

Impact of Polypropylene Fibres on the Properties of Concrete

Neeti Mishra^{1,*}

Abstract

This review paper explores the effects of polypropylene fibres on the mechanical and structural properties of concrete. The integration of short, discontinuous fibres into plain concrete enhances its post-cracking behavior and overall performance, with notable improvements in tensile strength, fracture strength, toughness, impact resistance, and flexural strength. These fibres effectively control crack propagation, increase energy absorption, and improve durability under varying loading conditions. A comprehensive analysis of prior research highlights key factors influencing the performance of fibre-reinforced concrete, such as fibre content, orientation, and distribution. Polypropylene fibres offer significant advantages in controlling shrinkage, reducing cracking, and enhancing long-term structural integrity. The study also examines the interactions between fibres and the cement matrix, providing insights into optimizing the mechanical behavior of concrete mixtures. The primary objective is to recommend strategies for the practical application of polypropylene fibres in concrete construction. This includes identifying optimal fibre dosages, mixing techniques, and application scenarios to maximize benefits. The findings address existing research gaps and propose directions for future studies to further advance fibre-reinforced concrete technologies. By enhancing understanding of polypropylene fibre use, this work aims to improve construction practices, promote sustainability, and support the development of resilient, high-performance concrete structures. The recommendations provided can serve as a foundation for adopting advanced materials in modern construction and infrastructure projects.

Keywords: Polypropylene fibres, concrete properties, tensile strength, fracture strength, toughness, impact resistance, flexural strength, mechanical properties

INTRODUCTION

Over a period of time, a variety of materials have been used to reinforce concrete and improve its resistance to tensile pressures. Polypropylene fibre, which comes in a variety of diameters, has become popular as a concrete reinforcement material. PP fibres, termed the new generation, are produced globally at a rate of 4 million tonnes per year [1]. The main problem with conventional concrete is that it is heavy, low tensile strength and brittle in nature [2]. Because of these drawbacks, conventional

concrete is inappropriate for the construction of distinctive structures and buildings, including bridge decks, offshore oil platforms, and field-fabricated beams [3]. To meet the demand for this kind of building and construction, it is necessary to develop a concrete composite that is lighter on its own and has higher mechanical capabilities.

In Addition of fibres, particularly polypropylene fibres, increases the overall strength of concrete. The primary function of fibres in cementitious composites is to control cracking, toughness,

*Author for Correspondence

Neeti Mishra
Email: neetibbd@gmail.com

¹Assistant Professor, BBD University, Lucknow, Uttar Pradesh, India

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increase tensile strength and refine deformation properties. The efficiency of fibre-reinforced concrete (FRC) is mainly dependent on the type of fibres used. Cement reinforced with fibres is particularly favoured for buildings exposed to severe working environments.

Advantages of fibre concrete

- Addition of fibres to concrete improves its strength, durability, resistance to cracking, and deformation [4].
- Steel reinforcement with fibres significantly improves structural strength against tensile and flexural forces throughout cross-sections.
- More ductility as compared to standard concrete, as a result making it more resistant to impacts, vibrations, and dynamic loads.
- It has great energy absorption and superior elastic, impact, and crack resistance.
- It reduces cross-sectional depth and saves material.
- the use of polypropylene fiber can enhance the serviceability of concrete by reducing the crack width [5].
- Polypropylene fibres help to enhance spalling behavior of concrete [6].

POLYPROPYLENE FIBRES

Polypropylene is a lightweight, synthetic polymer that is classed as thermoplastic. It is widely utilized in the production of a variety of products that require durability and elasticity. Polypropylene products are frequently used in civil and general engineering applications due to their versatility and ability to meet performance objectives. The use of fibres in cement composites is intended to improve tensile strength, durability, crack management, and hardness. The performance of fibre-reinforced concrete (FRC) varies with the type of fibre employed [7]. Because of their high modulus of elasticity, these fibres are known to reduce water permeability while increasing flexural strength. Polypropylene is economically viable and translucent in its natural, uncoloured state. Unlike acrylic or polystyrene, it is normally opaque or dyed for colour. Polypropylene is also highly resistant to fatigue.

Properties of Polypropylene Fibres

According to ACI Committee 544 [8], fibrous concrete aggregate is defined as concrete containing hydrated cement and varied proportions of discontinuous fibres. Researchers have extensively studied the effects of various fibre kinds on the mechanical characteristics of concrete.

M. R. Latifi et al. [9] conducted a literature review on polypropylene fibre-reinforced concrete mixtures. The study reviewed a variety of topics, including the historical context, advantages, disadvantages, workability, mechanical qualities, durability performance, and dimensional stability of different concrete mixes. Specifically, the review delves into compressive, tensile and flexural strengths, modulus of elasticity, flexural crack and post cracking behaviour, the resistance of freeze-thaw, sulfate, high-temperature and abrasion as well as alkali-silica reactivity, drying shrinkage-based length change and impact strength of fibrous concrete mixture. The findings give a detailed investigation of how polypropylene fibres influence these qualities, shedding light on the effectiveness of using such fibres in concrete applications.

Bagherzadeh et al. [10] studied how different polypropylene (PP) fibre contents and lengths affected the performance of lightweight cement composites. The PP fibres were chopped into 6 mm and 12 mm lengths and employed at 0.15% and 0.35% of the cement weight, respectively. Their findings demonstrated that all specimens supplemented with PP fibres had higher mechanical strength. However, the best overall performance in terms of physical and mechanical qualities was found with 0.35% PP fibres measuring 12 mm long.

Workability

Adding fibres to concrete increases entrapped air voids, resulting in higher air content, which affects workability and makes compaction more difficult. The fibres can also interfere, causing finishing issues.

As the volume proportion of polypropylene fibres increases, the concrete's workability diminishes [11]. While the use of polypropylene fibres reduces the workability of concrete, this problem can be overcome by using High Range Water Reducing Admixtures [12]. The impact of monofilament polypropylene fibres in self-compacting concrete containing fly ash and found no issues with workability or segregation [13]. Preti A Patel et al. [14] discovered that increasing the quantity of polypropylene fibres affects the workability of concrete. Their research revealed that workability is highest at 0.5% fibre concentration and medium at 1% fibre content.

Compression Strength

The compressive strength of concrete is a crucial property, reflecting its ability to withstand loads without failing. Generally, an increased binder ratio leads to enhanced compressive strength. [15] carried out an experimental investigation to examine the effect of polypropylene fibre on concrete characteristics. The impact of polypropylene fibre on compressive, tensile, flexural, Shear strength and plastic shrinkage Fibre addition in the range of 0.35% to 0.50% resulted in a small increase in compressive strength. A researcher [14] showed that by adding 1.5% polypropylene fibre to concrete increases its compressive, split tensile and flexural strengths.

In a study, [11] found that adding fibrillated polypropylene fibres (12 mm length, 34-micron diameter, and 0.9 kN/m³ density) to high strength concrete at concentrations of 0.5%, 1%, and 1.5%, along with the super plasticizer Conplast-Sp430, increased compressive strength.

Murahari and Rama Mohan Rao [16] examined the fly ash concrete with class C fly ash and coarse particles and polypropylene fibres at 0.15%, 0.2%, 0.25%, and 0.3% by volume fractions. Their experiments revealed that compressive strength gradually increased from 0.15% to 0.3% fibre content, with considerable early-age strength enhancements. Overall, adding polypropylene fibres to plain concrete can increase compressive strength by 4% to 17% [17].

Flexural Strength

Murahari and Rama Mohan Rao [16] carried out experimental investigation of specimens measuring 500 x 100 x 100 mm under three-point loading according to ASTM C78. Flexural strength increased with fiber content up to 0.3%, with stronger increases at 28 days compared to 56 days. Gencil et al. [13] discovered that the inclusion of fibres improved flexural strength. Rama Devi and Venkatesh Babu [18] investigated the flexural behaviour of hybrid steel-polypropylene fibre-reinforced concrete beams and discovered that the use of these hybrid fibres improves the beams' flexural performance when loaded. Mahendra Prasad et al. [19] conducted studies on polypropylene fibre reinforced silica fume concrete of grade M30, by substituting cement at 0%, 5%, 10%, and 15%, and fibre content at 0%, 0.2%, 0.4%, and 0.6% by volume fraction. They concluded that the addition of polypropylene fibres and silica fume boosted flexural strength by about 40%. Tamil Selvi and Thandavamoorthy [20] investigated the strength and durability of concrete, including hybrid fibres such as crimped steel and polypropylene. Their investigations indicated that adding these fibres to the concrete matrix improves performance.

Tensile Strength

Polypropylene (PP) fibres have a particularly large effect on concrete tensile strength. When fibres are employed at a volume concentration of 0.4%, the tensile strength of concrete can improve by up to 70% [21]. Different fibre volumes (0.5, 1.0, and 1.5%) and slenderness (45, 65, and 80) taken into consideration [22]. The authors concluded that there was an increase in compressive, tensile, and flexural strength up to 10, 14, and 58% with increased l/d of fibre.

Shrinkage

Aulia [23] showed that by adding 0.20% fibre to high strength concrete with silica fume decreases early shrinkage cracks while not affecting compressive strength or flexibility.

Banthia and Gupta [24] investigated the effect of polypropylene fibre shape on plastic shrinkage cracks. The results showed that thin, long, and fibrillated fibres are more effective in crack management. A study by Aly et al. [25] investigated the effect of inclusion of polypropylene fibres in blast furnace slag concrete affects shrinkage, also concluded that the concrete with fibre experiences increased shrinkage and modulus of elasticity, resulting in more cracking compared to non-fibrous concrete. Lura et al. used a stress riser to cause cracking in slabs using a steel insert plate [26].

Wang et al. [27] observed that combining rubber and polypropylene fibres minimizes drying shrinkage and length variations caused by alkali-silica interactions.

Mardani-Aghabaglou et al. [28] discovered that shrinkage-reducing admixtures and fibres both reduce shrinkage, with fibres being more effective. Song et al. [29] investigated polypropylene and plastic nylon fibres and found that nylon fibres are more effective at preventing shrinkage cracks.

Resistance to High Temperature

Due to its high melting point (165°C) and chemical neutrality, it becomes durable in high temperatures [30,31]. Aulia [23] and Varghese et al. [32] found that high-strength fibrous concrete has increased fire resistance. Noumowe [33] discovered that at 170°C, polypropylene fibres melt, forming air channels in concrete that reduce mechanical characteristics. However, the detrimental effects are less obvious in fibrous combinations than in fibre-free ones. According to Xiao and Felkner [34], high-strength concrete with polypropylene fibres resists explosions and cracking at temperatures as high as 400°C, but strength declines as temperature increases.

Abaeian et al. [35] discovered that incorporating 1 kg/m³ of macro synthetic polypropylene fibre into high-strength concrete increases compressive, tensile, and flexural strength by 14%, 7%, and 15%, respectively. Aygörmez et al. [36] found that adding 0.8% polypropylene fibre had no significant effect on geopolymer composites' high-temperature resistance. When polypropylene fibres melt in high-temperature environments, it creates pores that decrease osmotic pressure, enhancing the thermal durability of the concrete. However, this also leads to an increase in pore volume, which may lower the compressive strength of the material. The positive impact of reduced osmotic pressure is most evident in fibre concrete that is subjected to elevated temperatures.

APPLICATIONS

Polypropylene fibres have numerous industrial applications, including ropes, furniture, packaging materials, and labelling. Polypropylene fibre-reinforced concrete is used in a variety of important construction applications, including roads and pavements, driveways, overlays and toppings, ground-supported slabs, machine foundations, offshore buildings, and tanks and pools. The significance of polypropylene fibres in enhancing the performance and durability of concrete across different uses is showcased by its versatility.

CONCLUSION

Based on the previous literature, it can be concluded that:

- Adding polypropylene fibre to concrete mixtures decreases workability and increases the danger of flocculation.
- The compressive strength remains unaltered.
- Adding fibres significantly improves tensile and flexural strength.
- The flexural toughness and ductility of the mixtures are improved.
- The resistance of the mixtures to high temperatures is enhanced with fibre addition.
- High temperatures cause cracks in the samples due to increased osmotic pressure.

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