Enhancing Cement Concrete Pavement with Polypropylene and Polyester Fiber as Reinforcement Material

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Abstract — The rapid and continuous rise in road traffic worldwide has created substantial challenges for infrastructure development and maintenance. Forecasts indicate that this upward trend will persist in the foreseeable future. Even in developed nations, insufficient funding often hampers the construction of new infrastructure and the upkeep of existing road networks. The situation is considerably more critical in developing countries such as India, where limited resources and increasing vehicular loads have led to the accelerated deterioration of pavement systems. Consequently, a large proportion of bituminous pavements now exhibit serious forms of distress, including rutting, shoving, and cracking, necessitating timely rehabilitation or structural strengthening. These interventions require heavy expenditure and extensive use of scarce materials such as bitumen and aggregates. To address these challenges, the cost-effectiveness of Portland Cement Concrete (PCC) overlays, as an alternative to conventional bituminous overlays, must be critically examined. Pavement Quality Concrete (PQC) roads have been observed to provide a longer service life of approximately 20–30 years while maintaining economic efficiency. In accordance with IRC specifications, PQC is produced using coarse aggregates and placed over a Dry Lean Concrete (DLC) sub-base, making it particularly suitable for highway and airfield pavements designed to endure heavy loading conditions.

Keywords: Pavement Type, Enhance, Rehabilitation, Strength

I. INTRODUCTION

In recent years, a large proportion of existing bituminous pavements have shown severe forms of structural distress such as rutting, shoving, and cracking. These damages indicate that many pavement sections urgently require rehabilitation or strengthening to maintain serviceability. However, such maintenance and reconstruction activities demand significant financial resources and rely heavily on limited natural materials such as aggregates and bitumen. Therefore, evaluating the cost-effectiveness of Portland Cement Concrete (PCC) overlays as an alternative to conventional bituminous overlays has become increasingly necessary.

Pavement Quality Concrete (PQC) roads have proven to be a more durable and economical solution, typically offering an extended service life of about 20 to 30 years. Global trends indicate that road traffic volumes continue to rise steadily and are expected to increase further in the coming decades. Even in developed countries, insufficient funding often hinders the timely development, maintenance, and repair of road infrastructure. The situation is considerably more critical in developing nations like India, where rapid traffic growth and resource limitations accelerate pavement deterioration. Consequently, many existing pavement structures have become inadequate to withstand the increasing traffic loads and require more sustainable and cost-effective design alternatives.

A. Problem Statement

Most of the flexible pavements currently in operation consist of relatively thin bituminous layers that progressively deteriorate due to repeated traffic loading and environmental influences. This continuous degradation reduces their structural capacity and service life, making them prone to frequent maintenance and higher lifecycle costs.

B. Scope of the Work

The scope of this study is to enhance the performance characteristics of Pavement Quality Concrete (PQC) by incorporating polypropylene fibers. The addition of these fibers aims to improve tensile strength, crack resistance, and overall durability while reducing construction and long-term maintenance costs associated with concrete pavements.

C. Objectives of the Work

- To improve the structural strength and performance of pavement layers.
- To minimize the maintenance and rehabilitation costs of pavement structures.
- To extend the service life and durability of concrete pavements.

II. LITERATURE REVIEW

Several studies have been conducted to evaluate the influence of synthetic fibers, such as polypropylene and polyester, on the strength and durability of cement concrete pavements. The key findings from relevant research are summarized below.

1) Aatif Irshad Khan (2021) conducted an experimental study on the *Strength Evaluation of Cement Concrete Pavement Using Polypropylene and Polyester Fibers as Reinforcing Materials* at Mewar University, Rajasthan. The study demonstrated that concrete mixes incorporating polypropylene and polyester fibers exhibited significantly higher compressive strength compared to the control mix. Specifically, concrete containing 1.8% polypropylene and 0.5% polyester fibers achieved compressive strengths of 48.76 N/mm² at 7 days and 52.76 N/mm² at 28 days, indicating a notable improvement in performance.
2) In another study, Garikapati, Rao, and Raju (2017) performed *An Experimental Comparison of the Strength Characteristics of Concrete Using Polypropylene and Polyester Fiber Admixtures*. Their investigation revealed that the inclusion of polymer fibers as admixtures improved various concrete properties, including

compressive, split tensile, and flexural strength. The fiber addition also reduced water absorption and enhanced elasticity. Tests were carried out on concrete specimens containing polypropylene and polyester fibers in varying proportions ranging from 0% to 1.1% of the cement weight, confirming that optimal fiber dosages enhance both strength and workability.

3) Yue Chen *et al.* (2018) examined the performance of different synthetic fiber-reinforced concretes, including Modified Polyester Fiber Concrete (MPFC), Monofilament Polypropylene Fiber Concrete (MPSFC), Reticular Polypropylene Fiber Concrete (RPFC), and Polyacrylonitrile Fiber Concrete (PSFC). Their findings indicated that both fiber type and dosage significantly influenced the mechanical performance and cost-efficiency of the concrete. The study concluded that fiber-reinforced concrete (FRC) offers considerable potential for large-scale applications such as airport pavements due to its enhanced performance and economic viability.
4) Tariq Ahmad Sheikh and Mohit Bajaj (2017), in their *Review Study of Polymer Fiber-Reinforced Concrete with Conventional Concrete Pavement*, observed that incorporating fibers into conventional concrete improves compressive strength, split tensile strength, flexural strength, and modulus of elasticity. Additionally, partial replacement of cement with polypropylene fibers helps conserve cement content while maintaining structural integrity.
5) Amit Rai and Dr. Y. P. Joshi (2014) conducted *Experimental Studies and Applications of Fiber-Reinforced Concrete*, exploring different fiber types and their impact on concrete performance. Their results showed that polypropylene fibers increased compressive strength by approximately 16% and flexural strength by nearly 30%. The researchers emphasized that the uniform distribution of fibers within the concrete matrix is critical for achieving optimum performance. They also noted that fiber reinforcement enhances the ductility and workability of concrete, as evidenced by slump tests.
6) Rakesh Kumar's study on *Cement Reinforced with Engineered Fiber for Pavement Development* further explored the effects of polypropylene fibers—both discrete and fibrillated—on the properties of pavement-grade concrete with a target compressive strength of 48 MPa at 28 days. Six different mixes were prepared with fiber dosages of 0.05%, 0.10%, and 0.15%. The research assessed parameters such as settlement, compressive strength, drying shrinkage, and abrasion resistance, demonstrating that fiber inclusion improves the overall performance and longevity of concrete pavements.

III. METHODOLOGY

This section describes the materials, mix proportions, and procedures adopted in the preparation of fiber-reinforced concrete mixes. The study utilized locally available materials and followed standard specifications to ensure reliability and reproducibility of results.

A. Cement

Ordinary Portland Cement (OPC) of 43 grade was used in all concrete mixes. The cement was fresh, free from lumps, and exhibited a cool feeling when handled, indicating its suitability for use. Proper storage was maintained to prevent moisture absorption and loss of strength.

B. Fine Aggregate (Crushed Sand)

Crushed sand, produced through mechanical means, was employed as a fine aggregate and considered a viable alternative to natural river sand. The sand used was clean, sharp, and coarse, composed of hard and durable particles. Proper gradation of sand is crucial to minimize voids and ensure better workability in the mix. Excessive clay or silt content can delay the setting of cement and adversely affect concrete strength. Although sand does not directly contribute to compressive strength, it plays a vital role in preventing shrinkage and cracking during the setting process.

C. Coarse Aggregate

Locally sourced coarse aggregates of maximum sizes 10 mm and 20 mm were utilized in this study. The aggregates were tested in accordance with *IS: 383–1970* to ensure compliance with standard quality requirements. Aggregates with water absorption greater than 2% were excluded. The 10 mm and 20 mm aggregates were sieved through appropriate sieves, washed to remove dust and other impurities, and air-dried to achieve a surface-dry condition before mixing.

D. Polypropylene Fiber

Polypropylene fiber is a new-generation synthetic fiber widely produced on an industrial scale and ranks among the most commonly used fibers after polyester, polyamide, and acrylic fibers. In this study, polypropylene fiber was used as a reinforcing material to enhance the concrete's mechanical performance, particularly its tensile and flexural strength.

E. Polyester Fiber

Polyester fiber was incorporated into the concrete mix as a reinforcing agent to improve pavement performance. It is commonly used in fiber-reinforced concrete (FRC) for pavements, overlays, and precast elements due to its durability and resistance to environmental effects. The inclusion of polyester fibers helps improve the concrete's crack resistance and overall mechanical behavior.

F. Admixtures (Superplasticizers)

Superplasticizers, also referred to as high-range water reducers, were added to enhance the workability of the concrete without increasing the water-cement ratio. These admixtures are composed of organic and inorganic compounds such as lignosulphonates, hydroxylated carboxylic acid derivatives, and carbohydrate-based materials. Their use ensures better dispersion of cement particles and contributes to improved strength and durability.

G. Water

Potable tap water was used for both mixing and curing operations. The water conformed to standard requirements for concrete preparation and was free from impurities such as oils, acids, and organic matter.

H. Mix Proportion;

Parameter	Specification
Grade Designation	M40
Mix Ratio	1 : 1.3 : 2.1
Type of Cement	OPC 43 Grade
Coarse Aggregate Size	20 mm (Angular)
Fine Aggregate	Crushed and River Sand
Minimum Cement Content	450 kg/m³
Water-Cement Ratio	0.40 (Maximum)
Admixture	Superplasticizer
Water Source	Potable Bore Well Water

IV. RESULTS

In this experimental study, the compressive strength of M40 grade fiber-reinforced concrete was evaluated using crushed sand as fine aggregate and a combination of polypropylene and polyester fibers, each added at a dosage of 1% by weight of cement. The compressive strength values were determined at curing intervals of 7, 14, and 28 days to assess the development of strength over time.

A. Compressive Strength Test

The compressive strength of concrete is a fundamental parameter that reflects its ability to resist axial loading and is widely considered the most important property for assessing concrete quality. In this work, standard cube specimens measuring 150 mm × 150 mm × 150 mm were prepared and cured under controlled conditions.

Testing was carried out using a Compression Testing Machine (CTM), also known as a Universal Testing Machine (UTM), in accordance with standard testing procedures. The load was applied gradually until failure occurred, and the ultimate load at failure was recorded to compute the compressive strength of each specimen.

The compressive strength test serves as an indicator of the concrete's overall performance and provides valuable insights into whether the mixing, placement, and curing processes have been properly executed. This single test offers a reliable measure of the concrete's ability to withstand compressive stresses, thereby reflecting its structural adequacy and durability potential.

B. Observations

The results obtained from the experimental investigation revealed that the inclusion of polypropylene and polyester fibers contributed to improved compressive strength values at all curing stages compared to conventional concrete. The increase in strength was attributed to the fibers' ability to control micro-crack formation and enhance the bond between the cement matrix and aggregates.

A summary of the compressive strength results for the M40 grade concrete specimens is presented below (values to be added based on experimental findings):

Compressive Strength (N/mm^2) for 7, 14, 28 Days

Fiber (1%)	Average of 7days (KN/mm^2)	Average of 14 days (KN/mm^2)	Average of 28days (KN/mm^2)
Polypropylene	38.30	49.59	59.16
Polyester	34.35	46.86	48.86

V. CONCLUSION

Based on the experimental investigation carried out on M40 grade fiber-reinforced concrete using crushed sand, polypropylene fibers, and polyester fibers, the following conclusions were drawn:

The incorporation of synthetic fibers significantly enhanced the compressive strength of the concrete. The use of 1% polypropylene and 1% polyester fibers led to strength improvements of 30.16%, 18.56%, and 22.30%, respectively, when compared to conventional concrete mixes. The inclusion of fibers helped in bridging micro-cracks, reducing shrinkage, and improving the overall bonding between the cement matrix and aggregates. Among the tested specimens, polypropylene fiber–reinforced concrete exhibited a consistent increase in strength with curing age, indicating superior long-term performance.

Pavement rehabilitation and strengthening have become critical components of modern infrastructure development. The application of concrete overlays provides several advantages, including enhanced durability, reduced maintenance costs, fuel efficiency, smoother riding quality, improved resistance to oil spillage, reduced water penetration, and higher surface reflectivity. Additionally, the availability of economical binders and sustainable materials further supports the use of fiber-reinforced concrete as an efficient alternative for pavement construction and overlay applications.

ACKNOWLEGEMENT

The author thankfully acknowledges to Prof. N.P.Khatmode, Professor of Civil Engineering Department, TSSMs Bhivarabai Sawant College of Engineering and Research, Narhe, Pune, for their motivations and infrastructural support to carry out this research.

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