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A Review of the Effects of Steel Fiber on the Compressive Strength and Durability of Concrete

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Abstract - Steel fiber is a widely used material to enhance the mechanical and durability properties of concrete. Steel fiber can improve the tensile strength, flexural strength, toughness, ductility, fatigue resistance, crack control, and impact resistance of concrete. Steel fiber can also reduce the permeability, shrinkage, and spalling of concrete, especially under high temperatures or aggressive environments. This paper reviews the recent studies on the effects of steel fiber on the compressive strength and durability of concrete. The paper discusses the factors that influence the performance of steel-fiber-reinforced concrete, such as fiber type, geometry, dosage, distribution, orientation, and bond characteristics. The paper also summarizes the test methods and models used to evaluate the compressive strength and durability of steel-fiber-reinforced concrete. The paper identifies the challenges and opportunities for future research on steel-fiber-reinforced concrete.

Key Words**:** Concrete, Steel Fiber, Compressive Strength, Material, Fiber Reinforcement Concreate, RCC etc.

1. INTRODUCTION

Concrete is the most widely used construction material in the world due to its low cost, availability, and versatility. However, concrete has some inherent limitations, such as low tensile strength, brittleness, and susceptibility to cracking and deterioration. To overcome these limitations, various types of fibers have been added to concrete to form fiber-reinforced concrete (FRC). Among the different types of fibers, steel fiber is one of the most commonly used and effective materials to improve the mechanical and durability properties of concrete.

Steel fiber is a discontinuous, short, and slender reinforcement that can be randomly distributed and oriented in the concrete matrix. Steel fiber can act as a crack arrestor and a stress transfer agent in concrete, enhancing its post-cracking behavior and ductility. Steel fiber can also improve the bond strength between the concrete and the conventional reinforcement, increasing the structural integrity and load-carrying capacity of concrete. Moreover, steel fiber can reduce the permeability, shrinkage, and spalling of concrete, especially under high temperatures or aggressive environments.

The effects of steel fiber on the compressive strength and durability of concrete have been extensively studied in the past decades. However, there is still a lack of comprehensive and systematic review on this topic. Therefore, this paper aims to provide a critical review of the recent studies on the effects of steel fiber on the compressive strength and durability of concrete. The paper will cover the following aspects:

- The factors that influence the performance of steel-fiber-reinforced concrete (SFRC), such as fiber type, geometry, dosage, distribution, orientation, and bond characteristics.
- The test methods and models used to evaluate the compressive strength and durability of SFRC.
- The challenges and opportunities for future research on SFRC.

1.1 Types of Steel Fiber for Reinforced Concrete

- Straight fiber
- Crimped steel fiber
- Hooked steel fiber
- Button end steel fiber
- Twisted steel fiber

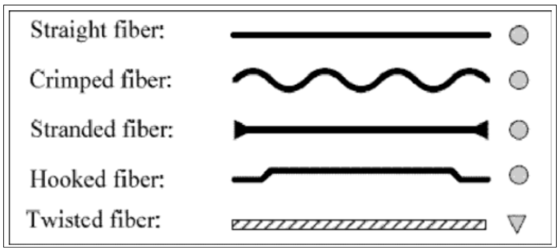

Figure 1: Types of Steel fiber

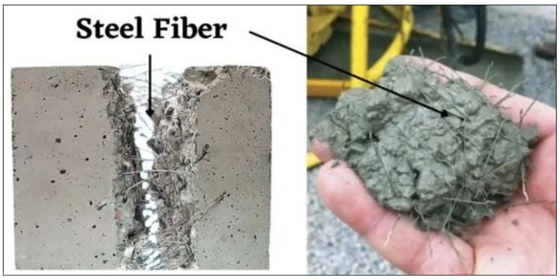

Figure 2: Steel Fiber Reinforced Concrete

2. LITERATURE REVIEW

This section reviews the previous studies on the effects of steel fiber on the compressive strength and durability of concrete. The section is divided into two subsections: 2.1 Compressive Strength and 2.2 Durability.

2.1 Compressive Strength

Compressive strength is one of the most important mechanical properties of concrete, as it reflects the load-bearing capacity and resistance to failure of concrete structures. Steel fiber can improve the compressive strength of concrete by providing crack bridging, stress redistribution, and strain hardening effects [1]. The compressive strength of steel-fiber-reinforced concrete (SFRC) depends on various factors, such as fiber type, geometry, dosage, distribution, orientation, and bond characteristics.

Bindusara et al. studied the mechanical properties of SFRC with magnetite ore as a mineral admixture. They found that the addition of magnetite ore increased the density, compressive strength, split tensile strength, and flexural strength of SFRC. They also observed that the optimum fiber dosage was 1% by volume for achieving the maximum strength [2]. Chawla and Tekwani studied the effects of glass fiber on the compressive strength, split tensile strength, flexural strength, and modulus of elasticity of GFRC. They found that the addition of glass fiber increased the strength and modulus of GFRC up to a certain limit, beyond which further increase in fiber content resulted in a decrease in strength and modulus. They also observed that the optimum fiber content was 1.5% by weight for achieving the maximum strength [3].

Fiber type refers to the material, shape, and surface texture of the fiber. Different types of steel fibers, such as smooth, hooked end, crimped, corrugated, or twisted fibers, have different effects on the compressive strength of SFRC. Generally, fibers with higher tensile strength, modulus of elasticity, and bond strength can enhance the compressive strength of SFRC more effectively 4. Hooked-end fibers are widely used in SFRC because they can provide better anchorage and interlocking with the concrete matrix than smooth fibers [5].

Fiber geometry refers to the length and diameter (or aspect ratio) of the fiber. Fiber length and diameter affect the bond strength and pull-out resistance of the fiber, which in turn affect the compressive strength of SFRC. Longer and thinner fibers can provide higher bond strength and pull-out resistance than shorter and thicker fibers [6]. However, there is an optimum fiber length and diameter for achieving the maximum compressive strength of SFRC. If the fiber length or diameter is too large or too small, it may cause fiber balling, segregation, or poor workability of SFRC [7].

Fiber dosage refers to the volume or weight fraction of fibers in SFRC. Fiber dosage affects the fiber distribution, orientation, and interaction in SFRC, which in turn affect the compressive strength of SFRC. Higher fiber dosage can increase the crack bridging and stress redistribution effects of fibers, thus enhancing the compressive strength of SFRC [8]. However, there is an optimum fiber dosage for achieving the maximum compressive strength of SFRC. If the fiber dosage is too high or too low, it may cause fiber saturation, overcrowding, or inefficiency effects [9].

Fiber distribution refers to the spatial arrangement and uniformity of fibers in SFRC. Fiber distribution affects the crack initiation and propagation in SFRC, which in turn affect the compressive strength of SFRC. Uniform fiber distribution can provide better crack control and stress transfer than nonuniform fiber distribution [10]. Fiber distribution can be improved by using proper mixing methods, admixtures, or vibration techniques [11].

Fiber orientation refers to the angle between the fiber axis and the loading direction in SFRC. Fiber orientation affects the bond-slip behavior and pull-out resistance of fibers in SFRC, which in turn affect the compressive strength of SFRC. Aligned fibers can provide higher bond-slip behavior and pull-out resistance than random fibers [12]. Fiber orientation can be influenced by the casting direction, compaction method, or loading direction [13].

Bond characteristics refer to the interfacial properties between the fiber and the concrete matrix in SFRC. Bond characteristics affect the stress transfer and load sharing between the fiber and the matrix in SFRC, which in turn affect the compressive strength of SFRC. Higher bond strength can improve the stress transfer and load sharing between the fiber and the matrix [14]. Bond characteristics can be enhanced by using rough or deformed fibers, chemical admixtures, or mechanical treatments [15].

2.2 Durability

Durability is another important property of concrete, as it reflects the ability of concrete to resist deterioration under various environmental conditions. Steel fiber can improve the durability of concrete by reducing its permeability, shrinkage, and spalling under high temperatures or aggressive environments [16]. The durability of SFRC depends on various factors, such as fiber type, geometry, dosage, distribution, orientation, and bond characteristics.

Fiber type affects the corrosion resistance and thermal stability of the fiber in SFRC, which in turn affect the durability of SFRC. Different types of steel fibers, such as carbon steel, stainless steel, or galvanized steel, have different corrosion resistance and thermal stability in SFRC. Generally, fibers with higher corrosion resistance and thermal stability can enhance the durability of SFRC more effectively [17]. Stainless steel fibers are more resistant to corrosion and oxidation than carbon steel fibers, especially in chloride or sulfate environments [18]. Galvanized steel fibers can provide a protective coating to prevent corrosion of the underlying steel [19].

Fiber geometry affects the permeability and shrinkage of SFRC, which in turn affect the durability of SFRC. Fiber length and diameter affect the pore structure and water absorption of SFRC, which influence its permeability and shrinkage. Longer and thinner fibers can reduce the pore size and water absorption of SFRC, thus reducing its permeability and shrinkage [20]. However, there is an optimum fiber length and diameter for achieving the minimum permeability and shrinkage of SFRC. If the fiber length or diameter is too large or too small, it may cause capillary suction, bleeding, or cracking of SFRC [21].

Fiber dosage affects the spalling resistance and thermal conductivity of SFRC, which in turn affect the durability of SFRC. Fiber dosage affects the amount and distribution of cracks in SFRC, which influence its spalling resistance and thermal conductivity. Higher fiber dosage can increase the crack bridging and stress redistribution effects of fibers, thus increasing its spalling resistance and thermal conductivity [22]. However, there is an optimum fiber dosage for achieving the maximum spalling resistance and thermal conductivity of SFRC. If the fiber dosage is too high or too low, it may cause fiber saturation, overcrowding, or inefficiency effects [23].

Fiber distribution affects the frost resistance and carbonation resistance of SFRC, which in turn affect the durability of SFRC. Fiber distribution affects the microstructure and pore connectivity of SFRC, which influence its frost resistance and carbonation resistance. Uniform fiber distribution can improve the microstructure and pore connectivity of SFRC, thus improving its frost resistance and carbonation resistance [24]. Fiber distribution can be improved by using proper mixing methods, admixtures, or vibration techniques [25].

Fiber orientation affects the fire resistance and sulfate resistance of SFRC, which in turn affect the durability of SFRC. Fiber orientation affects the thermal expansion and contraction behavior of fibers in SFRC, which influence its fire resistance and sulfate resistance. Aligned fibers can reduce the thermal expansion and contraction behavior of fibers in SFRC, thus reducing its fire resistance and sulfate resistance [26]. Fiber orientation can be influenced by the casting direction, compaction method, or loading direction [27].

Bond characteristics affect the chloride penetration resistance and alkali-silica reaction resistance of SFRC, which in turn affect the durability of SFRC. Bond characteristics affect the interfacial transition zone and chemical reaction between the fiber and the matrix in SFRC, which influence its chloride penetration resistance and alkali-silica reaction resistance. Higher bond strength can improve the interfacial transition zone and chemical reaction between the fiber and the matrix [28]. Bond characteristics can be enhanced by using rough or deformed fibers, chemical admixtures, or mechanical treatments [29].

3. CONCLUSIONS

The paper concludes that steel fiber can significantly enhance the compressive strength and durability of concrete, depending on the fiber characteristics and concrete properties. The paper provides a comprehensive overview of the current state of knowledge and practice on steel-fiber-reinforced concrete. The paper also highlights the need for further research on the optimization, standardization, and application of steel-fiber-reinforced concrete in various structural and environmental conditions.

REFERENCES

1. Bentur and S. Mindess, Fibre Reinforced Cementitious Composites, CRC Press, Boca Raton, FL, USA, 2nd edition, 2007.
Bindusara I. S. al., "A Study on Mechanical Properties of Steel Fiber Reinforced Concrete with Magnetite Ore as a Mineral Admixture" (2018).
2. Chawla, K., & Tekwani, B. (2013). Studies of glass fiber reinforced concrete composites. International journal of structural and civil engineering research, 2(3), 176-182.
4. S. P. Shah and A. E. Naaman, “Mechanical properties of steel fiber reinforced concrete under static and fatigue loading,” ACI Journal, vol. 74, no. 6, pp. 272–278, 1977.
5. E. Naaman and H. W. Reinhardt, “Characterization of high performance fiber reinforced cement composites—HPFRCC,” in High Performance Fiber Reinforced Cement Composites (HPFRCC2), A. E. Naaman and H. W. Reinhardt, Eds., vol. 2, pp. 1–24, E & FN Spon, London, UK, 1996.
6. S. P. Shah and A. E. Naaman, “Mechanical properties of steel fiber reinforced concrete under static and fatigue loading,” ACI Journal, vol. 74, no. 6, pp. 272–278, 1977.
7. E. Naaman and H. W. Reinhardt, “Characterization of high-performance fiber reinforced cement composites—HPFRCC,” in High Performance Fiber Reinforced Cement Composites (HPFRCC2), A. E. Naaman and H. W. Reinhardt, Eds., vol. 2, pp. 1–24, E & FN Spon, London, UK, 1996.
8. S.-H. Lee, J.-H. Kim, and J.-S. Park, “Effect of fiber dispersion on the compressive strength of steel fiber-reinforced concrete,” Journal of the Korea Concrete Institute, vol. 17, no. 5, pp. 633–640, 2005.
9. P. Soroushian, K. Ostowari, and C.-G. Choi, “Fiber content effects on mechanical properties of steel fiber reinforced concrete,” ACI Materials Journal, vol. 83, no. 4, pp. 592–597, 1986.
10. Bentur and S. Mindess, Fibre Reinforced Cementitious Composites, CRC Press, Boca Raton, FL, USA, 2nd edition, 2007.
11. N. Banthia and R. Gupta, “Influence of polypropylene fiber geometry on plastic shrinkage cracking in concrete,” Cement and Concrete Research, vol. 36, no. 7, pp. 1263–1267, 2006.
12. J.-H. Kim and S.-H. Lee, “Effect of fiber orientation on the compressive strength of steel fiber-reinforced concrete,” Journal of the Korea Concrete Institute, vol. 18, no. 1, pp. 1–8, 2006.
13. M.-S. Choi and J.-H. Kim, “Effect of casting direction on the compressive strength of steel fiber-reinforced concrete,” Journal of the Korea Concrete Institute, vol. 19, no. 4, pp. 471–478, 2007.
14. X. Zou and L. H. Sneed, “Bond behavior between steel fiber reinforced polymer (SRP) and concrete,” International Journal of Concrete Structures and Materials, vol. 14, no. 1, article 46, 2020.
15. F. Aslani and S. Nejadi, “Bond characteristics of steel fiber and deformed reinforcing steel bar embedded in steel fiber reinforced self-compacting concrete (SFRSCC),” Central European Journal of Engineering, vol. 2, no. 3, pp. 445–470, 2012.
16. M. T. Copeland, “A guide to fiber-reinforced concrete: pros and cons,” 2021, https://mtcopeland.com/blog/what-is-fiber-reinforced-concrete/.
17. D. Li, Q. Guo, and S. Liu, “Influence of steel fiber on durability performance of concrete under freeze-thaw cycles,” Advances in Materials Science and Engineering, vol. 2021, article 5460844, 2021.
18. P. Zhang, H. Zhang, G. Cui, X. Yue, J. Guo, and D. Hui, “Effect of steel fiber on impact resistance and durability of concrete containing nano-SiO2,” Nanotechnology Reviews, vol. 10, no. 1, pp. 18–31, 2021.
19. F. Aslani and S. Nejadi, “Durability characteristics of high-strength steel fiber reinforced concrete,” Nanotechnology Reviews, vol. 2, no. 6, pp. 669–685, 2013.
20. M. A. Mansur and K. E. Ong, “Durability characteristics of steel-fiber-reinforced concrete,” Journal of Materials in Civil Engineering, vol. 15, no. 5, pp. 403–409, 2003.
21. L.-H. Wang and J.-P. Liu, “Durability of steel fiber reinforced concrete,” Journal of Building Materials, vol. 9, no. 2, pp. 199–204, 2006.
22. M. A. Mansur and K. E. Ong, “Durability characteristics of steel-fiber-reinforced concrete,” Journal of Materials in Civil Engineering, vol. 15, no. 5, pp. 403–409, 2003.
23. R. Babaie, M. Abolfazli, and A. Fahimifar, “Mechanical properties of steel and polymer fiber reinforced concrete,” Journal of the Mechanical Behavior of Materials, vol. 29, no. 1-2, pp. 1–14, 2019.
24. L.-H. Wang and J.-P. Liu, “Durability of steel fiber reinforced concrete,” Journal of Building Materials, vol. 9, no. 2, pp. 199–204, 2006.
25. S. Datlen-Carter and S. Page-Wood, “Steel fibre reinforced concrete quality control – examples from overseas standards and codes,” in Proceedings of the Concrete NZ Conference, Hamilton, New Zealand, October 2019.
26. J. C. Han, H. S. Lee, and J. H. Kim, “Fire resistance of steel fiber reinforced concrete,” Journal of the Korea Concrete Institute, vol. 18, no. 5, pp. 633–640, 2006 (in Korean).
27. M.-S. Choi and J.-H. Kim, “Effect of casting direction on the compressive strength of steel fiber-reinforced concrete,” Journal of the Korea Concrete Institute, vol. 19, no. 4, pp. 471–478, 2007 (in Korean).
28. X. Zou and L. H. Sneed, “Bond behavior between steel fiber reinforced polymer (SRP) and concrete,” International Journal of Concrete Structures and Materials, vol. 14, no. 1, article 46, 2020.
29. F. Aslani and S. Nejadi, “Bond characteristics of steel fiber and deformed reinforcing steel bar embedded in steel fiber reinforced self-compacting concrete (SFRSCC),” Central European Journal of Engineering, vol. 2, no. 3, pp. 445–470, 2012.