

Shear Behavior for High Strength Concrete Beams with Steel Fibers

Prof. Dr. Hussam Ali Mohammed, Mahmoud Nassif Daher

AL-Furat Al-Awsat Technical University – AL-Mussaib Technical Collage–Building & Construction Department

Article information:

Manuscript received: 4 Sep 2025; **Accepted:** 10 Oct 2025; **Published:** 30 Nov 2025

Abstract: The current study reviews and synthesizes more recent studies about the shear action of steel fiber and high-strength steel rebar-reinforced high-strength concrete (HSC) beams. The beams act as the transfer point of loads and resistors for both flexural and shear forces in concrete structures and also play an essential role in the shear behavior. It has been shown from the literature that the presence of steel fiber (in different forms, volumes, and aspect ratios) affects the mechanical behaviour in concrete such as crack-bridging, ductility, and shear resistance. Optimal fiber types and weights (typically around 1–2% by volume) have been found to enhance performance, and crimped fibers frequently have better shear stability than hooked-end fibers. The shear strength improvement is attributed to factors such as fiber geometry, quantity of fiber and rebar, concrete compressive strength, span-to-depth ratio, and aggregate type. When stirrups may be displaced via fiber use, the hybrid mix of fibers and conventional reinforcement usually results in better shear–ductility. Even though predictive models have advanced, the existing code equations generally do not guarantee precise estimates for shear strength of the HSC beams with fibers, which underscores the importance of future studies and improved models that consider fiber type and other necessary parameters.

Introduction

Beams are one of the fundamental structural elements of concrete buildings where they transfer loads from the slabs to columns and foundations. These loads impose flexural forces on the beams, which must provide adequate resistance to tension and shear forces created by cracks and gravel interlocking, but are also required to prevent deflection due to longitudinal reinforcement. Shear force within a beam depends on many factors such as:

- The types of concrete used
- The reinforcement, especially stirrups

Today, the application of steel fibers in concrete is rather ubiquitous. The fiber acts to bridge cracks, delaying their appearance and reducing their width. Besides redistributed stress (Voo et al., n.d., Yoo & Yang, 2018), this research describes the recent findings in the context of the steel fibers on shear resistance of high-strength concrete beams.

Literature review

Steel fibers were of different aspect ratio (length to diameter) and fiber shape as straight or hook type. Next to the volume fraction of steel fibers in concrete, these elements affected shear strength. **Junior, 2011** studied the influence of steel fibers and compressive strength on shear strength of beam under static and revise load. It was concluded that compressive strength did not affect shear strength, but the stresses on the fibers under revise load was advantageous in that it provided the same strength as beam under static load. **Qi et al., 2016** reported that the strengthening of shear strength could be achieved by fiber as opposed to the flexural strength even with longitudinal reinforcement of the beam. **Yoo & Yang, 2018** produced 6 beams with high strength concrete, three with 0.75% by volume steel fibers and no stirrup, and the other three without fiber and reinforced with minimum stirrups required. Results showed that fibers reduced the propagation of cracks, but minimum reinforcement stirrup gave better results in comparison to beams using fibers

Ananthi, 2020, study the best fibers ratio in concrete using two kinds of steel fibers, using the collection of hook end and corrugated with variable amount (0%-2%) according to compressive and tensile strength. As illustrated in fig1, the optimum ratio was 1%. This volume of fiber was selected in beams to investigate the shear strength. Crimped steel fibers with a 1% volume fraction and an aspect ratio of 50 are considered the best type of fibers for replacing transverse stirrups in high-strength concrete beams, especially when compared to hooked-end steel fibers.

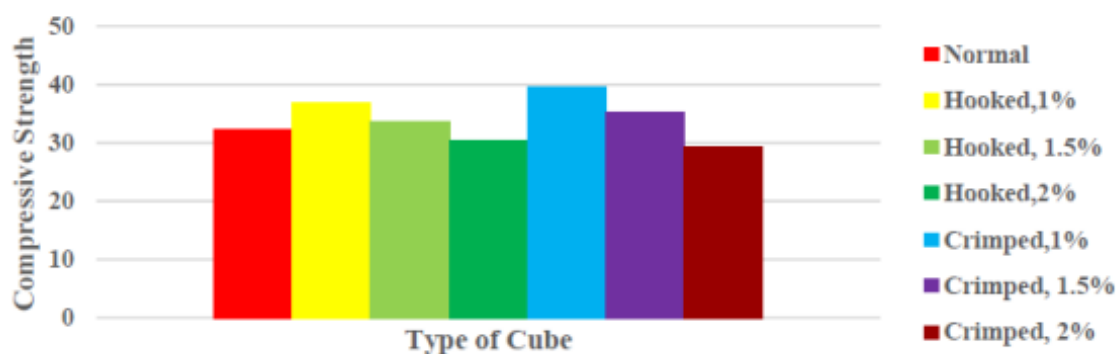


Figure 1 Compressive strength for concrete with fibers.

Awad et al., 2023, turned 45% from cement weight from polypropylene fiber and 7% from cement weight from steel fibers. This was done on high strength concrete and casted beams, and shear strength was increased by 18% against reference beam. **Li et al., 2023** were casted nine beams three normal concrete with 0.5% stirrups three beams casted using ultra-high performance concrete (UHPC) with no stirrups and 0% fibers. The last three beams were casted also with also UHPC and without stirrups but with volume fraction of 2%. It was found that fibers could increase shear resistance and it could be used instead of stirrups.

Lakavath and Chandrashekhar, 2018, also casted a pre-cast 12 rectangular section concrete in addition to 8 I-shaped section. In the process of fibers dosage was varying from 0.75%-2% by volume. Compared to all mixtures were 42MPa and when fibers been added the compressive strength increase and it rose by 10% when 1% of fibers were added but the deference in compressive strength between 1.75% and 2% was <1% which suggests fibers after 1.75% don't affect the compressive strength. The failure mode was deferent in control spesimnes (90% fibers) and mixtures with fibers so it was change from brittle to ductile behavior as it shown in fig2.

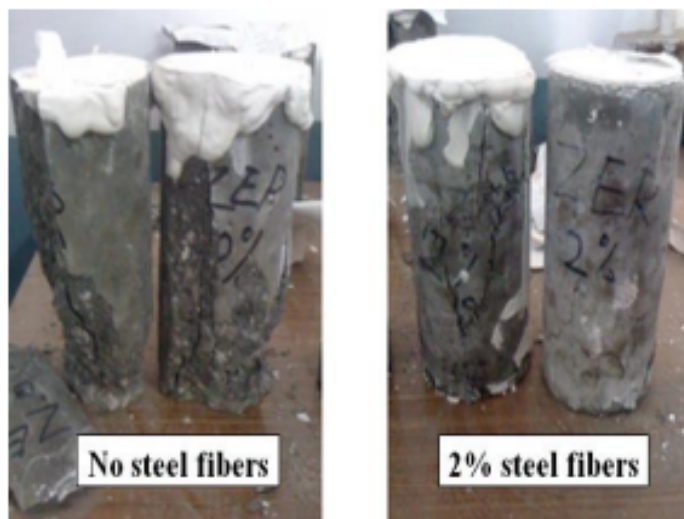


Figure 2 Modes of failure for concrete mixtures with and without fibers[Lakavath and Chandrashekhar, 2018].

For rectangular beam, 1.75% give a results as same as 2%, where is for I section , the increasing percentage in fiber beyond 1% didn't enhance the shear failure mush, but shear strength increased by 23% in 1% fibers volume.

Nzambi et al,2022 fixed a crimped flat steel fiber content of 1% by concrete volume to study the effect of fiber and longitudinal reinforcement on shear strength of beam. Eight beams casted without stirrups and divided to two groups, first without fibers and the second with fibers. The longitudinal reinforcement ratio was vary as shown in fig3.

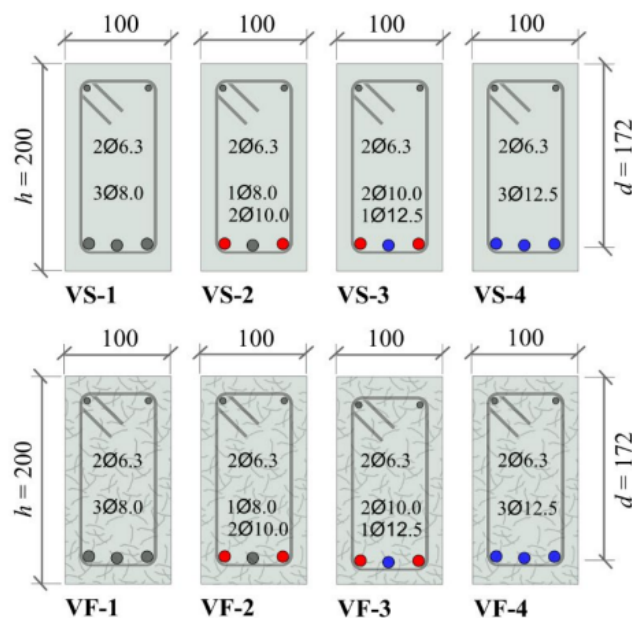


Figure 3 Longitudinal reinforcement of beams group [Nzambi et al,2022].

The results indicated that even when the beam without stirrups, the shear strength increase with the increase of longitudinal reinforcement. In term of fibers, best result was 109% increasing when the longitudinal reinforcement was 1.2% as it shown in fig4.

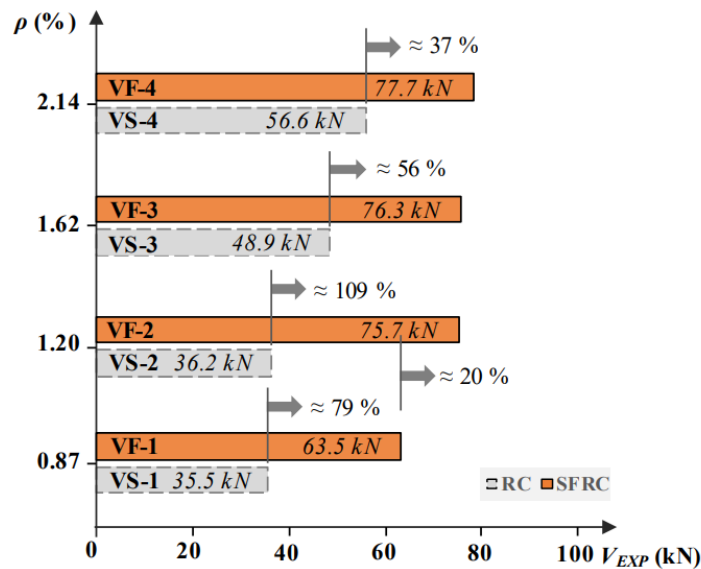


Figure 4 shear strength in beams[Nzambi et al,2022]

Shoukry,2023, fixed the longitudinal reinforcement, studied effect of the fibers type (with hook end or corrugated), fiber volumes (0.5%, 1% & 1.5%), and stirrup presence and absence by casting 12 beams. They concluded two key conclusions:

- The end hook and the corrugated produced similar results.
- It was found that 1.5% steel fibers are applied in beam without the need for stirrup and its strength was the same as stirrup with size 8mm at 150mm distance.

Kachouh, et al, 2022, analyze the behavior of deep beam with 100% recycle aggregate with and without steel fibers on top of control beam with normal aggregate. The recycle aggregate decreased shear strength by 5% and shear cracking reduced by 25%. Using 1% steel fibers completely recover deep beam original shear strength and raised.

Zakaria, et al, 2022, researches the shear strength of beam and FRB or hybrid wires bar as the main reinforcement used instead of steel bar. this will help to increase the shear strength of the beam by addition of steel fibers in three-dose; 0.4%, 0.8% and 1.2%. the hybrid wire bar contains steel and glass; best result when hybrid with 0.75 steel percentage bar used is being used and It can substitute of main reinforcement also as it gives higher shear strength. Also, by using 1.2% by volume steel fiber, increase the shear capacity and thus more ductility and therefore make it possible to replace part of stirrups.

For modeling the shear strength (V_c) of high-strength concrete (HSC) beams with steel fibers and without done by Agha and Ayad., 2022, a big experimental database was conducted and examined 26 existing equations. The data from HSC showed that, unlike most code equations, which equate shear strength with the square root of compressive strength (power 0.5), the actual data was of much lower exponent (approximately 0.1). The most existing models exhibit either overestimation or underestimate on real shear strength, and the better models present high error and do not align well with experimental results. A new model that combines multilinear and nonlinear regression (adding fiber factor, fiber content, aspect ratio, type) was developed to fit data better and be less variable. Nevertheless, the shear behaviour of HSC beams is complicated and not completely known, demonstrating that further study is necessary to identify more accurate predictive equations.

Alizadeh et al., 2023 inspects the shear behavior of steel fibers and high-strength steel rebars-reinforced composite bars in high-strength concrete elements. The testing consisted

of nine beams with the same length of concrete, with different longitudinal reinforcement ratios (1.5%, 2.0%, 3.1%) and different steel fiber contents (0%, 1%, 2%). According to the studies, high-strength concrete reinforced with steel fibers performs the shear performance better than conventional concrete. As the fiber content (up to 2%) increased, shear capacity and energy absorption is significantly better.

Yoo et al., 2024 investigate the influence of steel fiber volume and types on shear strength of high-strength concrete beam. Steel fibers added to elevate the shear strength of HSC beams, no stirrups. Higher volume fractions ($\sim 1.0\%$) had the greatest positive effect by virtue of the shear capacity being about 1.7 times that at 0% of the volume fractions. Metal-crimped steel fibers had superior shear resistance compared to hooked-end fibers. With the same fiber volume fraction, crimped fibers increased in overall shear strength and ductility 1.11–3.34 times.

Merdas & Shallal, 2024 investigate the shear strength of steel fiber concrete beams without shear reinforcement. The experimental findings provide information on various factors such as:

- compressive strength (20 and 50 MPa)
- flexural reinforcement ratios (0.77%, 1.14%, 1.54%)
- shear span to effective depth ratios (2, 3)
- aggregate types (natural and recycled/crushed brick)
- and the different steel fiber content (0%, 0.5%, 1%) that impact the mechanical response of a beam under load.

A higher compressive strength (50 MPa) raises maximum shear strength by 60%. Increasing flexure reinforcement has an approximately 53% effect upon shear strength. For an increasing shear span-to-depth ratio (from 2 to 3), the shear strength decreases by 30%. Half replacement of natural aggregate with recycled aggregate reduces shear strength 10.5% or so. On addition of steel fibers for further enhancement of performance: 0.5% steel fibers increase shear intensity by up to 18%, whereas 1% can produce an enhancement of between 30–50% depending upon other beam details

Yoo,et al, 2024 studied the shear behavior of high-strength concrete beams reinforced with high-strength steel rebars and hooked-end fibers at various ratios. Key findings include:

- Fibers had minimal effect on compressive strength, increasing it only by 7% when 2% fibers were added.
- Increasing rebar ratio (without fibers) raised load-bearing capacity, but the improvement rate decreased at higher ratios.
- Adding fibers enhanced energy absorption by at least 100%, especially at higher rebar and fiber contents—vital for earthquake resistance—while improving ductility and post-peak response.
- Fibers shifted peak deflection to higher values, with diminishing returns at higher rebar ratios.
- Increasing fiber content from 0% to 1% and 1% to 2% increased load-bearing capacity,
- most notably at lower rebar ratios.

Conclusions

Recent results indicate that incorporation of steel fibers into high-strength concrete beams is promising for increasing shear strength, ductility, and energy absorption with the improvement at fiber contents of 1–2% by volume. Crimped fibers usually perform better than hooked-end fibers. Though some stirrups can sometimes be partially or completely replaced by using only fibers, only when fibers work with conventional reinforcement is optimal performance provided. The performance can be influenced by fiber type, volume, aspect ratio, longitudinal reinforcement ratio, concrete strength, and aggregate type, that all influence the shear behavior. However, the current shear strength prediction models and code-based equations do not adequately represent the complex nature of fiber-reinforced HSC beams either by overestimating or underestimating their capacities. Next are the prediction model improvement and application of various fiber types and rebar types in terms of performance in structures.

References

1. Voo, Y., Poon, W., & Foster, S. (n.d.). *Shear strength of steel fiber-reinforced ultrahigh-performance concrete beams without stirrups*. [https://ascelibrary.org/doi/abs/10.1061/\(ASCE\)ST.1943-541X.0000234](https://ascelibrary.org/doi/abs/10.1061/(ASCE)ST.1943-541X.0000234)
2. Yoo, D. Y., & Yang, J.-M. (2018). Effects of stirrup, steel fiber, and beam size on shear behavior of high-strength concrete beams. *Cement & Concrete Composites*, 87, 137–148. <https://doi.org/10.1016/J.CEMCONCOMP.2017.12.010>
3. Junior, Armando. (2011). The Shear Strength of Steel Fiber-Reinforced Concrete Beams. *Revista IBRACON de Estruturas e Materiais*. DOI:10.1590/S1983-41952011000500006
4. Qi, J., Ma, Z. J., Wang, J., & Liu, T.-X. (2016). Post-cracking shear strength and deformability of HSS-UHPFRC beams. *Structural Concrete*, 17(6), 1033–1046. <https://doi.org/10.1002/SUCO.201500191>
5. Yoo, D. Y., & Yang, J.-M. (2018). Effects of stirrup, steel fiber, and beam size on shear behavior of high-strength concrete beams. *Cement & Concrete Composites*, 87, 137–148. <https://doi.org/10.1016/J.CEMCONCOMP.2017.12.010>
6. Ananthi, G. Beulah & Sathick, A. & Abirami, M.. (2020). Experimental investigation on shear behaviour of fibre reinforced concrete beams using steel fibres. *Journal of Construction Materials*. DOI:10.36756/JCM.v2.1.5
7. Awad, A. H., Tawfik, M., Deifalla, A., Ahmad, M., Sabri, M. M. S., & El-Said, A. A. E. (2023). Effect of hybrid-fiber- reinforcement on the shear behavior of high-strength-concrete beams. *Frontiers in Materials*, 9. <https://doi.org/10.3389/fmats.2022.1088554>
8. Li, P., Cheng, Q., Tian, Y., & Jiang, H. (2023). Experimental Study on Shear Behavior of Non-Stirrup Ultra-High Performance Concrete Beams. *Materials*, 16(11), 4177. <https://doi.org/10.3390/ma16114177>
9. Lakavath, Chandrashekhar. (2018). Shear Behavior of Steel Fiber Reinforced Pre stressed Concrete Beams. DOI:10.13140/RG.2.2.28418.90563
10. Nzambi, Aaron & Oliveira, Dênio & Monteiro, Marcus & Silva, Luiz. (2022). Experimental analysis of steel fiber reinforced concrete beams in shear. *Revista IBRACON de Estruturas e Materiais*.. DOI:10.1590/S1983-41952022000300001
11. Shoukry, Mohie & Mahmoud, Zaki & Elnaggar, Mohamed & Kamel, Mohamed. (2023). Shear Strength of Fiber Reinforced Concrete (FRC) Beams without Stirrups. *Journal of Engineering Research*. DOI:10.21608/erjeng.2023.187401.1145.

12. Kachouh, N., El-Maaddawy, T., El-Hassan, H., & El-Ariss, B. (2022). Shear Strength of Steel Fiber-Reinforced Recycled Aggregates Concrete Deep Beams. In H. El Naggar, J. Barros, & P. Cachim (Eds.), *Proceedings of the 7th World Congress on Civil, Structural, and Environmental Engineering, CSEE 2022 Article ICSECT 132* (World Congress on Civil, Structural, and Environmental Engineering). Avestia Publishing. <https://doi.org/10.11159/icsect22.132>.
13. Agha, Ayad. (2022). Prediction and developing of shear strength of reinforced high strength concrete beams with and without steel fibers using multiple mathematical models. PLOS ONE. 17. e0265677. 10.1371/journal.pone.0265677.
14. Zakaria, Mohamed & Salah, Donia & Mahmoud, Mohamed & Awadallah, Zakaria. (2022). Enhancement the Shear behavior of concrete beams reinforced with hybrid-wires bars by using steel fibers.. Journal of Advanced Engineering Trends. DOI:10.21608/jaet.2020.42204.1043
15. Alizadeh, A., Shaghaghi, T. M., Pourbaba, M., Mirrezaei, S. S., & Zandi, Y. (2023). Experimental Investigation of Shear Behavior in High-Strength Concrete Beams Reinforced with Hooked-End Steel Fibers and High-Strength Steel Rebars. *Buildings*. <https://doi.org/10.3390/buildings13082106>
16. Yoo, D.-Y., Soleimani-Dashtaki, S., Oh, T., Chun, B., Choi, J., Banthia, N., & Yoon, Y.-S. (2024). Effects of amount and geometrical properties of steel fiber on shear behavior of high-strength concrete beams without shear reinforcement. *Cement & Concrete Composites*, 151, 105606. <https://doi.org/10.1016/j.cemconcomp.2024.105606>
17. Merdas, H. S., & Shallal, M. A. (2024). Efficiency of Steel Fibers in Improving the Performance of Concrete Beams without Shear Reinforcement. *Salud, Ciencia y Tecnología - Serie de Conferencias*, 3, 830. <https://doi.org/10.56294/sctconf2024830>
18. Yoo, Doo-Yeol & Soleimani-Dashtaki, Salman & Taekgeun, Oh & Chun, Booki & Choi, Jin-Seok & Banthia, Nemkumar & Yoon, Young-Soo. (2024). Effects of amount and geometrical properties of steel fiber on shear behavior of high-strength concrete beams without shear reinforcement. *Cement and Concrete Composites*. DOI:10.1016/j.cemconcomp.2024.105606.