International Journal of
Science, Architecture, Technology and Environment

Strength Evaluation of Fiber-Reinforced Self-Compacting Concrete

Umesh K. Karhale[1*], L. S. Mahajan[2]

[1]*M.Tech Student, Department of Structural Engineering, Shreeyash College of Engineering & Technology, Chh. Sambhajinagar*

[2] *Assistant Professor, Shreeyash College of Engineering & Technology, Chh. Sambhajinagar*

[*]*Corresponding author, umeshkarhale2016@gmail.com*

DOI: https://doi.org/10.63680/ijsate1025012.10

Abstract

When compared to traditional concrete, self-compacting concrete (SCC) is known for its better workability, durability, and mechanical performance. It also has the advantage of not requiring vibration. Its tensile strength, ductility, and fracture resistance are further improved by the addition of discontinuous fibers. The impact of carbon, glass, and basalt fibers at different volume fractions (0.0–0.3%) on the mechanical, fresh, and durability characteristics of M30 grade SCC is examined in this work. According to the results, the inclusion of fiber had a substantial impact on workability. Glass fiber blends maintained better flow, whereas carbon fiber mixes exhibited the most drop because of their higher water absorption. The ideal dosages—0.15% carbon, 0.20% glass, and 0.25% basalt—provided significant increases in compressive and flexural strength in the hardened state. Glass guaranteed economy and early-age workability, carbon produced the greatest strength improvements, and basalt fiber provided the best balanced performance overall.

Keywords: Fiber Reinforcement; Glass Fiber; Carbon Fiber; Basalt Fiber; compressive strength

1. Introduction

Every year, Modern infrastructure is expanding quickly, necessitating the use of building materials that offer exceptional sustainability, performance, and longevity. Despite its widespread usage, conventional concrete frequently has drawbacks such poor flowability in severely reinforced areas, poor compaction, and a shorter service life. Self-compacting concrete (SCC), a novel material that can fill complex formworks without vibrating and flow under its own weight, was initially developed in Europe and Japan to address these issues. SCC has become a desirable choice for high-performance and intricate structural applications due to its distinct rheological characteristics as well as improved mechanical and durability performance. Like regular concrete, SCC has limited tensile and flexural strength and is nonetheless fragile despite its benefits. The use of fibers has grown in popularity as a solution to this problem. Fiber-reinforced SCC (FRSCC) increases toughness, ductility, fracture resistance, and energy absorption capacity in addition to improving post-cracking behavior. Because of their strength, longevity, and affordability, glass, basalt, and carbon have

become the most promising materials among the many fibers. The impact of fiber type, content, and dispersion on both fresh and hardened qualities has been emphasized in research on FRSCC. Fibers can decrease flowability because of interlocking and water absorption, but when utilized in the right amounts, they greatly increase compressive, tensile, and flexural strengths. Additionally, microstructural studies show that the fibers and cementitious matrix have a stronger connection, which improves durability and fracture resistance. The purpose of this study is to examine how carbon fibers, glass, and basalt affect the mechanical and durability performance of M30-grade SCC. This work determines the ideal fiber type and dosage for striking a balance between workability, strength, and cost-effectiveness by assessing new properties, strength development, sorptivity, and microstructural behavior. This helps to create sustainable high-performance concrete.

2. Literature Review

Improvements in high-range water-reducing admixtures, often referred to as superplasticizers, have been intimately associated with the development of self-compacting concrete (SCC). These admixtures allow SCC to achieve good flowability and resilience to segregation by improving workability without raising the water-to-cement ratio. According to a number of studies [Okamura, 1986; EFNARC, 2005], slump flow, viscosity, and stability are all greatly impacted by the kind and amount of superplasticizer. Adding mineral admixtures such fly ash, silica fume, and ground granulated blast furnace slag (GGBS) increases long-term durability, decreases bleeding, and improves cohesion [1]. Since Okamura and Ozawa (1986) first introduced SCC in Japan, it has been the subject of much research due to its capacity to flow under its own weight and accomplish full compaction without vibration. Early studies concentrated on resolving issues with crowded reinforcement and lower-quality craftsmanship. Guidelines for mix design and testing methods were later supplied by the European Federation of National Associations Representing for Concrete (EFNARC). Research continuously shows that SCC outperforms ordinary concrete in terms of surface quality, pumpability, and durability. Its relatively low tensile strength and brittleness, however, continue to be drawbacks that call for more development [2].

A lot of research has been done on adding fibers to SCC to increase its tensile strength, ductility, and post-cracking behavior. Although they don't contribute as much to long-term strength improvements, glass fibers have been demonstrated to improve early-age strength and preserve high workability because of their minimal water absorption. Compared to carbon fibers, basalt fibers are more affordable and offer balanced improvements in both fresh and hardened characteristics. At smaller doses, carbon fibers greatly increase compressive, tensile, and flexural strength because to their better crack-bridging and fracture energy, despite their high cost. Numerous studies have shown that the kind, dose, and dispersion of fibers determine their efficiency; the ideal amount usually falls between 0.15 and 0.30 percent by volume [3].

Overall, the research shows that fiber-reinforced SCC is a potential material for long-lasting and sustainable structural applications because it combines the toughness of fiber-reinforced composites with the flowability benefits of SCC. To determine the best effective fiber type and dose for various performance requirements, more comparative study is needed. Without the requirement for mechanical vibration, Self-Compacting Concrete (SCC), a highly flowable, non-segregating concrete, can fill formwork, spread under its own weight, and completely encapsulate reinforcement [4].

This innovative technology has transformed concrete construction by ensuring complete compaction in complex formworks, reducing labor requirements, minimizing noise pollution, and improving the overall working environment. Achieving self-compatibility in SCC relies on a carefully designed mix, characterized by high powder content, a low water-to-binder ratio, and the use of modern high-range water-reducing

admixtures (HRWR) or superplasticizers (SP) [5-6]. The addition of fibers to SCC, while enhancing mechanical properties, directly influences its rheological behavior. Fibers increase the internal surface area and can interlock within the mix, resulting in higher internal friction and reduced flowability. The magnitude of this effect depends on the type, geometry, and dosage of fibers used. Glass fibers are known for their high tensile strength and, in the case of alkali-resistant (AR) glass fibers, good chemical durability. However, uncoated or ordinary glass fibers may degrade in the high-pH environment of cementitious matrices, potentially compromising long-term strength and durability if proper precautions are not taken.

Basalt Fibers (BF): Produced by extruding molten basalt rock, basalt fibers offer high tensile strength, a large elastic modulus, excellent chemical resistance, and superior thermal stability compared to E-glass fibers. Additionally, they are considered a more environmentally sustainable alternative to carbon fibers due to their natural origin and lower embodied energy. Carbon fibers exhibit the highest specific strength and modulus of elasticity among commonly used fibers, resulting in substantial improvements in flexural strength, stiffness, and fracture resistance. They are also chemically inert and electrically conductive, making them suitable for specialized applications. The primary limitation of carbon fibers is their high cost, which restricts widespread use to high-performance or critical structures [6]. The fresh properties of SCC are defined by three essential characteristics: flowability (ability to fill formwork under its own weight), passing ability (capacity to flow through congested reinforcement without blockage), and segregation resistance (stability against separation of constituents). These properties are commonly evaluated using the slump flow, V-funnel, and L-box tests, respectively, as outlined in EFNARC (2005) guidelines. The influence of fibers on compressive strength is generally less pronounced and can vary depending on type, geometry, and dosage. While fibers can provide confinement and delay lateral expansion under compression, excessive fiber content may introduce voids or weak zones, potentially offsetting the benefits. Consequently, most studies report only marginal improvements or slight reductions in compressive strength with fiber addition [7].

3. Objective and Experiment

This study's main goal is to create an M30-grade self-compacting concrete (SCC) mix and assess the results of adding carbon fibers, basalt, and 12 mm chopped glass at different volume fractions (0.0%–0.3%). The study focuses on fiber-reinforced SCC's (FRSCC) fresh and hardened qualities. Flowability, passing ability, and segregation resistance are examples of new features that are evaluated utilizing common SCC tests as slump flow, V-funnel, and L-box. Compressive, tensile, and flexural strengths are examples of hardened characteristics. Microstructural analysis is also used to evaluate fiber–matrix bonding and hydration products. The goal of the study is to identify the best fiber type and dose to improve mechanical performance while preserving SCC's sufficient workability and durability.

The purpose of the experimental program was to assess the mechanical and fracture characteristics of M30-grade SCC reinforced with carbon (CFC), basalt (BFC), and 12 mm chopped glass (GFC) fibers. At volume fractions of 0.0% (control), 0.1%, 0.15%, 0.2%, 0.25%, and 0.3%, fibers were added. To guarantee the best fresh qualities, the SCC mix was made using silica fume and a superplasticizer in accordance with EFNARC (2005) requirements. To verify compliance with SCC criteria, each mix was tested for viscosity (V-funnel), passing ability (L-box), and flowability (slump flow, T50). Prisms (100 × 100 × 500 mm), cylinders (150 × 300 mm), and cubes (150 mm) were among the specimens cast for the examination of hardened properties. Compressive strength and split tensile strength were tested at 7 and 28 days. Mechanical Properties of fibers are given in Table1.

Table 1: Mechanical Properties of fibers

Fiber	Length (mm)	Density (g/cm^3)	Elastic modulus(GPa)	Tensile strength(MPa)
Basalt.	12 mm	2.65	93-110	4100-4800
Glass.	12 mm	2.53	43-50	1950-2050
Carbon.	12 mm	1.80	243-250	4600-4800

Table 2: Mix Proportion of SCC

Cement (kg/m^3)	Silica fume(kg/m^3)	Water(kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	SP (kg/m^3)
450.33	45.03	189.13	963.36	642.24	5.553
1	0.10	0.42	2.14	1.42	0.012

4. Result

The fresh and hardened properties of the SCC were significantly impacted by the fiber addition. Carbon fiber (CFC) exhibited the greatest decrease (63.88% at 0.3%) in fresh properties, particularly slump flow, as the fiber concentration rose because of its rapid water absorption. Therefore, mixtures higher than 0.2% are not suitable for SCC. Glass fiber (GFC) was the material that affected workability the least. Fresh properties are given in Figure 1.

The optimal fiber dosage was determined for each kind in order to optimize toughened properties and mechanical performance (Figure 2 and Figure 3). Basalt fiber (BFC) at 0.25% volume percent was used to provide the highest 28-day compressive strength (61.4 MPa, a 50.16% improvement over plain SCC) and flexural strength (61.74%). The compressive strength increase that was greatest (47.6%).

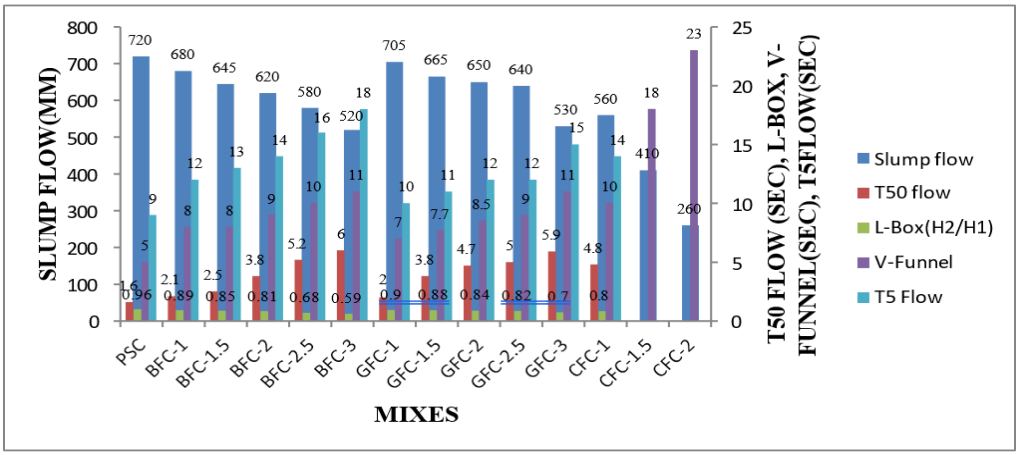


Figure 1: Results of Fresh Properties

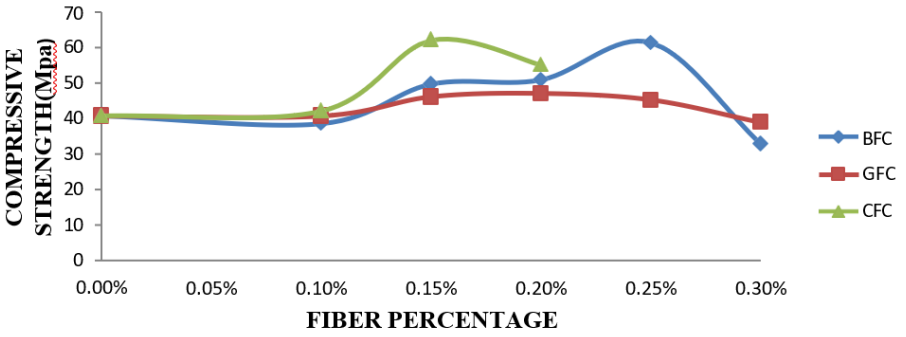


Figure 2: Results of Compressive strength

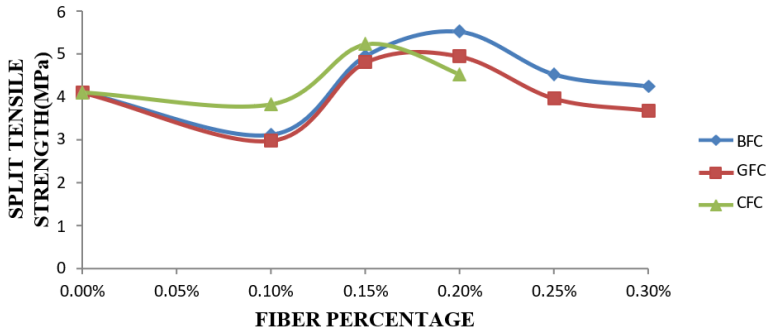


Figure 3: Results of Split tensile strength

5. Conclusion

Glass fiber (GFC) at 0.2% showed more moderate improvements, increasing flexural strength by 36.77% and compressive strength by 15.21%. This work clearly demonstrates that basalt, glass, and carbon fibers significantly enhance the mechanical and fracture properties of SCC when treated at the suggested dosages (0.25% for basalt, 0.2% for glass, and 0.15% for carbon). Despite producing the largest strength improvements, carbon fiber's high cost and detrimental workability consequences are limiting factors. Because of its remarkable strength, low cost, and enhanced ductility, basalt fiber offered an excellent balance. Because of its sorptivity and good fresh qualities, it is the most cost-effective and practical option for producing high-performance Fiber-Reinforced Self Compacting Concrete (FRSCC) for structural applications.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

Funding

The author received no financial support for the research, authorship and publication of this article.

References

[1] Banthia, N., & Gupta, R. (2006). Influence of polypropylene fiber geometry on plastic shrinkage cracking in concrete. Cement and Concrete Research, 36(7), 1263-1267.
[2] Al-Rousan, E. T., & Al-Omari, M. (2023). Fresh, mechanical, and durability properties of basalt fiber-reinforced self-compacting concrete. Construction and Building Materials, 365, 129-137.
[3] Okamura, H., & Ouchi, M. (2003). Self-compacting concrete. Journal of Advanced Concrete Technology, 1(1), 5-15.
[4] Grünewald, S. (2004). Performance-based design of self-compacting fibre reinforced concrete. PhD Thesis, Delft University Press.
[5] Dhand, V., Mittal, G., Rhee, K. Y., Park, S. J., & Hui, D. (2015). A short review on basalt fiber reinforced polymer composites. Composites Part B: Engineering, 73, 166-180.
[6] EFNARC. (2005). The European Guidelines for Self-Compacting Concrete.
[7] Chung, D. D. L. (2012). Carbon composites: composites with carbon fibers, nanofibers, and nanotubes. Butterworth-Heinemann.
[8] Tahwia, A. M., & Al-Hashmi, E. A. (2023). Chopped basalt fiber-reinforced high-performance concrete: Workability, compressive strength, and impact resistance. Materials, 7(6), 250.
[9] Onyelowe, K. C., & Okafor, F. O. (2025). Mechanical properties of self-compacting concrete: A review. Scientific Reports, 15(1), 96899.
[10] Yazici, Ş., İnan, G., & Tabak, V. (2007). Effect of aspect ratio and volume fraction of steel fiber on the mechanical properties of SFRC. Construction and Building Materials, 21(6), 1250-1253.