Experimental Investigation on Self-Compacting Concrete Reinforced with Fibers

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Abstract

Maintenance and life enhancement of buildings are crucial for infrastructure development. Concrete, composed of cement, aggregate, and water, is a composite material. However, plain concrete has limitations such as low elasticity, limited ductility, and susceptibility to cracking. Steel reinforcement is used to overcome these deficiencies and improve tensile strength. Micro cracks at the mortar-aggregate interface weaken plain concrete, leading to brittle fracture. The introduction of Self Compacting Concrete (SCC) has revolutionized the construction industry, offering improved properties. This study investigates the properties of fresh SCC and incorporates different fibers (glass, carbon, and basalt) at varying volume fractions. Remarkable improvements are observed in all properties of self-compacting concrete by adding fibers, with carbon FRSCC exhibiting the best performance in the hardened state. Basalt FRSCC follows, while glass FRSCC performs best in the fresh state. Basalt fiber is found to offer the best balance in terms of performance, dosage, and cost, enhancing the overall quality of self-compacting concrete.

Keywords: Fibrereinforcedconcrete,Self-compactingconcrete,Choppedglassfiber,Carbonfiber,Basaltfiber

1. Introduction

Self-compacting concrete (SCC) is a highly fluid and cohesive concrete mix that can flow and compact under its own weight without the need for external vibration. It is designed to improve workability, eliminate segregation, and ensure complete filling of formwork, even in congested reinforcement areas. SCC has gained significant attention in the construction industry due to its ability to enhance construction efficiency, improve durability, and provide aesthetic benefits. One of the areas of interest in SCC research is the incorporation of fibers, such as glass, carbon, and basalt, to further enhance its mechanical properties and performance [1].

Fiber-reinforced self-compacting concrete (FRSCC) combines the benefits of both SCC and fiber reinforcement, resulting in a material that exhibits improved tensile strength, flexural behavior, impact resistance, and crack control compared to traditional concrete. The use of fibers in SCC can effectively bridge micro cracks, distribute stresses, and improve the overall performance and durability of the concrete [2-5].

Glass fibers, known for their high tensile strength, corrosion resistance, and low cost, have been extensively used as reinforcement in various cementitious composites. They can enhance the flexural strength, impact resistance, and post-cracking behavior of concrete. Carbon fibers, on the other hand, possess high tensile strength, excellent fatigue resistance, and superior electrical conductivity. These properties make carbon fiber reinforcement suitable for applications requiring high-performance and durable concrete structures. Basalt fibers, derived from natural volcanic rock, offer good mechanical properties, high thermal stability, and excellent resistance to alkali environments. They have gained attention as a sustainable and environmentally friendly alternative to other synthetic fibers [6-10].

The article by Ozawa and Okamura investigates the use of fiber reinforcement in high-strength self-compacting concrete (SCC). The study examines the mechanical behavior, workability, and durability of fiber reinforced SCC. The research concludes that the incorporation of fibers improves the strength, crack resistance, and overall performance of SCC. Proper dosage and distribution of fibers are crucial for achieving the desired mechanical properties in SCC. The findings highlight the potential of fiber reinforcement in enhancing the performance and durability of high-strength self-compacting concrete.

The experimental investigation on self-compacting concrete reinforced with glass, carbon, and basalt fibers aims to study the mechanical properties, workability, and durability aspects of FRSCC. The research seeks to evaluate the effects of different fiber types and volume fractions on the fresh and hardened properties of the concrete. The findings from this investigation will contribute to a better understanding of the behavior and performance of FRSCC, providing valuable insights for its practical applications in construction.

The mechanical properties of FRSCC, including compressive strengthwill be assessed to determine the influence of fiber reinforcement. The workability of the concrete will be evaluated through slump flow tests, V-funnel tests, and L-box tests to assess its ability to flow and fill the formwork without segregation or blockage. The experimental investigation will involve the preparation of SCC mixes with varying fiber types (glass, carbon, and basalt) and different volume fractions. The fiber-reinforced self-compacting concrete mixes will be cast and tested in accordance with relevant international standards to ensure accurate and reliable results. The test specimens will undergo a comprehensive range of tests to evaluate their mechanical properties, workability, and durability.

The outcomes of this experimental investigation will contribute to the growing body of knowledge on FRSCC and its potential applications in the construction industry. The findings will provide insights into the optimal use of glass, carbon, and basalt fibers in SCC, enabling engineers and designers to make informed decisions regarding fiber selection and dosage in different structural applications. Ultimately, the aim is to develop more sustainable, durable, and high-performance concrete materials that meet the evolving needs of modern construction practices.

2. Materials and Methods

For the materials used in the study, Zuari Portland Pozzolana cement from the local market was utilized, meeting the physical properties specified in IS: 455-1989. Coarse aggregates of sizes 10 mm and 20 mm were obtained from a quarry near Chittoor, Andhra Pradesh, India. River sand collected from Chittoor, conforming to IS-383-1970 Zone-III, served as the fine aggregate. Silica fume, specifically Elkem Micro Silica 920D, was used as a pozzolanic material known for reducing porosity, permeability, and bleeding due to its fineness and pozzolanic reaction. An admixture from Sika, acting as a viscosity modifier and superplasticizer, was employed. Potable water meeting the requirements of IS: 3025-1986 part 22 and 23 and IS 456-2000 was used in the study. Glass fibers with a length of 12 mm and a modulus of elasticity of 72GPA, basalt fibers of 12 mm length, and carbon fibers of 12 mm length were employed in the experimental investigation.

This study focuses on investigating the mechanical behavior of M30 grade fiber-reinforced self-compacting concrete (FRSCC) using basalt fiber, glass fiber, and carbon fiber. Test specimens, including cubes, cylinders, and prisms, were prepared for each mix. The mechanical behavior of plain self-compacting concrete (SCC) and fiber-reinforced SCC (BFC, GFC, and CFC) was examined. The study followed a staged observational plan with objectives that involved preparing plain SCC, evaluating its properties, preparing and examining the properties of fiber-reinforced SCC mixes.

3. Results and Discussion

3.1.Fresh Properties

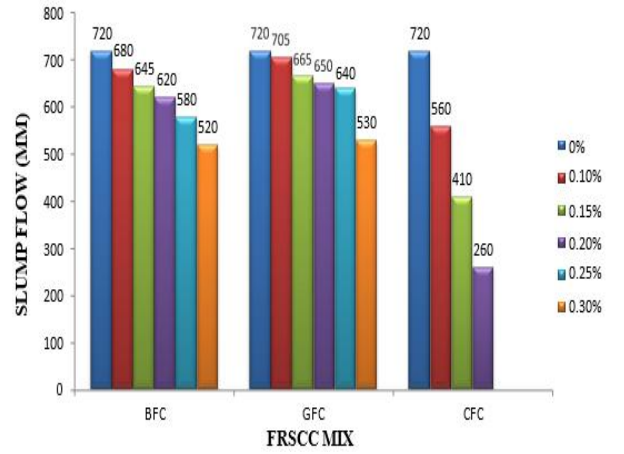
The addition of fibers in the concrete results in a decrease in the flow value, as indicated in Figure 1. This can be attributed to the formation of a network structure by the dispersed fibers within the concrete, which effectively hinders segregation and flow of the mixture.

As the percentage of fibers increases, the slump flow of the concrete decreases. The reduction in flow value is most significant for carbon fiber, with a decrease of 63.88 percent, followed by glass fiber with a decrease of 26.38 percent, and basalt fiber with a decrease of 27.77 percent compared to the control mix. This decrease can be attributed to the higher water absorption capacity of carbon fibers, which affects the workability of the mix. When the fiber content exceeds 0.2 percent, the mix no longer meets the standards for self-compacting concrete. On the other hand, glass fibers exhibit the lowest water absorption capacity among the three types of fibers.

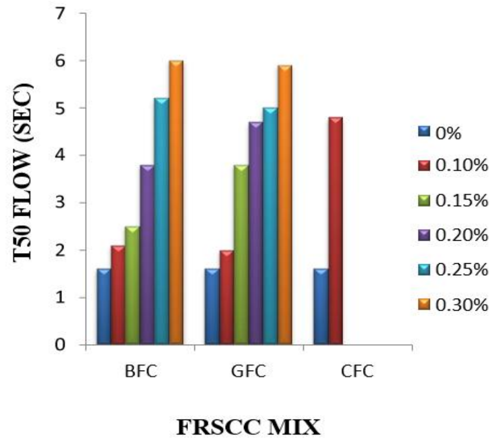
The decrease in slump flow value leads to an increase in the T50 flow, which measures the time it takes for the concrete to flow in seconds. The increase in fiber percentage discussed earlier contributes to the observed decline in slump value. Carbon fiber results in a 0.1 percent increase in the T50 flow time, while glass fiber shows a 0.3 percent increase.

With an increase in the slump flow value, the L-Box value also increases. This rise in slump value is influenced by both the fiber percentage and the L-Box value. The highest L-Box value was obtained in the case of the control mix with 0.2 percent basalt fiber, meeting the specifications for self-compacting concrete. The requirements are also fulfilled by 0.25 percent glass fiber and 0.1 percent carbon fiber.

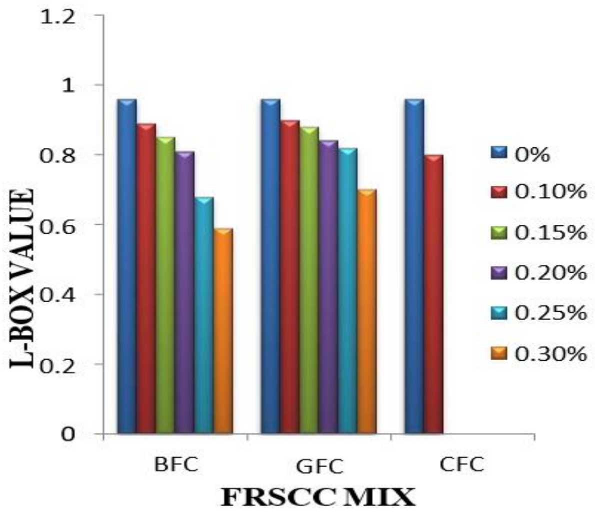
In the V-Funnel test, as well as the T50 flow measured in seconds, both values are interdependent. As the slump flow value decreases, the V-Funnel value and T50 flow increase. The decrease in slump value is a result of the increasing fiber percentage. It was observed that the SCC specifications were satisfied with 0.1 percent carbon fiber, 0.2 percent basalt fiber, and 0.25 percent glass fiber.



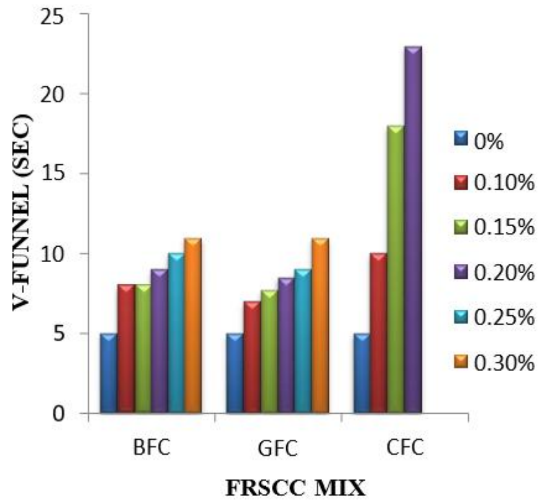
(a) Slump flow test



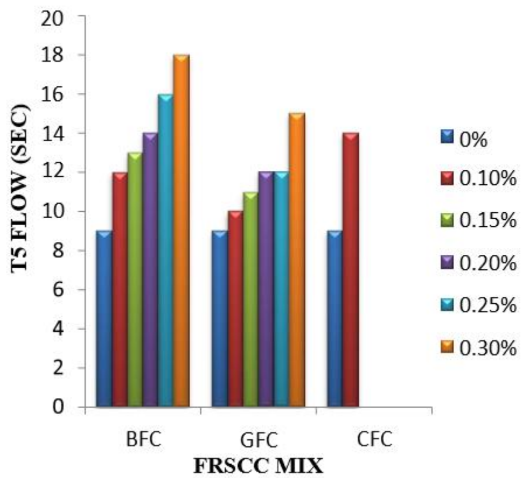
(b) T50 flow test



(c) L-box test



(d) V-funnel Test



(e) T5 Flow test

Figure 1. Fresh properties with FRSCC Mix

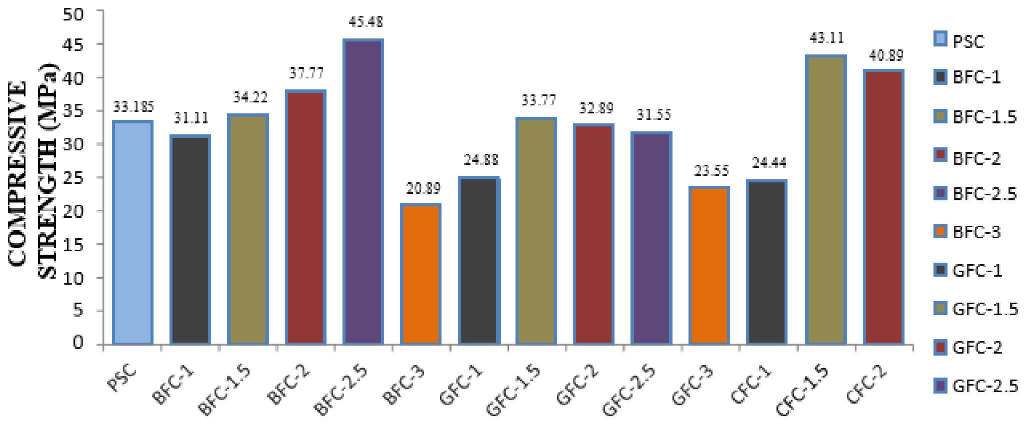
3.2.Compressive strength test

The addition of basalt fiber in volume fractions of 0.15 percent, 0.2 percent, and 0.25 percent to the concrete results in an increase in compressive strength of 3.12 percent, 13.82 percent, and 37.05 percent, respectively, compared to plain SCC. When glass fiber is added at a volume fraction of 0.15 percent, the compressive strength increases by 1.76 percent compared to plain SCC. However, no significant improvement is observed in the compressive strength of glass fiber-reinforced concrete after 7 days.

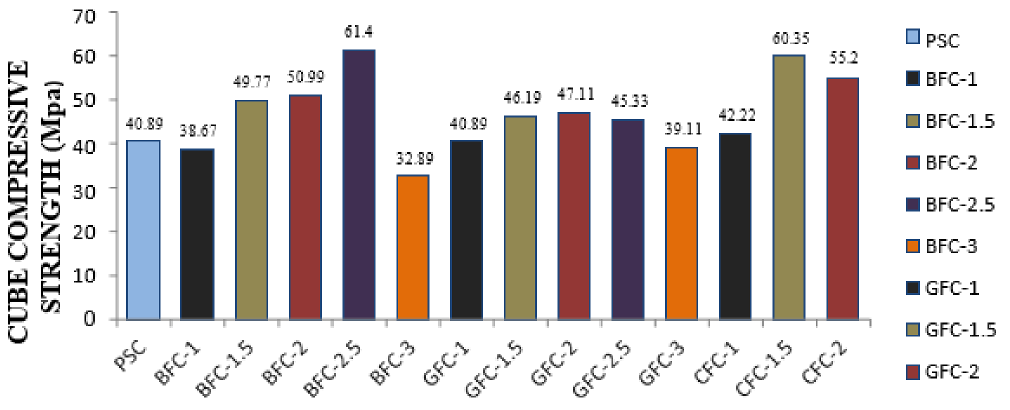
In contrast, carbon fiber-reinforced concrete demonstrates a noteworthy increase in compressive strength, showing improvements of 29.9 percent and 23.22 percent compared to plain SCC. The graph in Figure 2(a) illustrates that carbon fiber-reinforced concrete (CFC) and basalt fiber-reinforced concrete (BFC) exhibit higher compressive strength after 7 days, particularly at volume fractions ranging from 0.15 to 0.25 percent.

When compared to plain SCC, the addition of 0.15 percent basalt fiber increases the compressive strength by 21.72 percent, glass fiber by 10.52 percent, and carbon fiber by 47.6 percent, as shown in Figure 2(b). For every 0.2 percent increase in basalt fiber, the compressive strength of glass fiber and carbon fiber increases by 24.7 percent and 35 percent, respectively. Moreover, a 0.25 percent addition of basalt fiber results in a 50.16 percent increase in compressive strength, while glass fiber exhibits an 11 percent increase.

Based on the findings of this study, the optimum dosages for basalt fiber-reinforced concrete are determined to be 0.25 percent, 0.2 percent for glass fiber-reinforced concrete, and 0.15 percent for carbon fiber-reinforced concrete, as depicted in Figure 2.The addition of fibers to self-compacting concrete (SCC) improves compressive strength due to enhanced bonding, crack arresting, increased energy absorption, bridging effect, and reduced porosity. Fibers create a network structure, enhancing the bond between fibers and the cementitious matrix, improving load transfer. They help control crack propagation and distribute stress, increasing compressive strength. Fibers absorb energy during deformation, improving load-bearing capacity. They bridge across cracks, preventing further propagation. Additionally, fibers reduce porosity, enhancing density and strength. Overall, fiber reinforcement enhances the mechanical properties of SCC, resulting in improved compressive strength.



(a) Compressive strength variation of FRSCC at 7 days



(b) Compressive strength variation of FRSCC at 28 days

Figure 2. Compressive strength variation of FRSCC at 7 and 28 days

4. Conclusion

The current study provides the following conclusions: the addition of fibers to self-compacting concrete leads to a loss of basic SCC properties, such as slump flow, with the most significant reduction observed for carbon fiber followed by basalt and glass fiber, due to the higher water absorption of carbon fibers. Adding more than 2% carbon fiber creates a harsh mix that fails to meet SCC requirements. However, fiber addition enhances the mechanical properties of self-compacting concrete, especially compressive strength. The optimum percentages of each fiber type yield the most substantial improvement, with a combination of 0.15% carbon fiber, 0.2% glass fiber, and 0.25% basalt fiber demonstrating the highest mechanical properties. Incorporating 0.15% carbon fiber increases the 7-day compressive strength by 29.9% and the 28-day compressive strength by 47.6%. Similarly, introducing 0.25% basalt fiber enhances the 7-day compressive strength by 37.05% and the 28-day compressive strength by 50.16%. Adding 0.2% glass fiber results in a 1.76%

increase in the 7-day compressive strength and a 15.21% increase in the 28-day compressive strength.

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