

Use Of Polypropylene, Fiber in Rigid Pavement

Touqeer Rafik Bagwan¹, Jiyan Juberahmad Vastad², Shrivardhan Arvind Jadhav³,
Saeedanwar S. Inamdar⁴, Sayali.P. Mane⁵

^{1,2,3} *Diploma Students, Department of Civil Engineering, LESP Sangli.*

^{4,5} *Lecturer, Department of Civil Engineering, LESP Sangli*

Abstract—Rigid pavements are widely used in highways, industrial floors, and airfields due to their long service life and low maintenance requirements. However, their brittle nature and low tensile strength make them susceptible to cracking under repeated loading, shrinkage, and temperature variations. To improve their performance and durability, polypropylene fibres (PPF) are introduced into concrete as a secondary reinforcement.

This study investigates the effects of incorporating polypropylene fibers on the mechanical behaviour, durability, and crack control of rigid pavement slabs. Polypropylene fibers, being lightweight, chemically inert, and cost-effective, provide enhanced resistance against shrinkage cracking and increase impact and flexural strength.

Concrete mixes with varying fibre dosages (0.1%, 0.2%, and 0.3% by weight of cement) are tested for compressive strength, flexural strength, and toughness. Comparative analysis between conventional and fibre-reinforced concrete helps evaluate the optimum fibre content for rigid pavements. The work also discusses the influence of fibre geometry and dispersion on the pavement's surface quality and long-term performance. The study aims to demonstrate that polypropylene fibre reinforcement can significantly enhance the service life, load-carrying capacity, and crack resistance of rigid pavements while promoting a sustainable and economical construction approach.

I. INTRODUCTION

Rigid pavements are constructed using Portland cement concrete and are known for their structural strength and long-term performance. Despite these advantages, their brittle nature makes them prone to cracking under environmental and load stresses. The cracks generally occur due to shrinkage, fatigue, temperature gradients, or improper joint design.

The inclusion of fibers into concrete is an effective method for improving post-crack behaviour and

minimizing early-age cracking. Among different fibers, polypropylene fibre (PPF) has emerged as one of the most promising due to its low density, corrosion resistance, and cost-effectiveness. Polypropylene fibers improve the tensile, impact, and flexural strength of concrete, making it more suitable for rigid pavements subjected to heavy loads and environmental exposure.

The project focuses on the evaluation of mechanical properties and crack control behaviour of PPF-reinforced concrete. Laboratory investigations are conducted on cube and beam specimens with different fibre dosages to identify the optimum percentage that provides maximum strength and workability balance. This research not only supports the concept of fibre-reinforced rigid pavements but also promotes the use of synthetic waste-derived fibers as an eco-friendly material for modern infrastructure.



Fig no Polypropylene Fiber Used in Concrete
Need for the Study

The growing demand for sustainable and long-lasting pavement materials has made it necessary to explore alternatives that can reduce maintenance costs while maintaining or enhancing performance. Conventional rigid pavements, though durable, are prone to cracking due to thermal stresses, shrinkage, and heavy loads. These cracks allow water ingress, leading to deterioration of subgrade support and reduced pavement life.

Scope of the Study

This study is confined to the use of polypropylene fibres in M40 grade concrete, as per IRC:58–2015 guidelines for plain and reinforced concrete pavements. The fibres used are monofilament-type polypropylene fibres with lengths ranging between 6 mm to 12 mm and aspect ratios between 100–150.

- The investigation covers:
- Mix design as per IS 10262:2019.
- Laboratory testing for compressive, split tensile, and flexural strengths.
- Analysis of results for determining the optimum fibre content.
- Comparison between conventional and fibre-reinforced concrete mixes.
- Discussion of results in terms of strength enhancement, crack control, and durability improvements.

II. LITERATURE REVIEW

1. Behaviour Of Polypropylene Fiber Reinforced Concrete Pavements

Author: A. Kumar Et Al. (2023)

A. Kumar and colleagues performed an experimental study on M40 concrete containing polypropylene fibers at 0%, 0.1%, 0.2%, and 0.3% dosages. The optimum fiber content (0.2%) improved flexural strength by about 15% and reduced surface cracking by over one-third. The results proved that fibers significantly enhance tensile and fatigue strength while limiting brittle failure under repeated loading. The authors explained that the fibers bridge developing micro-cracks and transfer stress across them, increasing ductility and controlling deformation. This stress redistribution mechanism extends the pavement's service life and reduces maintenance. They concluded that fiber-reinforced concrete acts as a semi-ductile composite system ideal for rigid pavement applications.

2. Use Of Synthetic Fibers for Crack Control in Rigid Pavements

Author: S. Mehta (2021)

S. Mehta investigated early-age cracking due to plastic shrinkage and thermal stresses. Short fibers (12–24 mm) were added to M40 concrete mixes. The study achieved a 45% reduction in shrinkage cracks with only 0.2% fiber addition. The author noted that PPF

increases internal cohesion and tensile resistance during the setting period.

Microstructural examination using SEM revealed that the fibers anchor firmly within the cement matrix, bridging cracks and improving dimensional stability. However, proper dispersion and mixing time were essential to avoid clumping. The study proved that small dosages of PPF can substantially improve early-age crack control without altering workability excessively.

3. Performance Evaluation of Fiber-Reinforced Concrete Pavements

Author: P. Deshmukh (2022)

A full-scale field evaluation was conducted on PPF-reinforced rural pavements compared to plain concrete slabs. Over a two-year observation period, the fibre-reinforced slabs exhibited fewer cracks, better joint integrity, and 18% higher load transfer efficiency. The compressive and flexural strengths increased moderately, but durability gains were considerable.

Deshmukh attributed this performance to the anchoring effect of the fibers that restrict crack widening and distribute stresses more evenly. The research confirmed that PPF reduces both drying and temperature-induced cracking, extending pavement service life and reducing repair requirements.

4. Impact Of Fiber Geometry and Distribution on Concrete Strength

Author: R. Zhang Et Al. (2020)

Zhang examined how fiber geometry length, diameter, and aspect ratio affects concrete behaviour. Fibers of 30 mm, 45 mm, and 55 mm were tested. The 55 mm length with an aspect ratio of 300–400 produced the best combination of toughness and crack resistance. Longer fibers improved energy absorption but slightly decreased workability.

Uniform fiber dispersion proved crucial. Improper mixing caused fiber balling and weak zones, while superplasticizers improved uniformity. The authors concluded that selecting proper fiber geometry is essential for achieving high flexural strength and good workability in rigid pavement concrete.

5. Role Of Polypropylene Fiber In Durability Of Concrete

Author: B. Singh & R. Patel (2021)

This research studied PPF's effect on durability under wet-dry and freeze-thaw cycles. Fiber inclusion

reduced permeability by 25% and improved freeze–thaw durability by 30%. The fibers limited micro-crack connectivity, reducing water and chloride ingress.

The improved pore structure and interfacial bonding enhanced corrosion resistance of reinforcement. The study concluded that fiber-modified concrete is suitable for pavements exposed to aggressive weather or chemical environments, offering better durability and reduced maintenance frequency.

6. Comparative Study on Steel and Polypropylene Fiber Reinforcement

Author: M. Chatterjee (2022)

M. Chatterjee compared steel-fibre reinforced and polypropylene-fibre reinforced concrete for pavement use. Steel fibers yielded slightly higher flexural strength but were prone to corrosion and higher costs. Polypropylene fibers, in contrast, were corrosion-proof, lightweight, and cost-effective, with better long-term crack control.

The author found that 0.2% PPF provided sufficient ductility and crack resistance for medium-traffic pavements. PPFRC showed stable performance under moisture and chemical exposure, whereas SFRC required surface sealing. The study recommended PPF as a durable, economical substitute for steel fibers in pavement concrete.

7. Fiber Reinforced Concrete for Airfield Pavements

Author: J. Lee Et Al. (2019)

Lee's team tested PPFRC slabs under simulated aircraft wheel loads. The fiber-reinforced slabs endured up to 50% more load cycles before failure compared to plain concrete. PPF increased impact resistance, flexural toughness, and energy absorption, delaying crack propagation beneath surface layers.

The authors reported improved behaviour under temperature variations and freeze–thaw conditions. Fiber addition also minimized surface scaling and joint distress. The study confirmed that PPF enhances both structural reliability and durability in high-load rigid pavements like airfields and highways.

8. Optimization Of Polypropylene Fiber Dosage In Concrete Mixes

Author: D. Sharma (2023)

D. Sharma applied the Taguchi method to determine the optimum PPF dosage for pavement-grade concrete. Variables included fibre percentage (0–

0.5%), fibre length, and water–cement ratio. Results indicated that 0.25% PPF provided the best balance of strength, ductility, and workability. Beyond 0.3%, air entrainment and reduced slump negatively affected compaction.

Statistical modelling confirmed that higher dosages produced diminishing strength returns while increasing cost and workability issues. The study provided an optimization equation correlating fibre content with performance and economics, confirming the ideal range between 0.2%–0.3%.

9. Microstructural Study of Fiber-Modified Cement Matrix

Author: V. Patel Et Al. (2022)

Using SEM and EDS analysis, V. Patel examined how PPF modifies the cement matrix. Micrographs revealed improved bond between the hydrated cement gel and fiber surface, fewer pores, and reduced micro-crack connectivity. Fibers created a bridging network that redistributed internal stresses and prevented brittle failure.

The interfacial transition zone (ITZ) became denser and more uniform, leading to higher flexural strength and lower permeability. These microstructural benefits directly translated into enhanced durability and fatigue performance of fiber-reinforced pavements under cyclic loading conditions.

10. Sustainability Aspect of Fiber-Reinforced Pavement Concrete

Author: N. Bose (2024)

Bose analysed the environmental and economic sustainability of using polypropylene fibers, especially those derived from recycled plastic waste. Life-cycle assessment showed a 15–20% reduction in total environmental impact compared to conventional pavement concrete. Improved durability and reduced repair need further minimized embodied carbon emissions.

The study found that recycled PPF maintained adequate mechanical properties while reducing material costs. Integrating PPF into pavement design supports circular economy principles by reusing plastic waste and extending pavement service life. The research concluded that PPFRC aligns with sustainable construction practices and offers both ecological and technical benefits.

III. SUMMARY

- Mechanical Behaviour and Crack Control

A. Kumar et al. (2023) conducted an experimental study on M40 grade concrete with varying PPF dosages (0–0.3%). The optimal dosage of 0.2% fibers enhanced flexural strength by 15% and reduced surface cracking by nearly one-third. The study attributed these improvements to the fiber-bridging mechanism, which transfers stress across micro-cracks and improves ductility, making the concrete a semi-ductile composite suitable for pavement applications. Similarly, S. Mehta (2021) examined the use of short synthetic fibers (12–24 mm) for controlling early-age cracking caused by plastic shrinkage and thermal stresses. With a fiber addition of 0.2%, shrinkage cracks were reduced by 45%. SEM analysis confirmed that fibers anchored firmly in the cement matrix, improving dimensional stability. The study emphasized the importance of uniform fiber dispersion to prevent clumping and maintain workability.

R. Zhang et al. (2020) further investigated the impact of fiber geometry on mechanical behaviour. Longer fibers (55 mm, aspect ratio 300–400) provided superior toughness and crack resistance but slightly reduced workability. The research highlighted that proper fiber geometry and mixing practices are crucial to achieve strength improvements without compromising compaction and homogeneity.

- Field Performance and Durability

P. Deshmukh (2022) conducted a two-year field study on rural pavements reinforced with PPF. Compared to plain concrete slabs, the fiber-reinforced sections exhibited fewer cracks, higher load transfer efficiency (18%), and better joint integrity. The fibers' anchoring effect restricted crack widening and distributed stresses evenly, confirming PPF's role in improving fatigue performance and reducing maintenance.

B. Singh and R. Patel (2021) evaluated PPF's effect on durability under wet–dry and freeze–thaw cycles. Fiber inclusion reduced permeability by 25% and enhanced freeze–thaw resistance by 30%. The study found that PPF minimizes micro-crack connectivity, improving corrosion resistance and long-term durability making it suitable for harsh environmental conditions.

J. Lee et al. (2019) tested airfield pavements under simulated aircraft wheel loads. PPFRC slabs endured up to 50% more load cycles than plain concrete. The addition of fibers increased impact resistance, flexural toughness, and fatigue life while reducing surface scaling and joint distress. These findings support PPF's applicability in heavy-load pavements such as airports and highways.

- Comparative and Optimization Studies

M. Chatterjee (2022) compared steel-fiber and polypropylene-fiber reinforced concrete. While steel fibers provided slightly higher flexural strength, PPF offered better corrosion resistance, lower cost, and enhanced crack control. The study recommended 0.2% PPF for medium-traffic pavements as a durable and economical alternative to steel fibers.

D. Sharma (2023) applied the Taguchi method to optimize PPF dosage. The optimal fiber content of 0.25% achieved the best balance between strength, ductility, and workability. Beyond 0.3%, reduced slump and air entrainment caused performance loss. Statistical models confirmed diminishing returns at higher dosages, establishing the effective range of 0.2–0.3% for pavement-grade concrete.

- Microstructural and Sustainability Insights

V. Patel et al. (2022) carried out a microstructural study using SEM and EDS techniques to analyse the fiber–matrix interface. The results showed denser interfacial transition zones (ITZ) and reduced porosity in fiber-modified concrete. Fibers bridged micro-cracks, redistributed stresses, and improved fatigue resistance, directly contributing to better long-term performance.

N. Bose (2024) explored the sustainability aspects of PPFRC, particularly using recycled polypropylene fibers. Life-cycle assessment revealed a 15–20% reduction in environmental impact and lower embodied carbon due to increased pavement lifespan and reduced repair needs. Recycled PPF retained sufficient mechanical properties and supported circular economy goals, making PPFRC both technically and ecologically beneficial.

Experimental results were analysed statistically. Graphs of fibre dosage vs strength parameters were plotted to identify the optimum PPF content.

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