pattern, however, their addition of 0.3% polypropylene fibres resulted in a far greater drop in thermal conductivity of around 13.8%. Since they used PPFs with a length of 20 mm, the difference may have been caused by the fibres' differing diameters.

Table 6: Thermal Conductivity values for PPF

Polypropylene	TC(W/mK)
Han et al. [45]	0.11
Goswami et al. [46]	0.13-0.18
Maier et al. [51]	0.16-0.21
Guo et al.[45]	0.22

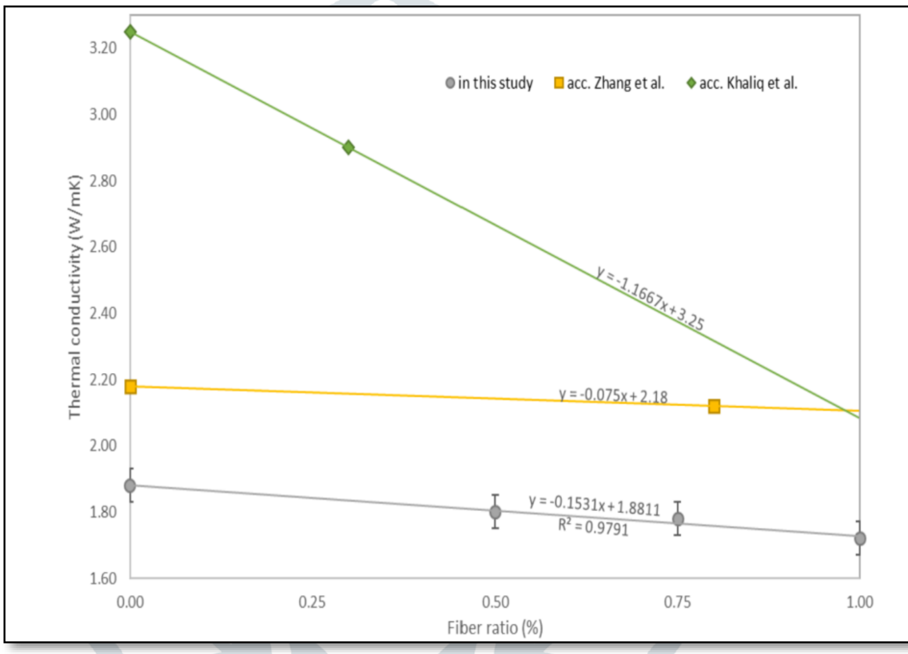

Figure 5: Thermal conductivity test result of polypropylene fibre concrete[48]

4. Advantages of PPF

PP has many benefits which have made it popular for many uses. Some of its advantages are given below:

1. The low specific gravity of polypropylene fibres makes them usable and lightweight.
2. Polypropylene fibres are reasonably priced, making them a cost-effective choice for reinforcing concrete buildings[52].
3. Use of intrinsic strength: These fibres enable the consistent and efficient use of concrete materials' inherent tensile and flexural strengths[53].
4. Reduction of plastic shrinkage cracking: The early phases of concrete curing may result in plastic shrinkage cracking, which may be greatly decreased by using polypropylene fibres [54].
5. Reduction of thermal cracking: Polypropylene fibres help reduce thermal cracking in concrete buildings, particularly in areas with significant temperature swings[54].

6. Reinforcement: They provide concrete more reinforcement, which improves its strength and structural integrity[55].

5. Disadvantages/Limitations of PPF

Some of the Disadvantages/Limitations of PPF are given below:

1. Vulnerability to UV deterioration: Because polypropylene is susceptible to UV degradation, it should not be used in high-UV conditions such as high-altitude regions or places with strong sunshine.
2. Temperature sensitivity: Polypropylene can experience chain breakdown at high temperatures, which can lead to oxidation and fracture development[56].
3. Poor adhesion: Painting or putting coatings on polypropylene can be difficult due to its weak bonding properties. This restriction can be overcome by using certain surface treatments that improve paint and print adherence to polypropylene surfaces[57].

6. Existing Problems and Countermeasures

Some of the existing problems and their countermeasures of PPF are given below:

1) **Exploring Higher Thresholds: Polypropylene Fiber Integration in Concrete:** The addition of PPFs to concrete, usually in the range of 0% to 2%, has been studied by several researchers. Studies on the incorporation of PPFs above this point have not, however, been conducted. Han et al. [10] examined the effect of incorporating ppfs at various proportions—up to 1.5%—while Hossain et al.[13] extended their investigation to include 2%. Another contributor to this field was Wioletta Raczkiewicz[14]. Beyond 2% of PPF. We could able to learn further about the strength of concrete at greater fibre concentrations by investigating content levels that are higher than 2%. This might allow for a more extensive replacement of polypropylene fibres. Concrete might start to decrease in strength as a result of higher water demand and interference with cement hydration.

   To countermeasure this problem, incorporating microfibers—such as glass or steel fibres can improve overall strength and durability while combining the benefits of PPFs[58,59]. The concrete matrix is strengthened with microfibers, which also lessen the harmful effects of high PPFs. Chemical admixtures that enhance workability, hydration, and overall performance include viscosity modifiers and superplasticizers. Moreover, the use of mineral additives such as silica fume or fly ash strengthens, decreases porosity, and increases packing density in concrete. Concrete strength could be maintained or even increased with greater PPF concentrations while obtaining desirable qualities like decreased weight and cost-effectiveness by modifying components and improving mix design[58,60].

2) **Workability Reduction with Increasing Polypropylene Fiber Content:** Studies have shown that the introduction of PPF lowers the workability of concrete. According to Wioletta Raczkiewicz's [14] studies, concrete mixes with fibre showed an average loss in workability of up to 20% compared to those without fibre. To mitigate the loss in workability induced by the fibres, certain additives or procedures are applied. High-Range Water Reducers (HRWR), also known as superplasticizers, are applied to greatly increase the workability of concrete without increasing water content. Additionally, Viscosity-Modifying Admixtures (VMAs) can increase the cohesiveness and stability of concrete mixes by modulating their rheological characteristics, hence minimizing bleeding and segregation and aiding ease of installation.

Another technique involves altering Fiber Characteristics, such as choosing PPF with changed features like shorter lengths or surface treatments. This helps limit the fibres' influence on workability while still delivering reinforcing advantages. Shorter fibers are simpler to add into the mix without severely impacting its flowability.

7. Applications of Polypropylene Fiber:

PPFs have an extensive variety of uses due to their distinctive characteristics. Here are a few popular applications:

1. **Reinforcement of Concrete and Cement Mortars:** Polypropylene fibres (PPFs) are essential for strengthening concrete and cement mortars, improving their capacity to withstand tension, hardness, and durability. At first, the compressive strength of reinforced concrete remains unaffected. However, following freeze/thaw cycles, reinforced concrete exhibits enhanced compressive strength and reduced water absorbency in comparison to ordinary concrete. While the impact of PPfs on compressive strength in cement mortars is not substantial, they do contribute to the enhancement of bending strength through the improvement of interfacial adhesion and mechanical anchoring, resulting in a more robust structure. Modifying the production procedure of PPFs results in an augmentation of their mechanical properties, rendering them very suitable for the reinforcing of concrete and cement. The modification increases the characteristics of new concrete. This enhancement improves the properties of new/fresh concrete and its post-freezing performance, while also augmenting its flexural strength through improved adherence to the surrounding material [62]. Figure 6 depicts the application of PPF in the context of concrete.

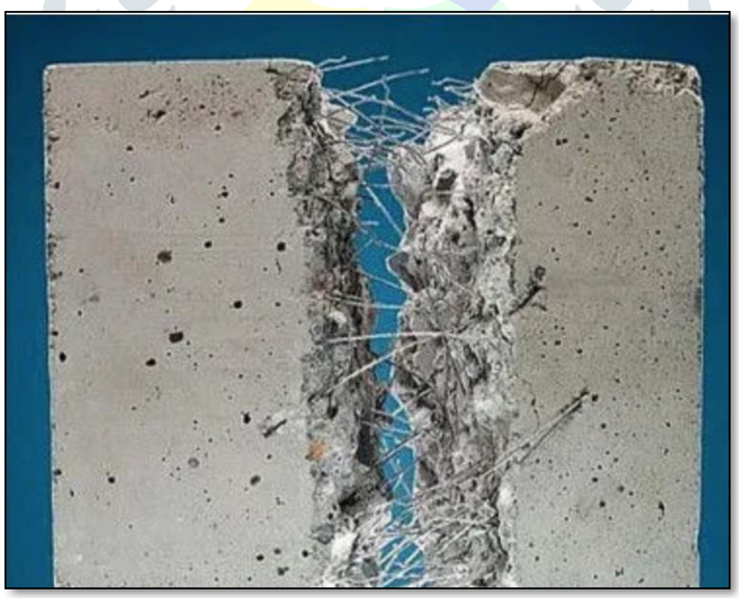

Figure 6: Use of PPF in reinforced concrete [61]

2. **Textiles:** PP fibres are utilized in the textile industry for a variety of applications, including garments, home furnishings, and industrial fabrics. They are combined with other fibres, such as cotton or polyester, to improve durability, abrasion resistance, and moisture wicking. PP fibres, which are highly prized for their abundance, cost-effectiveness, and adaptability, are utilized in numerous range of textile applications, including garments and carpets as well as technical and medical materials [62]. PP fibres are used to make carpets, upholstery fabrics,

ropes, and geotextiles because of their resistance and strength to mildew and germs. Figure 7 illustrates the application of PPF in textiles.

Figure 7: Polypropylene Fabric [63]

3. **Geotextiles:** PPFs are utilized in geotextiles for civil environmental purposes and civil engineering such as erosion control, soil stabilization, drainage, and filtration as depicted in Figure 8 below. Their high tensile strength, UV resistance, and chemical stability make them suitable for road construction, landfills, retaining walls, and landscaping projects. Muawia Dafalla[64] observed that PPFs are commonly utilized in geotextiles for environmental purposes and civil engineering such as erosion control, soil stabilization, drainage, and filtration, supporting applications such as road construction, landfills, retaining walls, and landscaping projects due to their superior tensile strength, UV resistance, and chemical stability. Furthermore, the burgeoning geotextile industry offers a variety of tailored products for engineers, leveraging polypropylene's durability and chemical resistance, as demonstrated by research on locally manufactured polypropylene geotextiles evaluating their retention capacity for various opening sizes, which informs erosion control system design.

Figure 8. Non-woven Polypropylene geotextile[65]

4. **Automotive Industry:** PPFs are used in automobile components such as carpets, upholstery, and interior trim because they are resistant to moisture, chemicals, and abrasion has been depicted in Figure 9. They improve the longevity and performance of automobile interiors. The Advanced Composites Mission, launched by DST and DRDO, aimed to develop innovative composite materials for a variety of applications. However, despite efforts, India's consumption of fibre-reinforced composites lags behind global leaders due to limited mass production and automation, necessitating increased research into natural fibre-based composites for automotive applications to address weight reduction and environmental concerns [66].

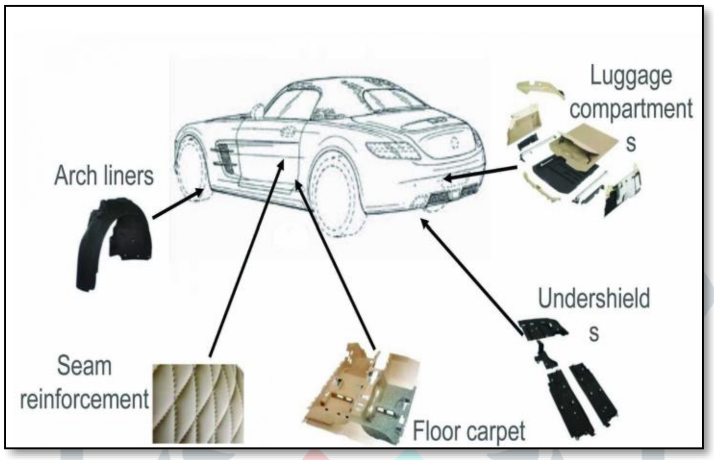

Figure 9. PP fibre application in the automotive industry [67]

8. Conclusion

In conclusion, PPF stands out as versatile and flexible having a wide range of uses across industries. Its unique blend of characteristics, such as thermal stability, high tensile strength and chemical resistance, make it ideal for reinforcing concrete, producing textiles, improving geotechnical engineering solutions, and improving automotive components. The ongoing research detailed in this review emphasizes the ongoing efforts to investigate and optimize the use of PPF, addressing existing issues and finding fresh opportunities for innovation.

Moving forward, it is apparent that the adaptability and versatility of fibre polypropylene continue to propel progress in the field of material science and engineering. Future studies may unlock the full potential of PPF in a variety of sectors by solving highlighted research deficiencies, such as maximizing PPF concentration in concrete mixes or building predictive models for masonry behaviour. Furthermore, as preservation becomes more important, researching eco-friendly alternatives and improving the recyclability of PPF can help to create more ecologically responsible solutions. Ultimately, this study emphasizes the significance of PPF as a crucial participant in the continuous search for novel materials that integrate technological advances, environmental sustainability and functionality.

9. Future Recommendation

1) Academic researchers may investigate possible approaches for mitigating concerns related to shrinkage, cracking, and water seepage in concrete structures. Increasing the proportion of polypropylene fiber (PPF) in the concrete mixture significantly decreases its weight, resulting in lightweight concrete. Nevertheless, this frequently leads to a reduction in strength. To mitigate this impact, researchers should explore the

possibility of integrating PPF with natural chemicals. By leveraging the potential additive effects of combining PPF with natural materials, it is possible to achieve weight reduction while concurrently enhancing strength. This novel methodology has not been extensively investigated but has great potential for transforming concrete building methods.

2) In order to tackle India's underutilization of fiber-reinforced composites in automotive applications, it is important to enhance research on natural fiber-based composites for autos, regardless of the efforts made by programs such as the Advanced Composites Mission. To connect with global trends and boost India's competitiveness in the automotive sector, it is imperative for this study to specifically concentrate on weight reduction and environmental sustainability.

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