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Effect of addition of polypropylene fibers on concrete properties- A Review

Anjali Jaglan[1], R.R. Singh[2]

[1]*PhD Research Scholar, Civil Engineering Department, Punjab Engineering College (Deemed To Be University), Chandigarh, India-160012*
[2]*Professor, Civil Engineering Department, Punjab Engineering College (Deemed To Be University), Chandigarh, India-160012*

Abstract - *Concrete is a brittle material having a low tensile strength when compared to its compressive strength. Fiber dispersion in concrete is one of the techniques for improving concrete's structural properties. Polypropylene fiber is a synthetic linear polymer fiber created by polymerizing propylene. Polypropylene fibers are lightweight and have high toughness, strength, and corrosion resistance. Compared to typical steel fibers, polypropylene fiber has a low modulus, density, and monofilament diameter. Like any secondary reinforcement, these fibers keep cracks from spreading by holding the concrete together, preventing cracks from becoming broader or longer. This study reviews the effect of the addition of polypropylene fibers on various concrete properties.*

***Key Words*: Concrete, Polypropylene fibers, workability, compressive strength, split tensile strength, etc.**

1. INTRODUCTION

Concrete is a common construction material in both developed and developing countries. During its service life, a concrete structure may be exposed to various environmental conditions. The durability of a concrete structure is characterized by its ability to resist these exposure conditions without requiring extensive repair or rehabilitation. Concrete has long been thought to be an innately durable material that may last for decades, if not centuries, with little or no care. Concrete's performance is determined by its constituents. Plain concrete is well recognized for being brittle in nature and weak in tension. Concrete's low tensile strength is the most unattractive feature as a brittle material. Therefore, concrete requires reinforcement in order to withstand tensile stresses. Traditionally, this reinforcement is in the form of continuous steel bars put in the concrete structure in the proper positions to sustain the imposed tensile and shear loads. Nowadays, short and discontinuous fibers randomly distributed throughout the concrete member are used as the reinforcing material. Adding fibers to concrete can prevent micro-cracks from forming, leading to gradual failure. Many fibers such as steel, carbon, glass, polypropylene, and natural fibers can be used as reinforcing materials in concrete structures.

The present research work aims to present a review of the effect of the addition of polypropylene fibers on the concrete properties.

2. POLYPROPYLENE FIBERS

Polypropylene fiber is a linear polymer synthetic fiber made from the polymerization of propylene. The characteristics of polypropylene fibers are light weight, high toughness, high strength, and corrosion resistance **[1]**. Compared to traditional steel fibers, polypropylene fiber has a low modulus, density, and monofilament diameter **[2]**.

2.1 Advantages of polypropylene fibers

- It is a relatively low-cost material.
- It possesses high flexural strength.
- It has a high moisture resistance.
- It is chemically resistant to a wide range of bases and acids.
- It has a good fatigue resistance.
- It has a high impact strength.
- It has good resistance to electricity.

2.2 Need of polypropylene fibers in concrete

Polypropylene fibers have a tendency to bind the concrete mix. The addition of these fibers to concrete lowers the rate of bleeding. A slower rate of bleeding implies a slower rate of drying, which means less plastic shrinkage cracking in the concrete. Moreover, polypropylene fibers act as crack arresters in hardened concrete. Like any secondary reinforcement, the fibers tend to prevent cracks from propagating by holding the concrete together, preventing cracks from spreading wider or becoming longer.

3. LITERATURE REVIEW

Bei-Xing et al. [2] compared two polypropylene fiber reinforced concretes to a steel fiber reinforced concrete in terms of compressive, shear, and abrasion-erosive resistance and flexural qualities. The experimental results showed that a low content of polypropylene fiber (0.91 kg/m^3 of concrete) slightly reduced the compressive and shear strengths while significantly increasing the flexural strength, toughness index, and fracture energy for the same mix proportion, implying that it acts as an anti-cracking and toughening agent in concrete. Moreover, it was found that the polypropylene mesh fiber outperforms the polypropylene monofilament fiber in terms of enhancing concrete flexural strength and toughness; however, both types of polypropylene fibers fall short of steel fiber.

Ahmed et al. [3] investigated the effect of the addition of various proportions of polypropylene fiber on the concrete properties. The experiments were conducted to see its effect on compressive, tensile, flexural, shear, and plastic shrinkage cracking strength. Flexural, tensile, and shear strength all increased significantly. However, there was no difference in compression strength. Furthermore, the addition of fibers in the range of 0.35 to 0.50% reduced shrinkage cracking by 83 to 85 %.

Sun and Xu [4] examined the reinforcing effects and mechanisms of polypropylene fiber on concrete's physical and mechanical properties. The crystal structures and aggregate-cement interfacial transition zone were studied using a scanning electron microscope (SEM). The effects of polypropylene fiber on increasing the engineering qualities of concrete were measured using physical and mechanical testing. The results show that polypropylene fiber changed the microstructure of concrete, reduced $Ca(OH)_2$ crystallization and orientation, and reduced micro-voids. The polypropylene fiber, in particular, formed a network that limited $Ca(OH)_2$ development, bridged cracks, and reallocated loads. At the aggregate-cement interfacial transition zone, polypropylene fiber has reduced the amount and size of crystalline and micro-cracking. As a result, polypropylene fiber has enhanced the compressive strength, flexural strength, bonding strength, dynamic performance, and fatigue life of concrete while reducing water penetration and abrasion mass loss. The results also showed that a 0.9 kg/m^3 polypropylene fiber concentration produced the best concrete performance output for the materials employed in this investigation.

Gencel et al. [5] evaluated the workability and mechanical properties of self compacting concrete (SCC) reinforced with polypropylene fibers. Two cement contents of 350 and 450 kg m^{-3} and four fiber contents of 3, 6, 9, and 12 kg m^{-3} were investigated. The water/cement ratio, fly ash content, and superplasticizer content were set at 0.40, 120 kg m^{-3}, and 1% cement content, respectively. The fresh properties of concrete were evaluated using slump flow, J ring, V funnel, and air content tests. Concrete was tested for unit weight, compressive strength, cracking tensile strength, flexural strength, pulse velocity, and elasticity modulus. When the fiber distribution was uniform, the materials employed in this investigation had no difficulty mixing or working. The polypropylene fiber addition enhanced compressive strength, split tensile strength, flexural strength, and elasticity modulus while decreasing pulse velocity. Polypropylene fibers considerably increased the strength of SCC without generating the well-known difficulties associated with steel fibers.

Kakooei et al. [6] evaluated the properties of polypropylene fiber reinforced concrete in their research study. Permeability, electrical resistivity, and compressive strength were measured to see how varying amounts of polypropylene fibers affected concrete qualities. This study made concrete samples with fiber ratios of 0, 0.5, 1.5, and 2 kg m^{-3}. The inclusion of polypropylene fibers produced a delay in the onset of the degradation process by reducing permeability and reducing the amount of shrinkage and expansion of concrete, both of which can substantially impact the structure's lifespan. Compared to the other samples in this investigation, the samples with a fiber content of 1.5 kg m^{-3} produced the best results.

Ramujee [7] studied the strength properties of concrete containing polypropylene fibers. The compressive strength and splitting tensile strength of concrete samples made with various fiber concentrations ranging from 0%, 0.5, 1%, 1.5, and 2.0 % were investigated. The increased fiber content reduces workability and over 1.5% dosage; the mix becomes fibrous, making it harder to handle. The compressive and split tensile strength tests revealed that, compared to the controlled mix without fibers, the strengths increased correspondingly with the increase in volume ratios of polypropylene fibers. Compared to the mix without fibers, the maximum increase in compressive strength and split tensile strength was reported to be 34% and 40%, respectively. The study recommended 1.5% to be the optimal content of polypropylene fibers for use in concrete.

Behfarnia and Behravan [8] experimentally investigated the application of high-performance polypropylene fibers (HPP fibers) in the concrete lining of water tunnels. Concrete mixtures containing 0.4, 0.6, and 0.8% (by volume) of HPP fibers and steel fibers were provided in this study. Compared to the control samples, changes in compressive strength, tensile strength, flexural strength, toughness, energy absorption, concrete water absorption, and chloride ion penetration resistance were assessed. According to the American Society for Testing Methods (ASTM) or British Standard (BS) test methods, all testing was carried out. The results showed that HPP fibers were not as effective as steel fibers in compressive strength, but they had substantial effects on concrete's tensile strength, flexural strength,

toughness, and energy absorption. According to the findings, HPP fibers had a more significant impact on concrete properties such as flexural toughness, concrete permeability, and resistance to chloride penetration than steel fibers. The results also demonstrated that using HPP fibers might increase the durability and serviceability of concrete structures.

Akça et al. [9] generated concrete mixes with different combinations using recycled concrete aggregates and polypropylene fiber. Natural aggregates were replaced by recycled concrete aggregates (RCAs), and volumes of 0%, 1%, and 1.5% fiber were introduced for each series. Although concretes' physical and mechanical properties were affected negatively by RCA due to RCA's higher porosity and water absorption capacity, high-strength concrete was eventually manufactured. Additionally, although fiber content increased flexural properties, there was no significant difference observed between 1% and 1.5%. Percentage contribution ratios of parameters that influence the results of experiments were also calculated using the analysis of variance (ANOVA) method. As the result of ANOVA, which was carried out on specimens containing fiber and recycled concrete aggregate, the main factor on compressive strength changes were determined as aggregate type, while fiber content was also influential on flexural and splitting tensile strength besides aggregate type.

Alsadey and Salem [10] conducted an experimental study to determine the optimum quantity of polypropylene fibers required to achieve the maximum compressive strength for M25 grade concrete. The polypropylene fibers were used in the percentage ranges of 0, 1, 1.5, and 2%. It was found that with the increase in polypropylene fiber content in concrete mix, there was a tremendous increase in the compressive strength. Even at 2 % polypropylene fiber content, compressive strength of 28 N/mm^2 was observed against compressive strength of 25 N/mm^2 at 0 %; hence an increase of 12% compressive strength was obtained.

Dharan and Lal [11] used polypropylene fibers (blended type) in different percentage ranges (0.5%, 1%, 1.5%, and 2%) to add in the concrete mixes. Tests on workability, compressive strength, flexural strength, split tensile strength, and modulus of elasticity were conducted on concrete specimens. The workability of concrete decreased with the increased usage of polypropylene fibers in the concrete mixes. However, the compressive strength, split tensile strength, flexural strength, and modulus of elasticity were found to increase with the increase in the polypropylene fibers content in the concrete mix. The optimum polypropylene fiber content was found to be 1.5%.

Ahmed and Daoud [12] studied the influence of the inclusion of polypropylene fibers on the fresh and hardened properties of concrete. The polypropylene fibers were used in the percentage ranges of 0, 0.1, 0.3, and 0.5% by volume of concrete. The slump test was conducted for fresh properties of concrete; also, concrete specimens were evaluated at different ages for mechanical properties of concrete, such as compressive strength, split tensile strength, flexural strength, and modulus of elasticity. According to the findings, the addition of polypropylene fibers reduced the workability of concrete. Compared to the reference concrete, the modulus of elasticity was also reduced (by roughly 2% to 9%) after 28 days. A 0.5% proportion of polypropylene fiber reinforced concrete increased flexural strength compared to the reference concrete. At 28 days, all fiber percentages showed a significant improvement in splitting tensile strength.

Sohaib et al. [13] aimed to find the optimal polypropylene fiber content that can be used in concrete to achieve the maximum strength of concrete. Forty cylinders of polypropylene concrete were cast and tested for compressive and split tensile strength at 7, 14, and 28 days. According to the test findings, after 7 and 28 days, there was a considerable improvement in ultimate compressive strength. The inclusion of a small amount of polypropylene to concrete increased its mechanical properties. The study suggested 1.5% by volume to be the ideal percentage of polypropylene fiber in cement.

3. CONCLUSIONS

Concrete is one of the most widely used construction materials. However, plain concrete is brittle and weak in tension. The addition of polypropylene fibers to concrete prevents cracks from propagating by holding the concrete together, preventing cracks from spreading wider or becoming longer. Moreover, polypropylene fibers have many advantages: low cost, high flexural strength, moisture resistance, chemical resistance, etc. From the review of various studies, it is found that the addition of polypropylene fibers generally reduces the workability of concrete. It does not have a significant effect on the compressive strength of concrete. However, the addition of polypropylene fibers enhances the split tensile strength, flexural strength, and toughness characteristics of concrete. Overall, it can be concluded from the present research that polypropylene fiber can be effectively used to improve the various properties of concrete.

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