A Review on Mechanical and Durability Properties of Multi Fiber Reinforced Concrete Beam

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***Abstract*—The increasing demand for durable and high-performance concrete structures has encouraged the development of fiber-reinforced concrete (FRC) as an alternative to conventional concrete. Single fiber reinforcement systems, such as steel fiber reinforced concrete (SFRC) and glass fiber reinforced concrete (GFRC), provide improvements in strength, crack resistance, and durability; however, each fiber type has certain limitations.**

This review focuses on the mechanical and durability properties of multi-fiber reinforced concrete beams incorporating 0.5% steel fiber and 0.3% glass fiber compared with conventional reinforced concrete beams. The combined use of steel and glass fibers provides a synergistic effect, where steel fibers contribute to enhanced tensile strength, ductility, and post-cracking performance, while glass fibers improve crack control, corrosion resistance, and durability.

The reviewed studies indicate that hybrid fiber reinforcement improves flexural strength, stiffness, energy absorption, fatigue resistance, and resistance to environmental deterioration compared with conventional concrete beams.

The mechanism of fiber bridging, crack arresting, and improved interfacial bonding contributes to better structural performance and service life. This review highlights the potential of steel–glass multi fiber reinforced concrete as a sustainable and durable material for structural applications and identifies the need for further experimental investigations on optimized fiber combinations under flexural and durability loading conditions.

***Index Terms*—Steel fiber, Glass fiber, Steel fiber Reinforced Concrete, Glass fiber Reinforced Concrete, Multi Fiber Reinforced Concrete, Flexural behaviour, Mechanical properties, Durability performance, Crack control.**

I. INTRODUCTION

Concrete is the most extensively used construction material worldwide due to its excellent compressive strength, availability, and cost-effectiveness. However, its inherent brittleness, low tensile strength, limited ductility, and poor resistance to crack propagation remain major challenges in structural applications. These limitations can lead to premature deterioration and reduced service life of concrete structures, especially under repeated loading and severe environmental conditions. Therefore, improving the mechanical performance and durability of concrete has become a significant research objective in civil engineering.

Fiber reinforced concrete (FRC) has emerged as an effective solution for enhancing the performance of conventional concrete by improving crack control, tensile capacity, toughness, and energy absorption. The addition of discrete fibers modifies the failure mechanism of concrete by bridging cracks and transferring stresses across cracked regions. Among various fibers, steel fibers are widely used due to their high tensile strength and stiffness, which significantly enhance flexural strength, shear resistance, ductility, and post-cracking behaviour. However, the susceptibility of steel fibers to corrosion may affect the long-term durability of concrete structures.

Glass fibers have also been introduced as reinforcement materials because of their lightweight nature, corrosion resistance, and high tensile strength. Glass fiber reinforced concrete provides improved crack resistance and durability; however, its relatively lower stiffness and bonding capacity limit its effectiveness in applications requiring high load-bearing capacity. To overcome the limitations associated with individual fibers, hybrid fiber reinforced concrete has been developed by combining different fiber types to achieve complementary performance.

The combination of steel and glass fibers provides a synergistic effect, where steel fibers enhance strength, ductility, and energy absorption, while glass fibers contribute to improved crack control and durability. The use of multi-fiber systems enables effective control of micro-cracks and macro-cracks, resulting in improved mechanical performance and service life compared with conventional concrete. In particular, the incorporation of 0.5% steel fiber and 0.3% glass fiber may provide an optimum balance between strength enhancement and durability improvement. Although numerous studies have investigated single fiber reinforced concrete, limited research has focused on the combined influence of steel and glass fibers on the mechanical and durability performance of concrete beams. Therefore, this review aims to evaluate the behavior of multi-fiber reinforced concrete beams containing 0.5% steel fiber and 0.3% glass fiber compared with conventional reinforced concrete beams, focusing on strength, ductility, crack resistance, and durability characteristics.

II. LITERATURE REVIEW

1) Zhao et.al (2018), In this paper, the shear behaviour of SFRC beams with high-strength reinforcement was studied. The effect of steel fiber volume fraction and stirrup ratio on the shear behaviour were investigated, including the load-deflection curve, concrete strain, stirrup strain, diagonal crack width, failure modes and shear capacity. Finally, the experimental values of the shear capacity were compared with the calculated values of CECS38:2004 and ACI544.4R. Their results showed that the addition of steel fibers improved beam stiffness, ductility, crack control, and shear capacity by reducing diagonal crack width through the fiber-bridging mechanism. The study also found that the contribution of steel fibers decreased as the stirrup ratio increased, indicating a complementary interaction between fibers and transverse reinforcement. Furthermore, the ACI 544.4R design provisions provided shear strength predictions that closely matched the experimental results, while the CECS 38:2004 model required modification for improved accuracy. The authors recommended a maximum steel fiber volume fraction of 1.5% for practical applications due to its effective balance between performance and material usage.

2) Hamoodi et al. (2021) experimentally investigated the shear behavior of steel fiber-reinforced concrete (SFRC) beams by evaluating the effects of fiber type, fiber volume fraction, aspect ratio, and transverse reinforcement. Eight beam specimens were tested under two-point loading with and without stirrups. The results showed that steel fibers significantly enhanced shear strength, controlled diagonal crack propagation, and improved the overall shear performance of the beams. Beams containing 1.0% and 1.5% steel fibers exhibited shear capacities comparable to or greater than those of conventionally reinforced beams with stirrups, demonstrating the potential of steel fibers as partial or complete shear reinforcement. The study also reported that existing design codes tend to underestimate the concrete contribution to shear resistance and highlighted the need for more accurate prediction models for SFRC beams.

3) Yan et al. (2023) experimentally investigated the flexural performance of recycled steel fiber reinforced concrete (RSFRC) beams to evaluate the feasibility of using recycled steel fibers as sustainable reinforcement. The study demonstrated that the incorporation of recycled steel fibers significantly improved the flexural strength, ductility, crack resistance, and energy absorption capacity of concrete beams. The fibers effectively bridged cracks, resulting in reduced crack widths and enhanced post-cracking behaviour. The authors concluded that recycled steel fibers can provide mechanical performance comparable to conventional steel fibers while promoting the sustainable utilization of recycled materials in structural concrete applications, highlighting their potential for eco-friendly reinforced concrete construction.

4) Sasikumar and Manju (2024) investigated the flexural behaviour of reinforced concrete beams reinforced with Glass Fibre Reinforced Polymer

(GFRP) bars through experimental testing and analytical evaluation. The study examined the load–deflection response, cracking behaviour, failure modes, and flexural capacity of GFRP-reinforced beams. The results indicated that GFRP bars provided excellent corrosion resistance and satisfactory flexural performance, although the beams exhibited lower stiffness and larger deflections than conventional steel-reinforced concrete beams because of the lower elastic modulus of GFRP. The analytical predictions showed good agreement with the experimental findings, demonstrating the reliability of existing design approaches for estimating the flexural behaviour of GFRP-reinforced concrete members.

5) Kassa et al. (2022) experimentally investigated the influence of discontinuous chopped E-glass fibers on the shear and flexural performance of reinforced concrete beams. Concrete beams incorporating 50 mm chopped glass fibers at volume fractions of 0.25%, 0.50%, and 0.75% were tested under third-point loading. The results showed that the inclusion of glass fibers enhanced the compressive and flexural strengths, increased the ultimate load-carrying capacity, and improved the post-cracking ductility of the beams. The fibers effectively bridged cracks, delayed crack propagation, and reduced the brittle nature of concrete, resulting in improved structural performance. The study concluded that increasing the glass fiber content up to 0.75% significantly enhanced the flexural behaviour and crack resistance of reinforced concrete beams, demonstrating the potential of chopped glass fibers as an effective reinforcement material for structural concrete applications. The authors concluded that chopped E-glass fibers can be effectively used as supplementary reinforcement in concrete beams to improve structural performance. However, compared with steel fibers, glass fibers provide lower stiffness and tensile resistance. Therefore, hybridization with steel fibers may provide additional benefits by combining the high strength and ductility of steel fibers with the durability and corrosion resistance of glass fibers.

6) Moawad and El-Hanafy (2023) experimentally investigated the flexural behaviour of concrete beams reinforced with biaxial geogrids and randomly distributed short glass fibers and steel fibers. Eleven beam specimens were tested under two-point loading to evaluate the effects of fiber type, fiber volume fraction (0.25% and 0.75%), and geogrid reinforcement configuration on flexural performance. The results showed that the inclusion of short glass fibers improved the first-crack load, crack control, post-cracking stiffness, toughness, and ultimate flexural capacity compared with beams reinforced only with geogrids. Increasing the glass fiber content from 0.25% to 0.75% further enhanced the load-carrying capacity and delayed crack propagation through the crack-bridging mechanism. However, steel fiber-reinforced specimens exhibited greater improvements than glass fiber-reinforced beams because of the higher tensile strength and bond characteristics of steel fibers. The study concluded that chopped glass fibers are an effective supplementary reinforcement for improving the flexural performance and ductility of concrete beams, particularly when used in combination with geogrid reinforcement.

7) Cui et al. (2023) investigated the fatigue behaviour of steel–polypropylene hybrid fiber reinforced concrete (SPHFRC) under uniaxial constant-amplitude cyclic compression. Their experimental results demonstrated that hybrid fibers significantly improved fatigue resistance by delaying crack initiation, reducing stiffness degradation, and extending fatigue life compared with conventional concrete. The fatigue damage process exhibited three distinct stages, including rapid initial deformation, stable crack propagation, and accelerated failure. Furthermore, the study showed that increasing stress levels substantially reduced fatigue life, whereas hybrid fiber reinforcement enhanced energy dissipation capacity and crack-bridging performance. Based on the experimental observations, the authors proposed a unified fatigue equation that accurately predicted the fatigue life of SPHFRC across different stress levels, providing a useful model for engineering design and fatigue assessment.

8) Ahmed and Lim (2023) investigated the mechanical performance, durability, and cost-effectiveness of sustainable recycled concrete reinforced with single and hybrid combinations of basalt (BF), polypropylene (PPF), and glass fibers (GF). The study evaluated eleven concrete mixtures incorporating recycled aggregates, pulverized fly ash (PFA), and ground granulated blast furnace slag (GGBFS). The experimental results showed that hybrid fiber reinforcement significantly enhanced the mechanical properties of recycled concrete compared with single-fiber systems. In particular, the 0.75% BF–0.25% PPF and 0.5% BF–0.5% GF hybrid mixtures achieved the greatest improvements, increasing compressive strength by 16–21%, splitting tensile strength by 36–49%, and flexural strength by 54–71%. The hybrid fiber systems also exhibited superior freeze–thaw durability, characterized by lower mass loss, reduced dimensional changes, and higher ultrasonic pulse velocity after prolonged exposure to cyclic freezing and thawing. A multicriteria performance assessment further identified the BF–GF and BF–PPF hybrid mixtures as the most effective solutions by balancing mechanical performance, durability, and production cost. The study concluded that hybrid fiber reinforcement is an efficient strategy for improving the structural and sustainability performance of recycled concrete, particularly for applications requiring enhanced strength and long-term durability. The hybrid mix showed improved ductility and higher energy absorption compared to single-fiber concrete.

III. SUMMARY OF THE LITERATURE REVIEWS

Previous studies have demonstrated that steel fibers significantly improve the strength, shear capacity, stiffness, ductility, and crack resistance of concrete beams. The fiber-bridging mechanism effectively controls diagonal and flexural crack propagation, resulting in enhanced post-cracking behaviour and energy absorption.

SFRC also shows improved fatigue performance and load-carrying capacity compared with conventional concrete. However, the higher density, corrosion susceptibility, and increased material cost of steel fibers may limit their long-term durability and practical applications in aggressive environments.

Glass fibers improve the tensile strength, flexural strength, toughness, and crack control ability of concrete by delaying crack initiation and propagation. GFRC provides good corrosion resistance, lightweight characteristics, and improved durability compared with steel reinforcement. However, the relatively lower tensile strength and bond capacity of glass fibers result in lower mechanical enhancement compared with steel fibers, particularly under high-load structural applications.

Hybrid fiber reinforced concrete combines the advantages of different fiber types to achieve superior mechanical and durability performance through a synergistic effect. Hybrid systems improve strength, ductility, toughness, fatigue resistance, crack control, and long-term durability by providing effective crack bridging at different stages of loading.

Compared with SFRC, hybrid fibers offer improved durability, reduced corrosion risk, and better sustainability, while compared with GFRC, they provide higher strength, energy absorption, and post-cracking performance.

Therefore, hybrid fiber systems are considered an effective solution for developing durable and high-performance concrete structures with improved strength, ductility, and resistance to environmental effects.

IV. CONCLUSION

The preparation of the concrete mix was carried out in accordance with IS 10262: 2019 – Guidelines for Concrete Mix Proportioning and IS 456: 2000 – Plain and Reinforced Concrete – Code of Practice. The objective was to produce a workable and uniform mix with consistent strength and durability for the experimental study. All materials were weighed by mass to ensure accuracy. The materials were batched separately as per the designed mix proportions. The water–cement ratio was maintained as 0.45 throughout the experiment. Care was taken to prevent moisture variation in M-sand and aggregates by oven-drying and adjusting the water content accordingly. Two concrete Beams were prepared:

1. CC – Conventional Concrete Beam
2. Multi Fiber Reinforced Concrete Beam (0.5% Steel + 0.3% Glass)

Concrete Beam size were prepared by 150 mm x 150 mm× 1000 mm. The Beam specimens were cured in water for 7 and 28 days. The results align with earlier investigations that highlighted the benefits of Multi fiber systems over single-fiber concrete, especially in improving tensile and flexural behaviour while reducing concrete brittleness. Therefore, the present study not only validates existing literature but also reinforces the suitability of multi-fiber reinforced concrete beam as a reliable material for structural applications requiring improved strength, toughness, and durability.

In conclusion, the experimental results establish that Multi Fiber - Reinforced Concrete Beam, especially with 0.5% steel and 0.3% glass fibers, offers substantial improvements in all key mechanical properties. The study also demonstrates that multi-fiber reinforced concrete reduces the brittle nature of conventional concrete and enhances its resistance to crack propagation, making it more suitable for structural applications.

Overall, multi-fiber reinforced concrete is a promising construction material for applications where improved strength, durability, and crack resistance are critical. The Multi Fiber Reinforced Concrete Beam carried higher load and showed greater deflection before failure, demonstrating enhanced ductility and crack resistance. Hence, the use of multi-fiber reinforcement can effectively improve the strength, durability, and structural performance of concrete. This mix can be recommended for use in pavements, slabs, industrial floors, and other structural elements where enhanced tensile and flexural performance is required.

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