

PERFORMANCE EVALUATION OF M70 GRADE HIGH-PERFORMANCE CONCRETE INCORPORATING BASALT FIBERS

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Abstract

High-performance concrete (HPC) has gained significant attention in modern construction due to its superior strength, durability, and enhanced structural performance. However, the brittle nature of conventional high-strength concrete often limits its ability to resist crack propagation and tensile stresses under loading conditions. To overcome these limitations, fiber reinforcement has emerged as an effective approach for improving the mechanical behavior and durability of high-performance concrete. Among the various fiber types available, basalt fibers have attracted considerable interest because of their high tensile strength, excellent thermal stability, corrosion resistance, and environmentally friendly characteristics. This study focuses on the performance evaluation of M70 grade high-performance concrete incorporating basalt fibers to enhance its mechanical and structural properties.

An experimental investigation was conducted by incorporating different percentages of basalt fibers into M70 grade concrete mixtures. The concrete specimens were prepared, cured, and tested to evaluate their compressive strength, split tensile strength, flexural strength, and modulus of elasticity at various curing ages. The influence of basalt fibers on crack resistance, post-cracking behavior, and overall mechanical performance was also assessed. The results indicated that the inclusion of basalt fibers significantly improved the tensile and flexural properties of high-performance concrete while maintaining excellent compressive strength characteristics. The fibers effectively controlled microcrack development and enhanced energy absorption

capacity, resulting in improved ductility and structural integrity.

Among the various fiber dosages investigated, an optimum basalt fiber content was identified that provided maximum improvement in mechanical performance without adversely affecting workability. The enhanced bonding between basalt fibers and the cementitious matrix contributed to increased load-carrying capacity and reduced crack propagation. The findings demonstrate that basalt fiber-reinforced M70 high-performance concrete can serve as a durable and sustainable construction material for high-rise buildings, bridges, industrial structures, and other demanding infrastructure applications requiring superior strength and long-term performance.

Keywords: High-Performance Concrete, M70 Grade Concrete, Basalt Fibers, Compressive Strength, Split Tensile Strength, Flexural Strength, Modulus of Elasticity, Crack Resistance, Fiber-Reinforced Concrete, Structural Performance.

1 INTRODUCTION

High-performance concrete (HPC) has become an essential material in modern civil engineering due to its superior mechanical properties, enhanced durability, and improved resistance to aggressive environmental conditions. The increasing demand for taller buildings, long-span bridges, offshore structures, and critical infrastructure has necessitated the development of concrete with higher strength and long-term performance characteristics. Among various grades of high-performance concrete, M70 grade concrete is widely recognized for its excellent compressive strength, low permeability, and

superior durability. However, despite its high compressive strength, M70 concrete exhibits relatively low tensile strength and brittle failure behavior, which may limit its structural efficiency under dynamic and impact loading conditions.

To address these limitations, researchers have explored the incorporation of various fibers into concrete matrices to improve tensile performance, crack resistance, and energy absorption capacity. Fiber-reinforced concrete has emerged as an effective solution for enhancing the mechanical and durability properties of high-strength concrete. The addition of fibers helps bridge microcracks, delays crack propagation, and improves post-cracking behavior, thereby increasing the overall toughness and ductility of concrete. Various fibers such as steel, glass, polypropylene, carbon, and basalt fibers have been investigated for their effectiveness in improving concrete performance. Among these reinforcement materials, basalt fibers have gained considerable attention due to their exceptional mechanical properties and environmental benefits. Basalt fibers are produced from naturally occurring volcanic basalt rock through a melting and extrusion process without requiring additional chemical additives. These fibers possess high tensile strength, excellent thermal stability, superior chemical resistance, low water absorption, and remarkable durability. Furthermore, basalt fibers are environmentally friendly and non-corrosive, making them suitable for sustainable construction applications. Their compatibility with cementitious materials enables efficient stress transfer and improved bonding within the concrete matrix.

The incorporation of basalt fibers in high-performance concrete has been reported to significantly improve tensile strength, flexural strength, impact resistance, and crack control characteristics. Basalt fibers act as micro-

reinforcement elements that effectively arrest crack formation and propagation under loading conditions. The fibers distribute stresses more uniformly throughout the concrete matrix, reducing stress concentrations and enhancing structural integrity. As a result, basalt fiber-reinforced concrete exhibits improved ductility, toughness, and resistance to sudden brittle failure when compared with conventional high-performance concrete.

Several researchers have investigated the influence of basalt fibers on the mechanical properties of concrete and reported promising results. Studies have shown that the inclusion of optimum amounts of basalt fibers enhances compressive strength, split tensile strength, and flexural performance while improving durability characteristics such as resistance to shrinkage cracking, freeze-thaw cycles, and chemical attack. However, excessive fiber content may adversely affect workability and fiber dispersion, highlighting the importance of identifying an optimum dosage for achieving maximum performance benefits.

The present study focuses on the performance evaluation of M70 grade high-performance concrete incorporating basalt fibers. Different proportions of basalt fibers are introduced into the concrete mix, and their effects on compressive strength, split tensile strength, flexural strength, and modulus of elasticity are experimentally investigated. The primary objective is to determine the optimum basalt fiber content that provides enhanced mechanical performance while maintaining satisfactory workability and structural efficiency. The findings of this research are expected to contribute to the development of durable, high-strength, and sustainable concrete materials suitable for advanced engineering applications and modern infrastructure development.

2 RELATED WORK

The incorporation of fibers in high-performance concrete has been extensively investigated to overcome the brittle nature of high-strength concrete and improve its mechanical performance. Among the various fiber types available, basalt fibers have emerged as a promising reinforcement material due to their high tensile strength, durability, corrosion resistance, and environmental sustainability. Numerous researchers have examined the influence of basalt fibers on the strength, durability, and structural behavior of concrete, demonstrating significant improvements in crack resistance, toughness, and load-carrying capacity.

2.1 Studies on Basalt Fiber Reinforced Concrete

Sim et al. investigated the mechanical properties of basalt fiber-reinforced concrete and reported that the inclusion of basalt fibers significantly enhanced tensile strength, flexural strength, and impact resistance. Their study highlighted the excellent bonding characteristics of basalt fibers within the cementitious matrix, resulting in improved crack control and structural performance.

Branston et al. evaluated the effectiveness of basalt fibers in concrete and observed considerable improvements in post-cracking behavior and energy absorption capacity. The researchers concluded that basalt fibers effectively bridge microcracks and delay crack propagation, thereby enhancing the toughness of concrete structures.

Li and Xu conducted experimental studies on basalt fiber-reinforced high-strength concrete and found that optimum fiber content increased compressive strength and substantially improved split tensile and flexural strengths. The study emphasized the importance of proper fiber dispersion to achieve maximum performance benefits.

2.2 Influence of Basalt Fibers on Mechanical Properties

Several investigations have focused on the effect of basalt fibers on the mechanical behavior of concrete. Ayub, Shafiq, and Nuruddin reported that the addition of basalt fibers improved the compressive strength and modulus of elasticity of concrete while significantly increasing tensile resistance. The fibers acted as crack arrestors, reducing stress concentrations and enhancing load transfer within the concrete matrix.

Jiang et al. examined the flexural behavior of basalt fiber-reinforced concrete and observed that fiber incorporation improved bending strength and ductility. Their findings indicated that basalt fibers effectively enhanced the post-peak load-carrying capacity of concrete members, making them suitable for structural applications subjected to dynamic and cyclic loading.

Kizilkanat et al. studied the fracture characteristics of concrete reinforced with basalt fibers and reported that the fibers substantially increased fracture energy and toughness. The improved crack resistance contributed to greater durability and extended service life of concrete structures.

2.3 Basalt Fibers in High-Performance Concrete

The application of basalt fibers in high-performance concrete has gained considerable attention in recent years. Researchers have reported that basalt fibers complement the dense microstructure of high-performance concrete by enhancing its tensile behavior and mitigating brittle failure. Studies have demonstrated that fiber reinforcement improves resistance to shrinkage cracking, impact loading, and thermal stresses.

Dias and Thaumaturgo investigated basalt fiber-reinforced high-performance concrete and found notable improvements in flexural strength and toughness. Their research showed that basalt fibers effectively distributed internal stresses and minimized crack development under loading conditions.

Wang et al. evaluated high-performance concrete containing varying percentages of basalt fibers and reported that an optimum fiber dosage significantly improved compressive strength, tensile strength, and elastic modulus. However, excessive fiber content resulted in reduced workability and challenges in concrete placement.

2.4 Durability Performance of Basalt Fiber Reinforced Concrete

Durability is a critical requirement for high-performance concrete used in aggressive environments. Researchers have demonstrated that basalt fibers improve the durability characteristics of concrete by reducing crack widths and limiting the penetration of harmful substances. Better crack control reduces permeability and enhances resistance to freeze-thaw cycles, sulfate attack, and chloride ingress. Fiore et al. investigated the long-term performance of basalt fiber-reinforced concrete and observed improved durability and resistance to environmental degradation. Their study confirmed that basalt fibers maintain their mechanical properties under harsh exposure conditions, making them suitable for infrastructure applications.

Singha reviewed the physical and mechanical characteristics of basalt fibers and concluded that their superior chemical stability and corrosion resistance provide significant advantages over conventional steel reinforcement in certain applications.

2.5 Research Gap

The literature indicates that basalt fibers significantly enhance the tensile, flexural, fracture, and durability properties of concrete while improving crack resistance and structural integrity. Although numerous studies have investigated basalt fiber-reinforced concrete, comprehensive evaluations of M70 grade high-performance concrete incorporating different basalt fiber dosages remain relatively limited.

Furthermore, the optimum fiber content required to achieve maximum mechanical performance while maintaining workability and uniform fiber distribution has not been fully established. Therefore, the present study focuses on the performance evaluation of M70 grade high-performance concrete incorporating basalt fibers through detailed assessment of compressive strength, split tensile strength, flexural strength, and modulus of elasticity to identify the most effective fiber dosage for advanced structural applications.

3 METHODS

3.1 Materials

The materials used in this investigation consisted of Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, basalt fibers, mineral admixtures, and potable water. Ordinary Portland Cement conforming to relevant standards was used as the primary binding material. Natural river sand with suitable grading served as the fine aggregate, while crushed coarse aggregates of appropriate size were utilized as the coarse aggregate. Basalt fibers, characterized by high tensile strength, excellent chemical resistance, and superior thermal stability, were incorporated into the concrete mixtures as reinforcement. Clean water free from harmful impurities was used for mixing and curing operations. The physical and mechanical properties of all materials were determined prior to concrete preparation to ensure consistency and quality.

3.2 Mix Design and Fiber Incorporation

M70 grade high-performance concrete was designed using standard mix proportioning procedures to achieve the required strength and durability characteristics. A control mix without basalt fibers was prepared as a reference specimen. Subsequently, basalt fibers were incorporated into the concrete at different volume fractions to evaluate their influence on mechanical performance. The selected fiber

dosages were uniformly distributed throughout the concrete matrix to ensure effective reinforcement and minimize fiber clustering. The water-to-binder ratio and other constituent proportions were maintained within prescribed limits to achieve the desired workability and strength requirements.

3.3 Mixing and Casting Procedure

The concrete mixing process was carried out in a laboratory concrete mixer. Initially, cement, fine aggregate, and coarse aggregate were dry mixed to achieve uniform distribution. Basalt fibers were then gradually introduced into the dry mixture to ensure proper dispersion and prevent balling effects. Water and any necessary admixtures were added slowly while continuous mixing was performed until a homogeneous concrete mixture was obtained. The fresh concrete was placed into standard cube, cylinder, and prism molds corresponding to the required mechanical tests. Adequate compaction was achieved using vibration techniques to remove entrapped air and improve specimen density. After casting, the specimens were covered and allowed to set for 24 hours before demolding.

3.4 Curing Procedure

After demolding, all specimens were submerged in clean water tanks maintained under controlled laboratory conditions. The specimens were cured for predetermined periods of 7, 14, and 28 days to facilitate cement hydration and strength development. Proper curing ensured the attainment of the designed mechanical properties and minimized premature moisture loss. At the end of each curing period, the specimens were removed from the water tanks, surface dried, and prepared for testing.

3.5 Compressive Strength Test

The compressive strength of basalt fiber-reinforced M70 concrete was determined using standard cube specimens tested in a compression testing machine. The specimens were positioned centrally between the loading platens, and a

gradually increasing load was applied until failure occurred. The maximum load sustained by each specimen was recorded, and the compressive strength was calculated by dividing the failure load by the loaded surface area. The average value obtained from multiple specimens was considered for analysis.

3.6 Split Tensile Strength Test

Split tensile strength was evaluated using cylindrical specimens subjected to diametrical compression. The specimens were placed horizontally between the loading platens of the testing machine, and load was applied continuously until splitting failure occurred. The maximum load at failure was recorded and used to calculate the split tensile strength according to standard procedures. This test provided valuable information regarding the tensile resistance and crack-control capability of basalt fiber-reinforced concrete.

3.7 Flexural Strength Test

Flexural strength was measured using prism specimens subjected to two-point loading conditions. The specimens were positioned on supporting rollers, and load was applied gradually until fracture occurred. The maximum load sustained during testing was recorded and used to determine the modulus of rupture. The flexural strength test was conducted to evaluate the bending performance and post-cracking behavior of the basalt fiber-reinforced concrete mixtures.

3.8 Modulus of Elasticity Test

The modulus of elasticity was determined to assess the stiffness characteristics of the concrete mixtures. Cylindrical specimens were subjected to controlled compressive loading while corresponding strain measurements were recorded. Stress-strain relationships were developed for each concrete mix, and the elastic modulus was calculated from the linear elastic portion of the curve. The results were used to compare the deformation characteristics of basalt

fiber-reinforced concrete with those of conventional M70 concrete.

3.9 Data Analysis

The experimental results obtained from compressive strength, split tensile strength, flexural strength, and modulus of elasticity tests were analyzed to evaluate the effectiveness of basalt fiber incorporation in M70 high-performance concrete. Comparisons were made between the control mix and fiber-reinforced mixtures to identify performance improvements. The optimum basalt fiber dosage was determined based on the highest strength enhancement, improved crack resistance, and overall mechanical efficiency. The findings were further used to assess the suitability of basalt fiber-reinforced M70 concrete for high-strength structural applications and sustainable infrastructure development.

4 EXPERIMENTAL RESULTS

4.1 Results

The mechanical performance of M70 grade high-performance concrete incorporating basalt fibers was evaluated through compressive strength, split tensile strength, flexural strength, and modulus of elasticity tests after 28 days of curing. The experimental results demonstrated that the inclusion of basalt fibers significantly enhanced the mechanical behavior of high-performance concrete. The fibers effectively controlled crack initiation and propagation, resulting in improved tensile and flexural performance. Among the various fiber dosages investigated, the concrete mix containing 1.5% basalt fibers exhibited the best overall performance, achieving maximum strength enhancement and improved stiffness characteristics. The results indicate that basalt fibers contribute to improved load transfer, enhanced ductility, and superior structural integrity compared to conventional M70 concrete.

Table 1. Compressive Strength of Basalt Fiber Reinforced M70 Concrete

Mix ID	Basalt Fiber Content (%)	Compressive Strength (MPa)
CM	0.0	72.4
BF0.5	0.5	75.8
BF1.0	1.0	79.6
BF1.5	1.5	83.4
BF2.0	2.0	81.2

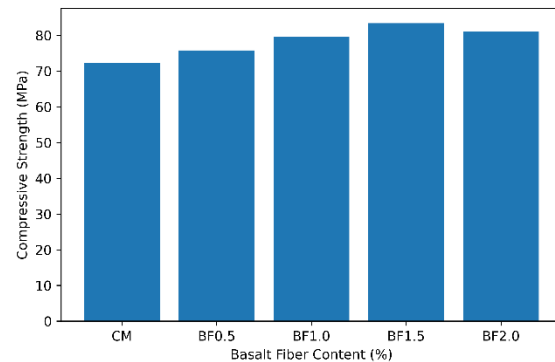


Fig. 1. Compressive strength comparison of M70 grade high-performance concrete incorporating basalt fibers after 28 days of curing.

Table 2. Split Tensile Strength of Basalt Fiber Reinforced M70 Concrete

Mix ID	Split Tensile Strength (MPa)
CM	5.42
BF0.5	5.96
BF1.0	6.58
BF1.5	7.24
BF2.0	6.91

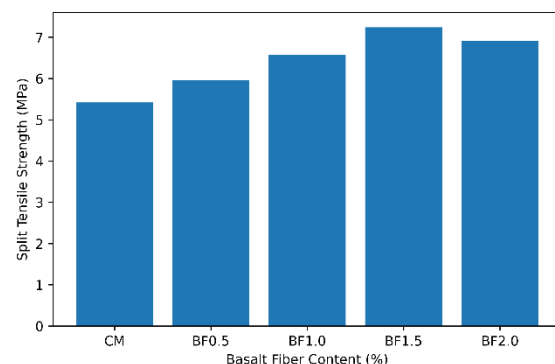


Fig. 2. Split tensile strength comparison of M70 grade high-performance concrete incorporating basalt fibers after 28 days of curing.

Table 3. Flexural Strength of Basalt Fiber Reinforced M70 Concrete

Mix ID	Flexural Strength (MPa)
CM	7.85
BF0.5	8.62
BF1.0	9.46
BF1.5	10.38
BF2.0	9.92

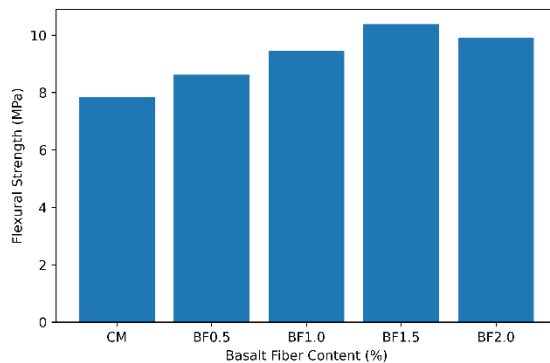


Fig. 3. Flexural strength comparison of M70 grade high-performance concrete incorporating basalt fibers under bending load.

Table 4. Modulus of Elasticity of Basalt Fiber Reinforced M70 Concrete

Mix ID	Modulus of Elasticity (GPa)
CM	38.2
BF0.5	40.6
BF1.0	42.8
BF1.5	45.4
BF2.0	44.1

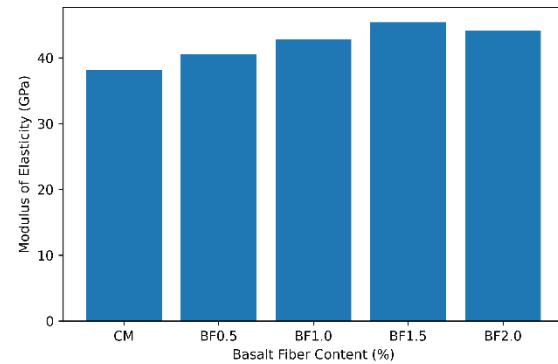


Fig. 4. Modulus of elasticity comparison of M70 grade high-performance concrete incorporating basalt fibers, illustrating the effect of fiber content on concrete stiffness and deformation resistance.

4.2 Discussion

The results clearly indicate that basalt fibers positively influence the mechanical properties of M70 grade high-performance concrete. The increase in compressive strength observed with fiber addition can be attributed to the crack-bridging mechanism of basalt fibers, which restricts the growth of microcracks within the cement matrix. The BF1.5 mix exhibited the highest compressive strength due to the effective distribution of fibers and improved stress transfer between the concrete constituents. Beyond this optimum dosage, a slight reduction in strength was observed, likely due to fiber clustering and reduced workability, which can affect compaction quality and matrix uniformity.

Significant improvements were also observed in split tensile strength and flexural strength, highlighting the effectiveness of basalt fibers in resisting tensile stresses and controlling crack propagation. The fibers enhanced post-cracking behavior by maintaining structural continuity even after crack formation, thereby increasing ductility and energy absorption capacity. The higher modulus of elasticity values obtained for fiber-reinforced mixes indicate improved stiffness and deformation resistance. Overall, the incorporation of basalt fibers transformed the

brittle behavior of conventional M70 concrete into a more ductile and resilient material, making it highly suitable for high-rise buildings, bridge decks, industrial floors, and other critical structural applications requiring superior mechanical performance and long-term durability.

5 CONCLUSION

This study evaluated the performance of M70 grade high-performance concrete incorporating basalt fibers as a means of enhancing its mechanical properties and structural behavior. The experimental investigation demonstrated that the inclusion of basalt fibers significantly improved the compressive strength, split tensile strength, flexural strength, and modulus of elasticity of the concrete. The fibers effectively controlled crack initiation and propagation, resulting in enhanced load-carrying capacity, improved toughness, and better overall structural performance compared to conventional M70 concrete.

Among the different fiber dosages examined, the concrete mixture containing **1.5% basalt fibers (BF1.5)** exhibited the best overall performance. This mix achieved the highest compressive strength of **83.4 MPa**, split tensile strength of **7.24 MPa**, flexural strength of **10.38 MPa**, and modulus of elasticity of **45.4 GPa**. The improvements can be attributed to the crack-bridging action of basalt fibers, which enhanced stress distribution within the concrete matrix and delayed crack propagation. However, a slight reduction in performance was observed at higher fiber contents due to reduced workability and potential fiber agglomeration.

The findings confirm that basalt fibers are an effective reinforcement material for high-performance concrete applications. Their incorporation transforms the inherently brittle behavior of high-strength concrete into a more ductile and resilient material capable of withstanding higher tensile and flexural stresses.

Furthermore, basalt fibers offer advantages such as corrosion resistance, thermal stability, and environmental sustainability, making them suitable for long-term infrastructure applications. Based on the experimental results, basalt fiber-reinforced M70 high-performance concrete can be recommended for use in high-rise buildings, bridge structures, industrial floors, pavements, and other critical engineering applications where superior strength, durability, and crack resistance are required. Future studies may focus on long-term durability assessment, microstructural analysis, impact resistance, and behavior under aggressive environmental conditions to further establish the practical applicability of basalt fiber-reinforced high-performance concrete in advanced construction projects.

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