Review On Experimental Investigation on Flexural and Shear Performance of Steel Fiber Reinforced Concrete Beam

Dheeraj C[1], Dr. Vathsala[2]
[1]PG Student (M. Tech), Department of Civil Engineering, Bangalore Institute of Technology, Bangalore, Karnataka, India
[2]Associate Professor, Department of Civil Engineering, Bangalore Institute of Technology, Bangalore, Karnataka, India

***Abstract*—Steel fibre reinforced concrete (SFRC) has gained attention for improving the brittle behaviour and low tensile capacity of conventional and high-strength concrete. This study evaluates the shear and flexural performance of SFRC using experimental observations from beams and prismatic specimens subjected to monotonic and cyclic loading. The inclusion of steel fibres significantly enhanced shear strength by delaying diagonal crack formation, reducing crack widths, and improving load-carrying capacity. Higher fibre contents (1–3%) showed a shift from brittle shear failure to more ductile behaviour.**

In flexure, fibres improved tensile strength, post-cracking resistance, and ductility. Under cyclic loading, SFRC exhibited better energy absorption and stable hysteresis response, indicating improved seismic performance. The effectiveness of fibres depends on volume fraction, aspect ratio, and distribution within the matrix. Overall, steel fibres enhance crack control and structural performance, making SFRC a promising material for durable and ductile structural applications.

***Index Terms*—Flexural performance; Shear strength; Diagonal crack delay; Crack width reduction; Ductility; Fiber volume fraction (1–3%); Aspect ratio; Cyclic loading; Energy absorption.**

I. INTRODUCTION

Concrete is one of the most widely used construction materials due to its high compressive strength and durability. However, its low tensile strength and brittle nature limit its performance, particularly in structural elements subjected to shear and flexural stresses. With the development of high strength concrete (HSC), these limitations have become more pronounced, as higher strength often leads to increased brittleness and reduced ductility. This makes HSC more vulnerable to sudden and catastrophic failures, especially under shear loading conditions.

Shear behaviour in reinforced concrete beams is complex and not fully understood, as it depends on multiple factors such as shear span-to-depth ratio, reinforcement ratio, and concrete properties. Shear failure typically occurs without warning and is governed by diagonal cracking. In conventional design, transverse reinforcement (stirrups) is provided to resist shear forces and control crack propagation. However, in high strength concrete, reduced aggregate interlocking leads to wider and smoother cracks, reducing shear resistance.

The introduction of steel fibres into concrete has emerged as an effective method to improve shear behaviour. Steel fibres act as crack-bridging elements that transfer tensile stresses across cracks, thereby restricting crack growth and improving post-cracking performance. Studies have shown that fibres can significantly enhance shear strength, delay crack initiation, and reduce crack widths. In some cases, sufficient fibre content can partially replace conventional stirrups, resulting in improved structural efficiency.

Flexural behaviour is another critical aspect influencing the performance of concrete structures. Under flexural loading, cracks form in the tension zone, leading to stiffness degradation and eventual failure. The addition of steel fibres improves tensile strength and maintains residual strength after cracking, thereby enhancing load-carrying capacity and ductility. This results in better deformation characteristics and improved serviceability performance.

The importance of flexural behaviour becomes more significant under cyclic loading, such as during earthquakes. Structural materials must be capable of dissipating energy and undergoing large deformations without failure. Steel fibre reinforced concrete exhibits improved cyclic performance, including enhanced energy absorption, reduced stiffness degradation, and better crack control. These properties make SFRC suitable for applications in seismic regions.

The performance of SFRC depends on parameters such as fibre volume fraction, aspect ratio, and distribution within the concrete matrix. While increasing fibre content generally improves strength and ductility, excessive fibres may reduce workability and lead to clustering, which decreases effectiveness. Proper mix design and placement are therefore essential to ensure uniform fibre distribution.

This study focuses on understanding the combined influence of steel fibres on both shear and flexural behaviour of concrete. Since real structural elements experience both actions simultaneously, a combined assessment provides a more realistic evaluation of structural performance. The findings contribute to the development of more durable, ductile, and efficient concrete structures using fibre reinforcement.

II. LITERATURE REVIEW

This section discusses previous studies on the behaviour of steel fiber reinforced concrete (SFRC) beams. Different experimental approaches and parameters explored by various researchers are briefly considered. Greater importance is given to studies involving flexural and shear performance, with emphasis on fibre content, aspect ratio, and distribution. The collected information helps in identifying key findings related to strength, ductility, and crack control, and also highlights areas where further investigation is required for improved understanding and practical application.

Hamid Pesaran Behbahani et al. (2012) [1] This study investigated the flexural behavior of steel-fiber-added reinforced concrete (SFARC) beams using C30 and C50 concrete grades. The methodology included compressive and flexural strength tests with fiber dosages ranging from 0% to 2%, followed by four-point bending tests on beams. Results showed that steel fibers significantly enhanced both compressive and flexural strengths. Among all percentages, 1% fiber content provided the best performance. The study also reported increased cracking load and delayed crack propagation. Stiffness and ductility of beams improved compared to conventional reinforced concrete. Crack widths were reduced, leading to improved post-cracking behavior. The authors concluded that 1% fiber dosage is optimal, especially for higher-strength concrete.

Shende et al. (2012) [2] This study evaluated the mechanical properties of SFRC using M40 grade concrete with fiber content ranging from 0% to 3%. The methodology included compressive, flexural, and split tensile strength tests. Results showed significant improvement in all strength parameters with increasing fiber content. Compressive strength increased by up to 24%, while flexural and tensile strengths improved by 49% and 41%, respectively. The enhancement was attributed to the crack-bridging effect of fibers. Improved ductility and energy absorption capacity were also observed. However, higher fiber content affected workability. The authors concluded that 3% fiber content with an aspect ratio of 50 is optimal.

Slater et al. (2012) [3] This study compiled a database of 222 SFRC beam shear tests without stirrups. The methodology involved regression analysis considering span-to-depth ratio, fiber type, and concrete strength. Results showed that fiber factor and span-depth ratio significantly influence shear strength. Steel fibers improved crack control and delayed shear failure. The proposed model provided better prediction accuracy than previous models. The study emphasized the importance of fiber orientation and distribution. It also identified limitations in models neglecting fiber contribution. The authors concluded that their regression model is reliable for shear strength prediction.

Minelli et al. (2012) [4] This study investigated the size effect on shear strength of SFRC beams. The experimental program included beams of different sizes with varying fiber contents. Results showed that shear strength decreases with increasing beam size. However, steel fibers mitigated this reduction effectively. Crack control and ductility were significantly improved. Larger beams showed better performance with fiber inclusion. The study emphasized the need for proper fiber dosage selection. The authors concluded that fibers help compensate for size-related strength reduction.

Zhang et al. (2014) [5] This study examined fracture behavior of SFRC under different loading rates. The methodology included three-point bending tests on notched beams. Results showed that fracture energy and peak load increased with loading rate. This was attributed to inertia effects and fiber pull-out resistance. Steel fibers effectively controlled crack propagation. Energy absorption capacity improved under dynamic loading. The fracture process zone was influenced by fiber bridging. The authors concluded that SFRC is suitable for impact-resistant structures.

Ruano et al. (2014) [6] This study investigated SFRC jacketing for strengthening RC beams under shear. The methodology involved testing original and retrofitted beams with fiber dosages of 30–60 kg/m³. Results showed significant improvement in shear strength after retrofitting. Repaired beams regained or exceeded original capacity. Crack control and ductility were enhanced. Debonding between layers was minimized. The study demonstrated improved deformation capacity. The authors concluded that SFRC jacketing is an effective strengthening technique.

Han Aylie et al. (2015) [7] This study analyzed flexural performance of SFRC beams with compression zone confinement. The methodology included testing beams under pure bending. Results showed increased cracking moment and improved ductility. Confinement enhanced ultimate load capacity. Crack propagation was delayed and better distributed. Interaction between fibers and stirrups improved performance. Stress redistribution was more effective in confined beams. The authors concluded that combining fibers with confinement improves flexural behavior.

Halit Cenan Mertol et al. (2015) [8] This study investigated flexural behavior of SFRC beams with varying reinforcement ratios. Four-point bending tests were conducted on 20 specimens. Results showed slight increase in ultimate load but significant improvement in ductility. Post-peak behavior was enhanced compared to conventional beams. Flexural toughness increased considerably. Crack propagation was slower and more controlled. Energy absorption capacity improved due to fiber bridging. The authors concluded that SFRC enhances toughness and post-cracking performance.

T. Tahenni et al. (2016) [9] This study examined shear behavior of high-strength SFRC beams with and without stirrups. A total of 24 beams were tested under two-point loading. Results showed improved shear strength and delayed diagonal cracking. Crack widths were reduced and more distributed. Fiber content between 1–3% provided optimal performance. In some cases, fibers replaced stirrups effectively. Ductility and energy absorption increased. The authors concluded that fibers significantly enhance shear resistance.

Bensaid Boulekbache et al. (2016) [10] This study analyzed SFRC beams under cyclic loading conditions. The methodology included four-point bending with repeated load cycles. Results showed significant improvement in flexural strength and stiffness. Energy dissipation capacity increased substantially. Crack patterns became more distributed due to fibers. Strength gains up to 242% were observed. Fiber orientation influenced performance. The authors concluded that SFRC is suitable for seismic applications.

Amin & Foster (2016) [11] This study investigated SFRC beams with conventional stirrups under shear. Large-scale beams were tested under four-point loading. Results showed increased shear capacity and reduced crack widths. Crack distribution was more uniform. Fibers improved serviceability performance. Interaction between fibers and stirrups enhanced ductility. Fibers could replace minimum shear reinforcement. Analytical models matched experimental results. The authors concluded that fibers can reduce reliance on stirrups.

Zhang et al. (2016) [12] This study proposed a shear strength model using modified compression field theory. The model was validated using 139 experimental tests. Results showed improved crack control and ductility. Shear strength predictions were accurate. Fiber bridging was effectively incorporated. The model outperformed existing methods. Post-cracking behavior improved significantly. The authors concluded that the model is reliable for SFRC design.

Cai et al. (2016) [13] This study investigated seismic shear capacity of SFRC coupling beams. Seventeen beams were tested under cyclic loading. Results showed improved strength, ductility, and energy dissipation. Fiber content above 2.5% was most effective. Brittle failure was significantly reduced. A Mohr-Coulomb based model was proposed. The model matched experimental results well. The authors concluded that SFRC is suitable for seismic applications.

Farid Bouziadi et al. (2018) [14] This study examined creep behavior of SFRC beams under sustained loading. Experimental and numerical methods were used. Results showed that 0.5% fiber reduced creep effectively. Higher fiber content increased creep due to clustering. Fibers reduced tensile creep more than compressive creep. Crack widths were minimized. FEM results matched experimental data. The authors concluded that optimal fiber dosage is essential.

Liu Jin et al. (2018) [15] This study evaluated static and dynamic properties of SFR-UHSC. Tests included compressive, tensile, and impact loading. Results showed improved tensile strength and ductility. Energy absorption increased under dynamic loading. Crack propagation was well controlled. Fibers enhanced toughness and resistance to fragmentation. Dynamic performance was superior to conventional concrete. The authors concluded that SFR-UHSC is suitable for protective structures.

Tung & Tue (2018) [16] This study extended the critical shear band theory for SFRC beams. The model included fiber effects and residual tensile strength. Results showed delayed crack formation and improved shear resistance. Predictions matched experimental data well. Fiber contribution was clearly quantified. The study improved understanding of shear mechanisms. Analytical accuracy was enhanced. The authors concluded that the model effectively predicts SFRC behavior.

Mahmood et al. (2018) [17] This study investigated continuous SFRC beams under displacement loading. Six beams were tested with varying fiber contents. Results showed improved ductility and crack distribution. Moment redistribution was achieved effectively. Load capacity was maintained under large deformation. Crack widths were reduced. Serviceability performance improved. The authors concluded that SFRC beams allow safe moment redistribution.

Liu Jin et al. (2019) [18] This study examined SFRC beams under repeated impact loading. Drop-weight tests were conducted on beam specimens. Results showed improved impact resistance and energy absorption. Crack propagation was slower due to fiber bridging. Surface damage and spalling were reduced. Structural performance improved with higher fiber content. The beams showed better durability under dynamic loads. The authors concluded that SFRC is suitable for impact-resistant structures.

Momani et al. (2021) [19] This study developed AI-based models for predicting SFRC shear strength. ANN and GEP techniques were used. Results showed high prediction accuracy. Nonlinear fiber effects were captured effectively. Predictions were better than regression models. Key parameters were identified through sensitivity analysis. Models showed good generalization. The authors concluded that AI methods are reliable.

Nzambia et al. (2022) [20] This study investigated SFRC beams without stirrups. Results showed up to 109% increase in shear strength. Failure mode changed from brittle to ductile. Crack distribution improved significantly. Fibers enhanced energy absorption. Reinforcement interaction improved performance. Crack propagation was delayed. The authors concluded that fibers can replace shear reinforcement.

ETASR Study (2022) [21] This study used finite element modeling for SFRC beams. Results showed accurate prediction of crack patterns. Shear strength predictions matched experiments. Fiber effects were successfully modeled. Stress distribution was well captured. The model provided design insights. Numerical analysis proved effective. The author's concluded FEM is a powerful tool.

Tarawneh et al. (2022) [22] This study examined SCC beams with steel fibers. Results showed improved shear strength and ductility. Crack widths were reduced. Fiber distribution was improved due to SCC workability. Energy absorption increased. Structural performance improved significantly. Durability was enhanced. The authors concluded fiber-reinforced SCC is effective.

Al-Bayati & Taki (2023) [23] This study used ANN and regression models for shear prediction. Results showed ANN performed better. Predictions matched experimental data closely. Fiber content was a key parameter. Nonlinear behavior was effectively captured. Model accuracy was high. Regression models were less precise. The author's concluded ANN is reliable.

Zhao et al. (2024) [24] This study analyzed the effect of fiber type on shear strength. Hooked fibers performed best. Fiber geometry influenced crack bridging. Shear strength increased with better anchorage. Crack distribution improved. Straight fibers were less effective. Fiber selection was critical. The authors concluded fiber type is important.

Gao et al. (2025) [25] This study examined recycled aggregate SFRC beams. Results showed fibers improved shear strength. Crack control and ductility increased. Recycled aggregates reduced strength slightly. Fibers compensated for this reduction. Energy absorption improved. Sustainability benefits were highlighted. The authors concluded SFRC is suitable for sustainable construction.

Yoo & Banthia (2016) [26] This study investigated UHPFRC behavior with different fiber orientations. Results showed improved tensile strength and ductility. Fiber alignment influenced performance. Multiple fine cracks were observed. Energy absorption increased significantly. Durability improved due to crack control. Flexural strength was enhanced. The authors concluded that optimized fiber orientation improves performance.

di Prisco et al. (2013) [27] This study analyzed SFRC beams without shear reinforcement. Results showed improved shear strength and ductility. Crack propagation was controlled. Residual tensile strength was important. Analytical results matched experiments. Fiber dosage influenced performance. Brittleness was reduced. The authors concluded that SFRC can replace stirrups.

III. SUMMARY OF LITERATURE REVIEW

Steel fibre reinforced concrete (SFRC) significantly improves the shear and flexural performance of conventional concrete. The addition of steel fibres in the range of 1–3% enhances compressive, tensile, and flexural strengths, with optimal performance depending on fibre content and aspect ratio. Studies on shear behaviour highlight that parameters such as fibre factor, span-to-depth ratio, and residual tensile strength play a key role in predicting shear capacity.

Experimental investigations show that steel fibres delay diagonal crack formation, reduce crack widths, and in some cases partially or fully replace conventional stirrups. This leads to a transition from brittle to more ductile failure behaviour. In flexure, fibres improve post-cracking response, toughness, and deformation capacity, although the increase in ultimate load is sometimes moderate.

Under cyclic and dynamic loading, SFRC exhibits improved energy absorption, stable hysteresis behaviour, and enhanced impact resistance, making it suitable for seismic and protective structures. Advanced analytical and AI-based models have also been developed to accurately predict SFRC behaviour by capturing nonlinear fibre effects.

Recent studies emphasize the importance of fibre type, geometry, and sustainability. Overall, fibre volume fraction, aspect ratio, orientation, and distribution are critical parameters governing the performance of SFRC.

IV. RESEARCH GAP

From the literature review, the following observations were made:

1. Limited Studies on Shear Behaviour of SFRC Beams:

Many studies focus on shear performance, but the behaviour is still not fully understood due to the influence of multiple parameters such as fibre content, shear span-to-depth ratio, and concrete strength. Accurate prediction of shear failure in SFRC beams remains a challenge.

2. Limited Studies on Flexural Behaviour of SFRC Beams:

Although improvements in flexural strength and ductility are reported, there is insufficient understanding of post-cracking behaviour, stiffness degradation, and failure mechanisms in SFRC beams under flexural loading.

3. Uncertainty in Fibre Contribution and Replacement of Reinforcement:

While steel fibres enhance crack control and ductility, their exact quantitative contribution to load-carrying capacity is not clearly defined. The potential replacement of stirrups using fibres lacks validation in full-scale applications.

4. Effect of Fibre Distribution, Orientation, and Workability:

The performance of SFRC beams depends on proper fibre dispersion. However, clustering and random orientation during mixing and casting significantly affect behaviour and are not well accounted for in current studies.

V. CONCLUSION

Steel fibre reinforced concrete (SFRC) improves beam performance by enhancing shear strength, flexural capacity, crack control, and ductility. Fibres delay crack formation and convert brittle failure into ductile behaviour, while also improving energy absorption under cyclic loading. However, key gaps remain, including limited understanding of combined shear–flexural behaviour, unclear quantification of fibre contribution, and uncertainty in replacing conventional reinforcement. Practical issues such as fibre distribution and workability further affect performance. Additionally, the lack of large-scale and realistic loading studies restricts field application. Therefore, further research is needed to develop reliable design guidelines and ensure effective use of SFRC beams in structural engineering.

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