

Experimental studies on flexural action of RC beams made with hybrid rebars - A brief review

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Abstract: Reinforced Steel bars used in concrete constructions are particularly susceptible to corrosion since they don't have enough corrosion resistance, which decreases durability and long-term performance. The main cause of steel bar corrosion is moisture interaction, which results in rust, which causes cracks and spalling, which affects durability and long-term performance. FRP bars, which have several benefits over steel bars such as strong resistance to corrosion, higher tensile strength than steel bars, and a 1/4th of the weight of steel bars, which decreases shipping and labor costs, are now entering the market as a solution to the aforementioned issues. Polypropylene fibers in concrete have high mechanical strength, stiffness, and durability. This paper tells about the type of FRP bar and Fiber that has been chosen in order to enhance the studies on the performance of flexure of RC beams made with a combination of FRP and Steel bars. From previous studies, it has been concluded that 0.25% of fibers are used as optimum dosage in terms of volume fraction in order to improve the behavior of flexure and ductility of beams made with a combination of Steel and FRP bars.

Key words : Glass Fiber Reinforced Polymer bar, Polypropylene fiber.

1 Introduction

Concrete is the most adaptable, long-lasting, and dependable building material on the planet. It is a sensitive material with profoundly contrasting malleable and compressive qualities since it has a high compressive strength yet a much lower rigidity. In many countries, the use of waste materials is beyond the capacity of the production company due to the increase in raw material costs and the continuous depletion of natural resources. Since the beginning of time, fibers have been utilized for reinforcement.

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Fiber-reinforced concrete (FRC) became significantly more important in the 1950s. By the 1960s steel, glass fibers and synthetic fibers like polypropylene and polyolefin had significantly increased in importance. Fibers play a role in preventing both plastic shrinkage and drying shrinkage, which can lead to cracking. When fibers like polypropylene are added to concrete, it loses compressive strength but gains durability and transverse rupture strength. In contrast to regular concrete, they have more pores. The material also gains tensile and flexural strength as a result of this fiber's bridging action. Additionally, the fiber improves resistance to ion penetration, reducing the risk of reinforcing bar corrosion. Concrete transforms into a ductile, homogeneous, and isotropic material when fibers are added. Concrete will have additional support from these fibers, preventing fractures from spreading. Concrete, concrete, and properly discrete, scattered, irregular strands are consolidated to make fiber-built-up concrete, a composite material. Samples containing both polyvinyl alcohol and silica fume exhibit greater ductility than silica fume-only samples in a study. The term "Hybrid fiber reinforced concrete" (HyFRC) refers to concrete that has been reinforced with a variety of fibers. Using a large, strong fiber will control fracture growth, whereas using a thick, soft fiber will limit crack initiation and spread. The ductility of hybrid fibers and steel has been shown to increase, according to studies. Filling cracks in concrete mixtures with steel fiber can increase the joint's shear strength.

1.1 Polypropylene Fiber

Propylene polymerization produces the synthetic fiber known as polypropylene fiber (PPF), which is a linear polymer. Its benefits include low weight, superior strength, outstanding durability, and resistant to corrosion. Construction, energy, clothes, environmental protection, and the chemical sector all utilize it extensively. PPFs are primarily made up of polypropylene fibers, either continuous or broken, organized in a plastic matrix. Due to its adaptability, minimal specific weight, mechanical and chemical characteristics, dimensional rigidity, and vapour barrier, polypropylene is used as a reinforcement material.

It is used in precasted concrete, concrete with great resistance, industrialized floors, sidewalks, channels and specialty mortars. It has exceptionally great temperature dimensional firmness and extraordinary chemical resistance to common solvents and vapor barriers. Mesh is a great reinforcement, but polypropylene fibers are more affordable, faster, and easier to use. They improve safety on construction sites, reduce the appearance of shrinkage and shrinkage cracks, increase construction speed, reduce labor costs, provide uniform secondary reinforcement, are not prone to corrosion and are non-magnetic, enhanced toughness, increased impact resistance, enhanced three-dimensional reinforcement and has outstanding tensile strength.



Fig 1 PPF

1.2 Glass Fiber Reinforced Polymer

Glass Fiber Reinforced Polymer (GFRP) substances are being utilized to restore and adapt old infrastructures, such as bridges and homes, to improve their strength and stiffness. However, the link between the GFRP plate and the floor of the RC beam significantly affects the strength of externally bolstered RC beams which may be bolstered with GFRP plates and textiles and subjected to harsh environmental conditions. It is important to examine the general overall performance of the RC beams which have been externally bolstered with GFRP plates and textiles and subjected to numerous environmental elements. The technological sectors have grown significantly over the past several decades due to their excessive particular stiffness and strength. In aerospace and other structural applications, GFRP buildings commonly experience cycle stress, or fatigue. In the lab, fatigue is defined as an inusoidally variable load or stress, with the weight ratio, frequency, and most pressure being the defining traits. Impact fatigue is the time period for this phenomenon (IF), which is critical to the structural integrity of additives and structures due to its poor effect on overall performance. It can occur after a modest variety of low amplitude cycles, making it critical to the structural integrity of additives and structures.

Table 1.1 GFRP bar Physical Properties

Tensile Strength	940 MPa
Young’s Modulus	Greater than 65 GPa
Ultimate Strain	1.5 to 2%
Bar Density	2100Kg/m ³
Bond Strength to Concrete	>20
Transverse Shear Strength	220
Yield Strain	>58%
Yield Tensile Strength	>13
Crack tolerations in aqueous condition	0.7mm
Length	2m
Diameter	12mm

2 Literature review

Sankalamaddi Rakesh Reddy and CH Lakshmi Nagabala (2022) proposed the use of reinforced polypropylene as an additive to increase the strength of concrete. They concluded that the maximum compressive strength of SFRC is 38.61 MPa reaching 2% concrete added with steel fiber (class M30). The maximum Compressive Strength (CS) of PPRC is 36.12 MPa obtained at the addition of 0.30% PPF concrete (grade M30). The compressive strength of HFRC is 40.19 MPa obtained at (2% S and 0.30% PP) concrete addition (M30 grade). The maximum tensile strength of SFRC is 3.23 MPa 42.2% increase in contrast to conventional concrete. The tensile strength of PPRC of 3.14 MPa obtained at 0.30% by adding compared to ordinary concrete is 51.1%. In Contrast to SFRC, it increased by 6.1%.

Husain Abbas et al. (2022) inspected the affect of changing the layout and quantity of steel and GFRP reinforcement on the deflection of reinforced concrete beams. Sixteen normal concrete beams and SFRC beams with reinforcement were tested. Investigation of initial stiffness, first crack and ultimate load, ductility and flexural strain was done. The increased surface area of the reinforcement has resulted in improved maintainability and ductility. Estimate the beam's bending resistance by incorporating strain hardening, in accordance with the experiments. The studied parameters were load at the first crack, stiffness at the initial stage, load at a critical point, ductility, working load and deflection at 50% and 100% of the critical load. The increase in the surface area of the reinforcement has resulted in improved serviceability and improved ductility. Affiliation of Steel fibers (SF) into the concrete improved load at the first crack and stiffness at the initial stage.

Binbin Zhou et al. (2021) arranged a hybrid combination of FRP and steel rebars in the bearing region of the beams. The benefits of FRP and steel is that it can make full use of the material in improving the flexural strength and ductility of RC beam. The paper reinforces the design method of flexural strength of FRP hybrid steel. RC beams are recommended. Ensures ductility that corresponds to design tolerance of the reinforcement rate. Three common bending failure modes have been specified from then the following computational approach.

Mahdi Nematzadeh & Saber Fallah-Valukolae (2021) mentioned that the mixture of conventional concrete and FRC in beams in form of 2 layer composite elements may increase bending performance, provides appropriate SF distribution, and is a well-organized outcome for lowering structural component prices. The study's goal was to assess the load-bearing capability of 2 layer FRC beams with GFRP and reinforcing bars undergoing quasi-static loading. The testing was done under 3 point loading. It showed that computing fibers in compression region resulted in greater malleability in GFRP and steel bars RC beams while adding fibers in tension region increased overall bending strength. The combination of increased GFRP with steel reinforcement, combined with a higher concrete compressive in the layered beams, improved the flexural performance of the steel rebars; however, the replacement of steel rebars by GFRP resulted in a decrease in the load carrying capacity, the flexural stiffness and the malleability.

Filipe R.G.de Sa et al. (2020) conducted an experimental program in which they added 10kg/m³ of PPF to the flexural as well as tensile behavior of concrete. The pull-out tests and mechanical properties were carried out in order to establish the characteristics of the element. The addition of PP macro fiber had no significant effect on the bonding performance between GFRP and concrete. However, at the cracking stage, the usage of fibers increased the stiffness of the structural components.

Wenjie Ge et al. (2019) used sixteen beams to examine the performance of flexure. They classified these beams into groups. Each category included two specimens, one cast with concrete and the other using Engineered Cementitious Composite (ECC). Some of the beams

were strengthened using hybrid steel rebars, while others were strengthened with FRP bars. However, in one category, they used either of the two for reinforcement. Steel rebars of various grades were utilised. The results revealed that the use of ECC in the beams improved the moment capacity. ECC specimens reinforced with FRP bars outperform steel reinforced beams. In comparison to concrete beams, the introduction of ECC in the beams has demonstrated an improvement in curb weight, displacement, and fracture width.

Piti Sukontasukkul et al. (2018) studied the impact of SF and PPF hybridization on the flexibility of fiber-reinforced geopolymers. They discovered that for single-type FRC, compressive and flexural strength rose with an increase in fiber content, mostly due to the fibers' ability to bridge fractures and the geopolymer mixture's silica smoke addition's higher binding strength. The proportion of steel fiber added to the mixture increased the flexural performance.

Cong Zhang et al. (2018) studied the effects of SF, PPF (macro & micro) on the flexural behaviour of SCC beams with different longitudinal reinforcement proportions. This was done taking individual fiber and also in their mixtures. Adding SF can increase the ultimate flexural bearing capacity of reinforced SCC beams, and combining SF with PPF(macro) can increase that capacity even further. Cracks in the reinforced SCC beams became minor, thinner, and more dispersed as a result of the fiber addition. A mathematical model that considers how various fibers transfer stress and how HyF contribute to SCC in the tension region was proposed to determine the final bearing capacity of flexural SCC beams. The proposed model may be used to calculate the crucial flexural carrying capacity of SCC beams incorporating HyF at room temperature.

Antonio Caggiano et al. (2016) conducted an experimental investigation to see how different PPF and SF combinations affected the cracking behaviour of HyFRC. Five different mixtures of samples were bent and compressed. The kind of fibers had a significant impact on the general form of the stress crack-opening-displacement curves of HyFRC evaluated under bending. In contrast, an obvious decline in post-cracking response was shown, particularly at broad crack openings, for FRC specimens constructed of solely PPF. These specimens showed good post-cracking toughness for the narrow fracture opening ranges relevant to the Serviceability Limit State. The experiment's findings demonstrated that mixing SF and PPF was an appealing way to improve the post-cracking behavior of cement-based matrices and maybe modify the reaction of the material to meet certain structural needs. The experimental findings on the characterized specimens were less variable when PPF was present.

Ahsana Fathima K M & Shibi Varghese (2014) stated that using PPF increases compressive strength by 15.24%, Split tensile test by 20.65% and flexure strength by 9.80% by adding 0.5% to concrete. The findings of this experimental work shown the effect of SF, PPF on compressive strength, split tensile test, and flexure strength. SFRC provides greater compressive strength with the incorporation of 0.75% steel fiber by mass, while fiber-reinforced concrete with 25mm length bent steel fibers with 50 aspect ratio provides better tensile strength and greater flexural strength with the incorporation of 0.5% PPF to concrete.

3 Objectives

The purpose of this study is

1. To study the various types of FRP bars in terms of flexural capacity and ductility.
2. To study the different types of fibers which enhance the flexural properties and conclude optimum dosage of fibers in volume proportions.

4 Conclusions

1. The maximum compressive strength of SFRC and PPRC increases 16.9% and 21.7% respectively, while the maximum split tensile strength of HFRC increases 51.1% and 39.8% respectively.
2. SFRC yields higher compressive strength and splitting tensile strength while PPF added to concrete increases splitting tensile strength.
3. Combining SF and PPF can enhance post-cracking behavior of cement-based matrices, resulting in higher post cracking bending strengths and tougher behavior.
4. High temperatures significantly reduce the ultimate load of hybrid concrete GFRP reinforced beams.
5. High fiber content causes mixing and compaction issues, non-uniform fiber distribution, and more voids. Hybrid systems can address PFRG weaknesses, but careful selection and fiber content are crucial.
6. Hybrid reinforcement reduces deformation and crack width compared to FRP reinforcement. HyRC has lesser displacements and fracture width, respectively, while HyRC ECC has minor deflections and fracture width, in contrast to FRP reinforced specimens with similar tensile capacity.

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