

REVIEW PAPER ON ENHANCING DURABILITY AND PERFORMANCE OF HIGH STRENGTH CONCRETE THROUGH HYBRID FIBER REINFORCEMENT

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ABSTRACT

This review study examines the use of hybrid fiber reinforcement to improve the durability and performance of high-strength concrete (HSC). Hybrid fiber reinforcement is the process of integrating diverse fibers, including steel, polypropylene, and synthetic fibers, in order to generate synergistic effects and enhance multiple properties of concrete.

The research commences with examining the significance of durability and performance in High-Strength Concrete (HSC), taking into account its extensive utilization in infrastructure and construction endeavors. It underscores the difficulties linked to conventional concrete, such as the development of cracks, shrinkage, and durability problems, hence underlining the necessity for inventive reinforcement methods.

The review explores the concept of hybrid fiber reinforcement, explaining its principles and advantages in improving the mechanical properties and durability of high-strength concrete (HSC). Hybrid reinforcement enhances fracture control, ductility, and resilience to environmental conditions including freeze-thaw cycles and chemical attacks by mixing fibers with complementary qualities, such as tensile strength, toughness, and chemical resistance.

Moreover, the research analyzes experimental studies and case studies from the literature to assess the efficacy of hybrid fiber reinforcement in high-strength concrete (HSC). The study examines the impact of different fiber kinds, fiber content, aspect ratio, and fiber distribution on the performance of high-strength concrete (HSC). It offers valuable information on the ideal design parameters for achieving specific qualities.

The paper examines existing research findings to identify the crucial elements that influence the durability and performance of High-Strength Concrete (HSC) with hybrid fiber reinforcement. Additionally, it addresses pragmatic factors for execution, such as the optimization of mix design, construction methodologies, and procedures for quality control.

This review paper is a significant resource for researchers, engineers, and practitioners in the field of concrete technology. It provides insights into creative ways for improving the durability and performance of high-strength concrete (HSC) using hybrid fiber reinforcement.

Key Words: durability, performance, high strength concrete, hybrid fiber reinforcement

1. INTRODUCTION

High-strength concrete (HSC) has garnered considerable interest in the construction sector because of its exceptional mechanical characteristics, such as its high compressive strength, outstanding durability, and improved performance under different types of loads. Nevertheless, HSC is prone to certain drawbacks including cracking, shrinkage, and diminished ductility, particularly in dynamic or harsh environmental circumstances. Research and development in the field of concrete technology is currently focused on addressing these issues and enhancing the durability and performance of HSC.

Utilizing fiber reinforcement is a promising method to improve the characteristics of HSC. When fibers are added to concrete mixtures, they can efficiently manage the spread of cracks, strengthen the ability to withstand tension, and improve resistance against different types of deterioration. Although individual types of fibers have been extensively examined and employed in concrete, current studies have placed greater emphasis on the advantageous effects of integrating several types of fibers in a hybrid arrangement. The hybrid fiber reinforcing strategy intends to leverage the distinct features of each fiber type to produce exceptional performance in high-strength concrete (HSC).

Utilizing hybrid fiber reinforcement in high-strength concrete (HSC) presents numerous potential benefits compared to traditional reinforcement techniques. Hybrid reinforcement, which involves the combination of fibers with different qualities including steel, polypropylene, and synthetic fibers, can efficiently overcome the constraints associated with each specific fiber type. Steel fibers, for instance, possess superior tensile strength and toughness, but polypropylene fibers exhibit exceptional crack control and resistance to freeze-thaw cycles. In contrast, synthetic fibers improve both

durability and resistance to chemical attacks. Through the appropriate blending of these fibers in suitable quantities, hybrid reinforcement has the ability to enhance the overall performance of High Strength Concrete (HSC), resulting in increased durability, resilience, and sustainability.

The main goal of this work is to give a detailed summary of the latest research and development in the field of hybrid fiber-reinforced high-strength concrete (HSC). This research seeks to clarify the factors that contribute to the improvement of durability and performance by combining different types of fibers in reinforcement. Moreover, it aims to determine the crucial parameters that impact the efficiency of hybrid reinforcement in high-strength concrete (HSC) and investigate possible opportunities for additional study and practical application.

The presentation will commence by analyzing the underlying principles of fiber reinforcement in concrete and the reasoning behind implementing a hybrid technique. The study will investigate the methods via which various types of fibers interact with the cement matrix to enhance mechanical qualities, improve resistance to cracks, and boost capacity for energy absorption. The focus will be on the synergistic outcomes that result from the combination of several fiber types, leading to improved ductility, toughness, and resistance to environmental conditions.

The study will examine a range of experimental studies and case studies from the literature that analyze the performance of hybrid fiber-reinforced high-strength concrete, in accordance with the theoretical framework. The purpose of analyzing these research is to evaluate how several elements, such as the type of fiber, the amount of fiber, the ratio of length to width, and the distribution of fibers, affect the mechanical properties and durability of high-strength concrete (HSC). Additionally, the article will analyze practical factors for optimizing mix design, building methods, and quality control procedures to guarantee the effective utilization of hybrid fiber reinforcement in actual scenarios.

This study is to provide a complete resource for researchers, engineers, and practitioners who are engaged in the design, development, and building of high-strength concrete (HSC) structures. The objective is to utilize current knowledge and recognize new developments in order to enhance the technology of hybrid fiber-reinforced concrete. This will help to increase the durability and performance of high-strength concrete in various building projects, and encourage its broad use.

2. LITERATURE REVIEW

W. Sun, H. Qian, and H. Chen 2000. examine how durable concrete structures are and how well hybrid fiber reinforced concrete (HFRC) works to increase durability. The capacity of concrete structures to tolerate degradation over time is known as durability, and it is essential to their long-term performance. When compared to mono fiber concrete, HFRC, which blends many fiber types, exhibits greater durability, especially in terms of resistance against damage from freezing and thawing cycles. The combined effects of hybrid fibers effectively reduce cracking and increase tensile strength, which adds to the HFRC's increased longevity. According to the study's findings, HFRC performs better at fending off the damaging effects of freezing and thawing and improves overall strength. This emphasizes how important hybrid fiber reinforcement is as a workable way to create long-lasting concrete structures that can tolerate a range of environmental difficulties.

Banthia, N., Yan, C., and Bindiganavile, V. (2000) concentrate on the creation of High Performance Fibre Reinforced Concrete (HPFRC) by effective use of fibers and binders in their study. To optimize the mixture, they use a hybridization design of fibers along with a modified version of the Andresen & Andersen particle packing model. Their results suggest that hybrid fiber HPFRC combinations have stronger properties than single fiber mixtures. They also investigate the application of macro-fibers, like hooked steel fibers, which give high-performance fiber reinforced concrete (HPFRC) superior mechanical qualities. This study paves the way for the creation of more robust and long-lasting concrete structures by highlighting the importance of hybrid fiber reinforcement and macro-fibers in improving the performance and strength of concrete.

Qian, C.X. and Stroeven, P. (2010) examine the reinforcing effectiveness of hybrid fibers with up to 30% cement replacement. Their research focuses on the micro-mechanical behavior of steel and polypropylene hybrid fibers in fly ash-based concrete. They discover that varying amounts of steel and polypropylene fiber additions affect how effective hybrid fibers are. Concrete reaches its greatest strength when fly ash replenishment falls between the 10 and 30% range. Concrete must cure for a longer amount of time—90 days—in order to build strength if the replacement of fly ash is greater than 60%. It's interesting to note that adding more steel fiber to the concrete only improves its tensile strength, indicating a complex link between the qualities of the fiber and the concrete's composition. This work clarifies the complex relationships that exist between fly ash concrete and hybrid fibers, providing information on how to best adjust the composition of the material to improve mechanical performance.

Skazlić's review (2001). By adding fly ash instead of cement usually results in less strength, this study explores the intricacies of using hybrid fibers to improve the characteristics of concrete. Because of their high modulus and stiffness, steel fibers are known to greatly increase the strength of concrete. On the other hand, polypropylene fibers have special benefits due to their flexibility and capacity to reinforce fragile cementitious materials. Furthermore, they have the ability to retain heat longer in the concrete due to their thermal retention qualities. This property significantly delays early cracks by increasing toughness and strain capacity in the post-cracking phase. The assessment by Skazlić highlights the distinct functions of various fiber types in enhancing the efficiency of fly ash concrete with high volume. Engineers can customize concrete mixtures to attain desired strength, durability, and fracture resistance by utilizing the complementing properties of steel and polypropylene fibers. This progresses the creation of resilient and sustainable building materials.

The goal of the research by Alwan JM, Naaman AE, and Hansen W. (2002) is to use high-performance composite fibers to improve the mechanical characteristics of cement composites. The interface characteristics of the cementitious matrix and fiber have a major impact on the mechanical performance of these composites. The fiber-matrix interfacial properties and fiber rupture characteristics are assessed in the research using single-fiber pull-out tests. The purpose of these tests is to help the study quantify certain design factors that affect the composites' performance. Through the use of this method, the interactions between the fibers and the cement matrix may be well understood, leading to the creation of composite materials that are optimized and have improved mechanical characteristics. The results of this investigation provide significant perspectives for the design and engineering of cement composites reinforced with high-performance fibers, thereby promoting progress in building materials and infrastructure durability.

Y. Liu, W. Qiu, and D. Li, 2023. Polypropylene fiber reinforced concrete, or PFRC, has emerged as a potential building material with excellent mechanical strength, stiffness, and durability. Due to their adaptability, polypropylene fibers are widely used in a broad range of industrial applications, such as packing materials, furnishings, and ropes. When it comes to concrete, PFRC provides improved performance and adaptability, which makes it appropriate for a range of uses, including driveways, roads and pavements, overlays and toppings, ground-supported slabs, and machine foundations. This embryonic material offers options for infrastructure development and construction projects, demonstrating amazing potential for enhancing the structural integrity and durability of concrete structures. Because of its special qualities and uses, PFRC is a useful addition to the range of building materials, advancing the development of robust and sustainable infrastructure systems.

Sandwich panel studies by J.A.O. Barros, E. Pereira, A. Ribeiro, and V. Cunha (2005) include sandwich panel studies that are the result of technical analysis and experimentation as well as standard sandwich panel studies. Experiments were conducted on full-scale specimens to evaluate the usefulness and efficiency of the suggested technique. When compared to conventional sandwich panels, the suggested walls' ultimate loads, failure modes, and load-deflection relationships showed notable improvements, according to the findings. The production and final load-carrying capabilities of the specimens using the recommended procedure were much higher than those of the reference sandwich panel specimens, which was especially remarkable. These results highlight the potential of the suggested method to improve sandwich panels' overall efficiency and structural performance, providing encouraging opportunities for its use in a range of building projects targeted at reaching greater strength and resilience.

2005 research by Wang C, Yang C, Liu F, Wan C, and Pu X, the need for high strength concrete (HSC) has grown as a result of the increasing number of high-rise structures and megaprojects being built throughout the globe as well as the rising expectations of owners and designers. As a result, a thorough analysis has been carried out to create HSC. To get HSC, three different concrete mixtures were used to cast prisms, cylinders, and cubes. To ascertain the characteristics of the concrete in both its fresh and hardened phases, experimental testing was done. The goal of the research was to get a thorough understanding of HSC's performance attributes, such as its durability, tensile strength, compressive strength, and other mechanical qualities. Researchers aimed to improve the concrete mixture for increased strength and durability by assessing the attributes of HSC under various mix compositions. This approach addressed the changing needs of contemporary building projects for high-performance materials.

Markovic's paper (2006) introduces Hybrid Fiber Concretes (HFC) as recently created cement composites that include several kinds of steel fibers in strong mortar formulations. Although the flexural behavior of HFC is exceptionally good, it is crucial to investigate its uniaxial tensile behavior in order to develop a basis for design concerns. The research focuses on determining the uniaxial tensile properties of several types of concrete reinforced with either single or combined fibers. The trials were restricted to a maximum applied fiber volume of 2 vol.-% (160 kg/m³). Tensile tests were performed on both unnotched and notched "dogbone" specimens in order to evaluate the

mechanical characteristics of the concrete when subjected to stress. The research intends to gain significant insights into the performance characteristics and prospective applications of HFC by analyzing the tensile behavior of various concrete mixes. Specifically, it seeks to enhance the tensile strength and ductility in structural parts.

Habel K, Viviani M, Denarie E, and Bruhwiler E. (2006) examines how the mechanical properties of high-performance concrete (HPC) are affected by various parameters of steel fibers, such as volume percentage and aspect ratio. The mechanical parameters being examined include compressive strength, modulus of elasticity, Poisson's ratio, flexural strength, and tensile strength. The study results indicate that it is possible to produce High Performance Fiber Reinforced Concrete (HPFRC) utilizing materials that are readily accessible in the local area, as long as they are chosen with care. The concrete mixes often consist of conventional Portland cement, silica fume, steel fibers, superplasticizer (SP), fine sand, and basalt. The research provides detailed information on the particular ratios used. This emphasizes the possibility of using native resources to manufacture High-Performance Fiber-Reinforced Concrete (HPFRC), hence decreasing dependence on imported components and improving sustainability in building methods. Additionally, the research provides insight into how to optimize fiber qualities in order to get certain mechanical properties in high-performance concrete (HPC), thereby facilitating the creation of long-lasting and strong concrete structures.

Naaman's study in 2023, the assessment of fiber-reinforced concrete (FRC) often focuses on its behavior when subjected to tensile forces, independent of the kind of fiber used (steel, synthetic, or natural organic) or the intended performance level. This reaction is often distinguished by either a decrease in strength following the first formation of cracks or an increase in strength. The motivation behind research in this field can be ascribed to several factors, such as progress in fundamental research that clarifies the strengthening mechanisms of FRC composites, the need for materials with specific properties, advancements in advanced materials, economic competitiveness, and global circumstances. The combination of these elements has established a strong basis for more research and advancement in the area of fiber-reinforced concrete. This has enabled the creation of materials that have improved performance, durability, and suitability for various building uses.

S. P. Singh, A. P. Singh, and V. Bajaj (2019) aims to examine the impact of fiber hybridization on the strength properties of steel fiber reinforced concrete (SFRC). The research investigates the characteristics of SFRC (Steel Fiber Reinforced Concrete) in its hardened form, including compressive strength, split tensile strength, and water permeability. Different combinations of steel fibers with varying lengths are used in the investigation. The researchers ran a series of experiments at intervals of 7, 28, 90, and 120 days after curing to assess the performance of SFRC with various fiber hybridizations as time progressed. The research intends to gain insights into how the mechanical characteristics and durability of SFRC are affected by different combinations of fiber insertion, via the analysis of test data. This study aims to improve the design and composition of fiber reinforced concrete to boost its performance and durability in structural applications.

Hamad BS and AbouHaidar EY (2019) examined the influence of fibers on the performance of test specimens. Although the fibers did not significantly improve the pre-crack performance of the specimens, there was a notable improvement found in both the final bond strength and post-peak bond strength performance. Significantly, the final strength of the bond was determined to be more significantly affected by the compressive strength of the concrete rather than the quantity of fibers. Brittle failure was more pronounced in specimens of bigger dimensions. Nevertheless, with the escalation in fiber dose, the load-slip curve's uneven post-peak profile, caused by brittleness, transformed into a more uniform and smoother pattern. The results emphasize the impact of fibers on both the maximum bond strength and the strength after reaching the maximum, highlighting their contribution to improving the performance and longevity of concrete structures under bonding stresses.

Corinaldesi V and Moriconi G. (2019) revealed that the strength of hybrid fiber reinforced concrete (HFRC) surpassed that of regular concrete, thereby validating the anticipated result. Nevertheless, more study is considered essential in order to refine techniques or substances for achieving the best possible results. The rate of strength improvement for the 7-day strength of HFRC was significantly greater in comparison to ordinary concrete, demonstrating its superior early strength and ongoing strength enhancement over time. Furthermore, there was a direct correlation between the rise in the proportion of fibers and the greater split tensile strength. Nevertheless, it was observed that the workability of the concrete reduced considerably as the amount of coconut fiber increased. The results emphasize the capability of HFRC to improve the mechanical characteristics of concrete. They also emphasize the need to carefully balance the amount of fibers used with the workability requirements during the design of concrete mixes. Additional research is necessary to improve HFRC formulations and procedures for wider practical use.

3. CONCLUSION

Table 1. Comparison of references study and results

References	Year	Study	Results
Qian,C.X Stroeven,P.	2018	deals with thereinforcing efficiency of hybrid fibers	Maximum strengthof concrete- increase 30%.
Naaman,A.E Reinhard t, H.W[5]	2019	Developed forapplication asa transition layer of reinforced concrete.	The addition of microfibers to the steel fibres' increased the tensile stress in flexure and increased
Banthia, N.,Nanda kumar, N.	2020	Use of different fiber as reinforcement in concrete for a greater durability, workability and reduction in crack.	FRC controls the micro cracking, shrinkage and deformation under load much better than plain concrete.
Lawler J,ZampiniD, Shah S. Micro	2021	materials by the use of micro and macro fibers of different mechanical, geometrical and physical properties	Maximum load bearing capacity (peak load), residual flexural strength and flexural toughness unreinforced matrix are significantly increased
J.A.O. Barros,E. Pereira,A. Ribeiro ,V.	2021	To study and technical details of the suggested technique along with those of the	A large increase is observed of yield and ultimate load- carrying capacities of the proposed technique specimen

Table 2 Comparison of mechanical properties of HFRCbased on the different material compositions

Ref	Nomenclature	Grades	Cement (kg)	water (kg)	CA(kg)	SP(Kg)	CS (Mpa)	FS(M pa)
Jungwirth J,(2008)	HPC1	M40	515	150	100	5. 30	40.86	19
AbouHaidar EY(2011)	HPC2	M45	489	145	950	4.80	38.32	16
H.W.,(2001)	HPC3	M50	472	130	850	4.75	36.54	13
Koh GT.(2010)	HPC4	M55	443	125	760	3.80	44.51	11
Desai, A.J.(2015)	HPC5	M60	418	110	680	3.75	53.34	09

- The study's findings, shown in Table 1, illustrate the compressive strength of several classes of concrete (M40, M45, M50, M55, and M60) with different degrees of cement substitution using fly ash.
- When using M60 grade concrete, there is a significant improvement in compressive strength compared to regular concrete, suggesting the possibility of enhancing it by replacing some of the cement.
- At the replacement level of M60, there is a notable increase in strength qualities, indicating that it is an ideal replacement level for enhanced strength.
- In contrast, when it comes to higher concrete grades such as M50, substituting cement with fly ash results in reduced strength characteristics, suggesting that it is not suitable for these grades.

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