COMPRESSIVE STRENGTH OF STANDARD CYLINDERS, SPLIT TENSILE STRENGTH OF PRESTRESSED CORES, AND MICROSTRUCTURAL ANALYSIS OF POLYPROPYLENE FIBER REINFORCED CONCRETE

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Abstract- This experimental study conducted on mono fiber reinforced concrete to check the effect of polypropylene fibers on compressive strength of standard cylinders and split tensile strength of prestressed cores that are taken out from the prestressed beams. The study also included a microstructure analysis of control and fiber reinforced concrete. The results showed that the PPFRC IV mix achieved an optimum content. Among the mixes, PPFRC IV demonstrated the highest performance, showing a 17% increase in ultimate stress and a 5% increase in split tensile strength compared to the controlled specimen. After 28 days of exposure to sodium chloride solutions, the controlled specimen (CS) and PPFRC I showed the highest percentage loss in strength, reaching up to 11%. Additionally, more open pores were observed in controlled specimen by the SEM analysis. Moreover, hydration products were also observed in SEM analysis. PPFRC IV fibers bonded with the matrix firmly due to which this mix showed improvements in the strength of concrete.

Keywords- Fiber-Reinforced Concrete, Polypropylene Fibers, Split Tensile, Ultimate stress, Microstructure

1 Introduction

The most widely used construction material is concrete, and it is weak in tension, however concrete technology has advanced, there has been growing need to use chemical and additives like fibers to improve its strength. Researchers have been studying the characteristics of fiber reinforced concrete to make it stronger [1], [2]. Research also have been conducted on hybrid fiber reinforced concrete to strengthen concrete. a study conducted by Afroughsabet et al. [3] on hybrid fiber reinforced concrete. Integrating fiber into high performance concrete boosts the mechanical behavior, especially in terms of tensile strength, flexural strength and ductility. In addition to these improvements, fiber inclusions also help minimize shrinkage and creep related deformations, contributing to the materials long term durability and stability. Zulqarnain et al. [4] worked on ferrocement confined columns of different dimensions, and their performance was compared to that of unconfined control specimen. The findings showed a noticeable improvement in load bearing capacity, reduced deflection and greater energy absorption in the ferrocement confined columns compared to the control group. Rashid et al. [5] worked on hybrid fiber (steel and polypropylene) reinforced concrete. The results showed that the incorporation of fiber enhanced the ductility, tensile and flexural properties of fiber reinforced concrete. A study conducted on fiber synergy and results revealed that the combined use of fibers led to a noticeable enhancement of compressive and split tensile strength of fiber reinforced concrete [6]. Rashid et al. [7] captured high resolution images through SEM analysis of hybrid fiber reinforced concrete. He concluded that steel fibers showed signs of rust, the surrounding concrete remained largely unaffected, exhibiting minimal signs of deterioration despite the corrosion of the embedded fiber. The shear performance of prestressed concrete beams made with fibers reinforced concrete was evaluated, revealing notable improvements. A beam incorporating 0.65% steel fibers demonstrated a 50.71% increase in ultimate failure load, a 67% rise in the initial cracking load, and 36% enhancement in ultimate deflection when compared to the control beam [8]. Research conducted by [9] to check the impact of polypropylene fiber geometry on plastic shrinkage cracking in concrete. The findings showed that polypropylene fibers are generally effective in reducing plastic shrinkage cracks. However, finer fibers outperformed shorter fibers. Additionally, fibers with fibrillated structures were found to be particularly effective in minimizing shrinkage related cracking. A study [10] assessed the performance of concrete reinforced with polypropylene fiber waste and silica fume as partial cement replacements. Silica fumes were used at 4%,8%, 12% and 16% while polypropylene waste was added at 0.4%, 0.8%, 1.2% and 1.6% by weight of cement. Tests conducted on 7, 14, 28 and 90 days showed significant improvements in workability, compressive and tensile strength. SEM and XRD analysis confirmed that enhanced mechanical performance was linked to a denser microstructure. Although fiber reinforced concrete has been widely studied, there is still not enough research on hybrid fiber reinforced concrete, especially when it comes to its internal structural (microstructure). In this study the main focus is placed on polypropylene fiber reinforced concrete to evaluate its compressive strength in form of cylinders, and a comparison was made between the splitting tensile strengths of core specimens taken from prestressed beams, where one group of cores was immersed in a sodium chloride solution for 28 days, while the other group remained unexposed and a microstructure analysis of control and mono and fibers are analyzed.

2 Research Methodology

2.1 Materials

In this study type II cement was utilized as a cementitious material. The cement conformed to the specification in ASTM C150/C150M [11], ensuring suitable performance for structural applications. Coarse aggregates used in this study were utilized in accordance with ASTM C33-03 [12]. While sand was used as a fine. Ordinary drinkable water is used for this research. A chemical admixture with accordance ASTMC494/C494M-19 [13] was selected as well. Polypropylene fibers were mixed to the concrete with different percentages as shown in figure.

Figure 1: Polypropylene fiber

2.2 Concrete specimen preparation

All the concrete specimens were prepared at Bannu Mukhtar concrete casting yard as shown in the figure below 2 (a), (b), Material mixing in the concrete mixer and placement of concrete in the shuttering bed. Concrete samples were prepared with different ratios of polypropylene fibers. The specimens casting included prestressed beams as well as standard cylindrical specimens. All the specimens were cured for 28 days. Upon completion of the curing period, the specimens were transported to the UET Taxila concrete yard for further testing. In total 6 prestressed beams and 18 cylindrical specimens were cast. The concrete mix ratio was the same for all the specimens. The concrete mixes with different fiber combinations, and nomenclature used for each mix type is detailed in table 1 below. Also, small cores were taken out from the beams to perform mechanical testing as shown in figure 2 (b).

a)

b)

Figure 2: (a) Material mixing in the concrete mixer (b) placement of concrete in the shuttering bed and cores taken out from prestressed beams

Table 1 concrete mixes with different fiber combinations, and nomenclature used for each mix type

Sr No.	Sample Identity	Description of Specimens
1	CS	Control Specimen
2	PPFRC I	Specimen containing 0.30% of polypropylene fiber dose
3	PPFRC II	Specimen containing 0.40% of polypropylene fiber dose
4	PPFRC III	Specimen containing 0.50% of polypropylene fiber dose
5	PPFRC IV	Specimen containing 0.60% of polypropylene fiber dose
6	PPFRC V	Specimen containing 0.70% of polypropylene fiber dose

2.3 Testing

Compressive strength test

To find compressive strengths of standard cylinders, test performed on all the samples in compression testing machine (CTM) having 2000 KN capacity according to ASTM standard [14] as shown in the figure 3 below. All the specimens were kept carefully between the loading plates.

Figure 3: standard cylinders in the compression testing machine (CTM) having 2000 KN capacity

Split tensile test

To find the splitting tensile strength of cores, the test was performed as per ASTM C496 [15] in compression testing machine, during the test the cores were kept side wise into the machine as shown in figure. This test aimed to compare the splitting tensile strength of cores taken from beams. Two kinds of cores were tested. The first type consisted of cores that had been immersed in a sodium chloride solution for 28 days, while the second type included cores that had not been exposed to any chloride solution.

Figure 4: Split tensile strength test of cores taken from prestressed beams

Scanning electron microscopy (SEM) analysis

Scanning electron microscopy (SEM) analysis was performed to check the fiber's influence on microstructure of concrete after applying the loads. The samples were kept into the SEM machine and images were captured at different magnifications.

3 Results and Discussion

Compressive strength test of standard cylinders

Figure 5 illustrates the ultimate stresses of the standard cylinders. It can be observed that the PPFRC IV mix achieved the highest ultimate stress, showing a 17% increase over the controlled specimen. In contrast, PPFRC III exhibited the lowest value, with 12% reduction. PPFRC I, II and V showed increases 7%, 7% and 12% respectively, compared to the controlled specimen.

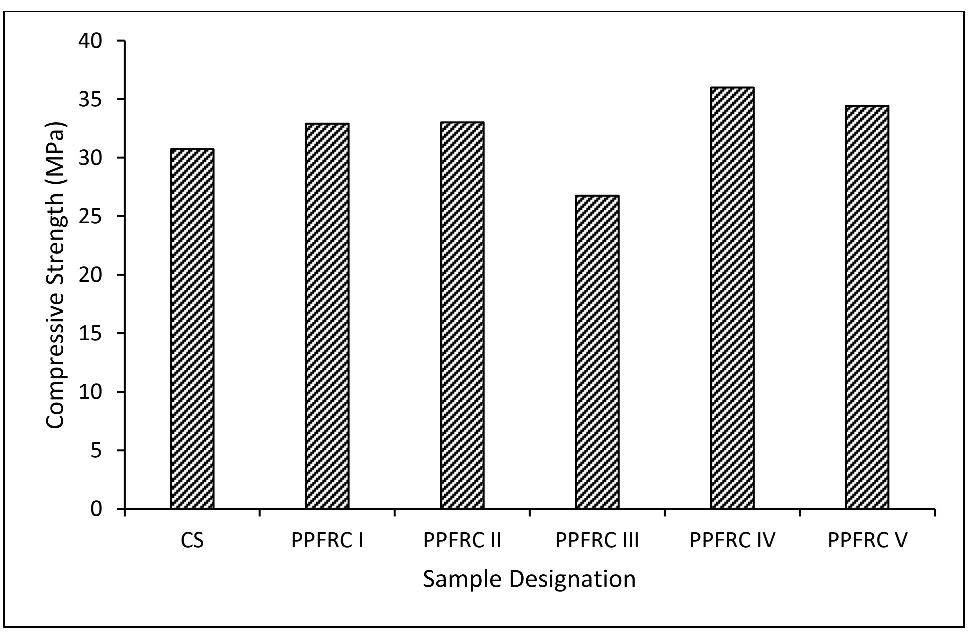

Figure 5: The ultimate stresses of the standard cylinders

Split tensile strength of cores before and after immersion in sodium chloride solution

Figure 6 shows a comparison of the splitting tensile strength of core samples taken from prestressed beams. In the bar graph, the diagonal lined bars represent the tensile strength of cores before immersion in sodium chloride solution, while the dotted bars show tensile strength after 28 days of exposure. The results show that exposure to sodium chloride solutions negatively affected the splitting tensile strength of all specimens. Among the mixes, PPFRC II and PPFRC IV show the highest tensile strength values before immersion, with an increase of 3% and 5% compared to the control specimen. PPFRC I, PPFRC III and PPFRC V showed reductions of 25%, 6% and 2% in splitting tensile strength prior to immersion. After 28 days of immersion in sodium chloride solutions, the percentage losses in splitting tensile strength for each mix were as CS with 11%, PPFRC I, PPFRC II, PPFRC III, PPFRC IV and PPFRC V with 11%, 8%, 4%, 2% and 6 % respectively. The highest splitting tensile strength loss was observed in the CS and PPFRC I mix, both with a reduction of 11% after exposure to the sodium chloride solution.

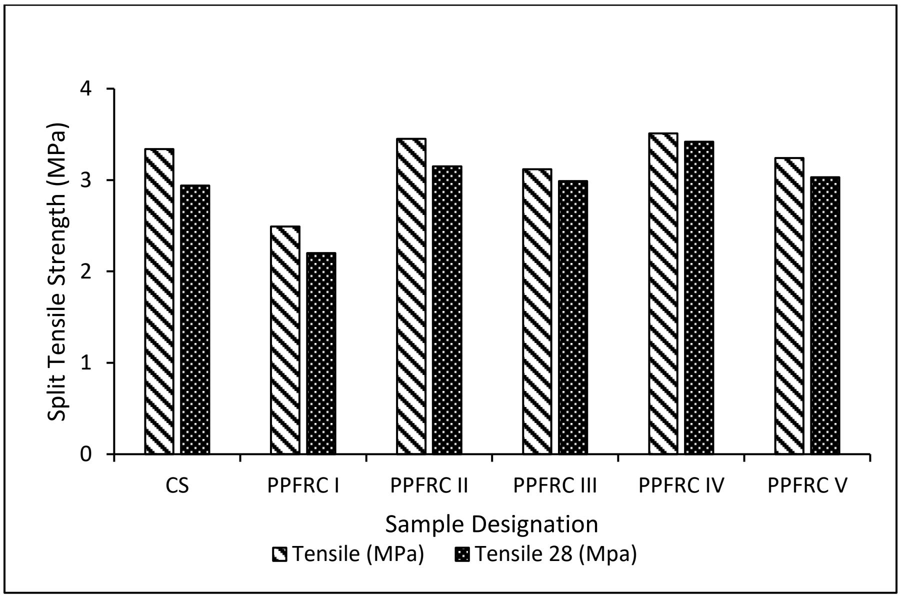

Figure 6: comparison of the splitting tensile strength of core samples taken from prestressed beams, with and without exposure to sodium chloride solution

SEM analysis

Figure 7 shows SEM images of different samples, including the control specimen and fiber reinforced concrete matrix. In the control specimen, a significant number of small micro pores can be observed, including a relatively porous structure. While in PPFRC I and PPFRC II mixes show inclusion of polypropylene fiber in the mix. The whitish marks on the PPFRC IV mix which are likely hydration products formed during the early cement hydration. The mix PPFRC IV shows a strong bond between fibers and concrete matrix, with fibers appearing strongly embedded. This strong fiber matrix is likely a key factor contributing to the highest ultimate stress and splitting tensile strength observed among all the tested mixes.

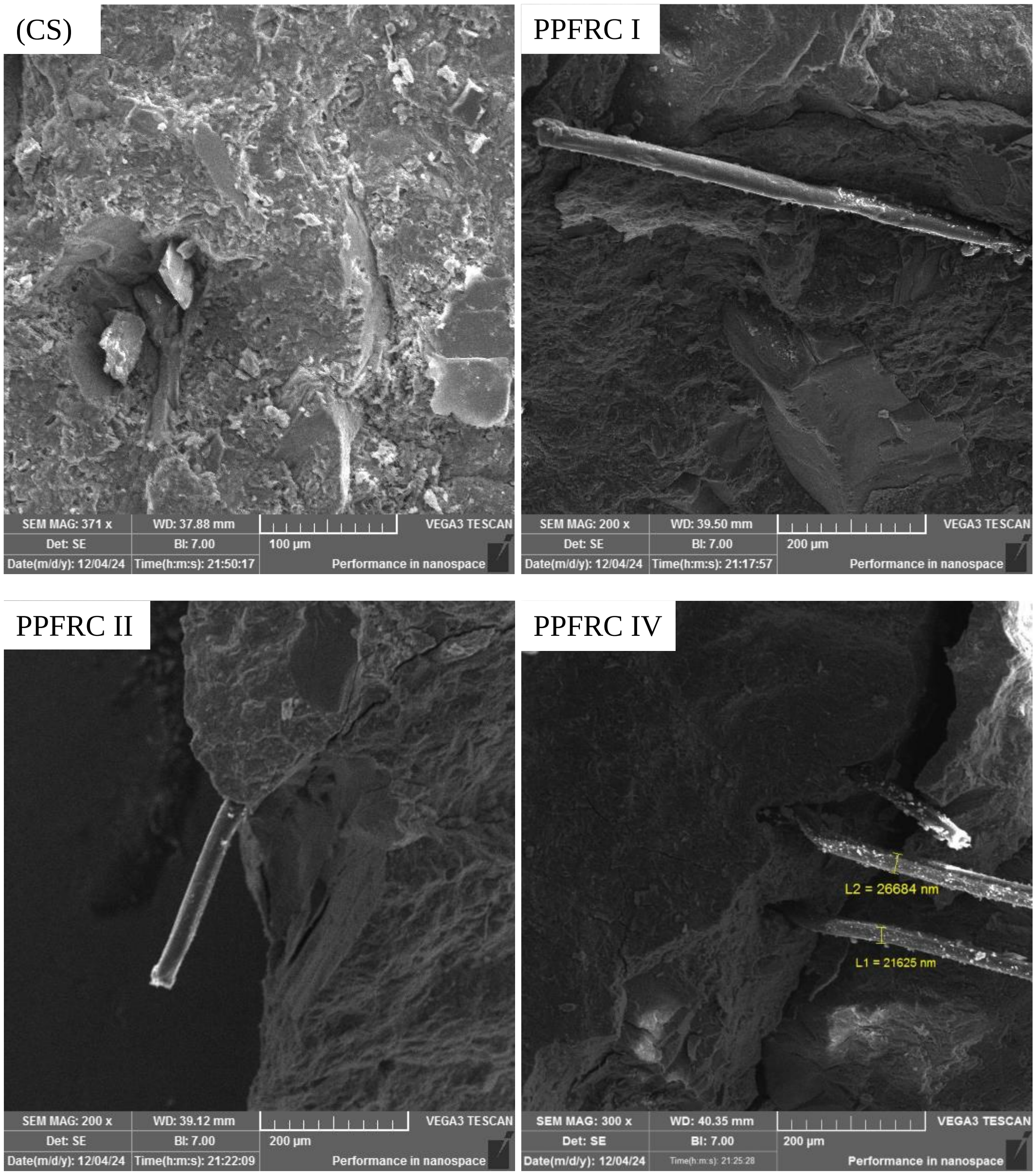

Figure 7: SEM images of CS, PPFRC I, PPFRC II, PPFRC IV

4 Practical Implementation

This research can contribute to helping engineers and the construction industry to use fiber reinforced concrete more effectively in real life construction projects. By understanding how different fibers work and improve the compressive and split tensile strength of concrete, the findings can help to make stronger structures. It can also guide the development of new concrete mixes that perform better under heavy loads

5 Conclusion

From the experimental work the following conclusions are drawn as follows:

1. PPFRC IV exhibited the highest ultimate stress, showing a 17% increase compared to the control specimen.
2. PPFRC IV mix also showed the highest splitting tensile strength, 5% greater than that of the control, while PPFRC I exhibited the highest reduction, with a 25% decrease in splitting tensile strength.

3. After 28 days of immersion in sodium chloride solution, the CS and PPFRC I mix showed the greatest loss in splitting tensile strength, an 11% reduction which is the highest loss of all the specimens.
4. Hydration products observed in the SEM images as well as the control specimen showed more micro pores. It was also observed that fibers have strongly bonded the concrete matrix.

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