INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)

www.ijprems.com
editor@ijprems.com

Vol. 04, Issue 05, May 2024, pp: 2031-2035

e-ISSN : 2583-1062

Impact Factor: 5.725

REVIEW PAPER ON INVESTIGATION INTO THE USE OF HYBRID FIBRE REINFORCEMENT IN HIGH STRENGTH CONCRETE

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ABSTRACT

In-depth analysis of the developments, difficulties, and prospects in the field of hybrid fibre reinforcement in high-strength concrete (HSC) is provided in this review paper. To fulfil the needs of contemporary building, high-strength concrete—known for its exceptional mechanical properties—is being used more and more in a variety of structural applications. The performance and longevity of HSC are further enhanced by the addition of fibres, both natural and synthetic, which provide better tensile strength, ductility, and resistance to cracking.

This research focuses on hybrid fibre reinforcement, which blends several fibre types to maximise the mechanical properties of HSC in a coordinated manner. Through combining fibres with complementary properties, like steel and glass or steel and polypropylene, scientists hope to maximise the benefits of each type of fibre while minimising its drawbacks. This research investigates the impact of hybrid fibre reinforcement on the mechanical characteristics, workability, and durability of HSC through a thorough evaluation of the literature.

Important discoveries from the examined research encompass the noteworthy enhancements in toughness, impact resistance, and fracture control attained by means of hybrid fibre reinforcement. Furthermore, the combination of fibres has synergistic effects that improve strain capacity and bond strength, resulting in concrete structures that are more ductile and resilient. But issues like compatibility, mix design optimisation, and fibre distribution are also covered, emphasising the need for more study and advancement in these areas.

The potential of hybrid fibre reinforcement to transform the performance of high-strength concrete and progress the area of structural engineering is highlighted by this review, in its entirety. This paper offers researchers, engineers, and industry experts useful insights for using hybrid fibre reinforcement in the design and construction of resilient and sustainable concrete structures by examining the most recent research findings and technology advancements.

Key Words: High-strength concrete, Hybrid fibre reinforcement, Synthetic fibres, Natural fibres, Mechanical properties, Crack resistance, Ductility, Tensile strength, Bond strength

1. INTRODUCTION

Due to the changing requirements of contemporary infrastructure projects, the construction industry has seen an increase in demand for high-strength concrete (HSC) in recent years. Superior mechanical qualities, such as increased durability, less permeability, and higher compressive strength, make high-strength concrete perfect for a variety of structural uses. But reaching peak performance in HSC comes with a number of difficulties, especially when it comes to improving its tensile strength and crack resistance. Researchers and engineers have shown that fibre reinforcement is a workable approach for addressing these issues.

The mechanical qualities of concrete can be improved with fibre reinforcement, especially in terms of toughness, ductility, and fracture management. Synthetic or natural fibres are mixed into the concrete mixture to slow the spread of cracks and enhance the material's post-cracking performance. In order to maximise the performance of HSC, there is growing interest in investigating the synergistic effects of combining different types of fibres, known as hybrid fibre reinforcement. Fibres such as steel, polypropylene, glass, and synthetic fibres have all been extensively studied in isolation.

The idea behind hybrid fibre reinforcement is combining fibres with complimentary qualities to improve concrete's mechanical properties in a way that works well together. In order to maximise the benefits of each fibre type while minimising its drawbacks, researchers combine fibres with different geometries, aspect ratios, and material qualities. Steel fibres, for instance, are renowned for their exceptional hardness and tensile strength, whereas polypropylene fibres provide superior impact resistance and crack management. Researchers want to develop a composite material with improved toughness, durability, and ductility by mixing these fibres.

A notable development in concrete technology, the incorporation of hybrid fibre reinforcement in HSC may have positive effects on structural performance, constructability, and sustainability. More robust constructions with improved ductility and fracture control can endure environmental stressors and dynamic loading. Additionally, using fibres can lessen the need for traditional reinforcing techniques, resulting in more effective and economical building approaches.

Although the idea of hybrid fibre reinforcement seems promising, there are a number of issues and factors that need to be taken into account. Key elements that affect the efficacy of hybrid fibre reinforcement include achieving a uniform dispersion of fibres inside the concrete matrix, optimising mix proportions, and guaranteeing compatibility between various fibre kinds. To confirm that HSC with hybrid fibre reinforcement is suitable for practical uses, more research is needed to determine its durability and long-term performance.

Within this framework, the goal of this study is to present an extensive analysis of the most recent findings and advancements regarding the application of hybrid fibre reinforcement in high-strength concrete. This research will investigate the impacts of hybrid fibre reinforcement on the mechanical characteristics, durability, and structural performance of HSC by synthesising findings from recent investigations. In addition, it will examine the difficulties, prospects, and future developments in the use of hybrid fibre reinforcement for durable and sustainable concrete building.

2. LITERATURE REVIEW

Al-Salloum et al. (2019) In their study, Al-Salloum et al. (2019) examined the mechanical characteristics of high-strength concrete (HSC) that was reinforced with a combination of steel and polypropylene fibres. Their research showcased that the amalgamation of steel and polypropylene fibres yielded enhanced fracture control and ductility in contrast to conventional reinforcement techniques. The researchers determined that the use of hybrid fibre reinforcement improves the performance of high-strength concrete (HSC) in terms of toughness and resistance to cracking.

Bijen (2000) In a review by Bijen (2000), the application of hybrid fibre reinforcement in concrete was examined, emphasising its ability to enhance the post-cracking behaviour and durability of concrete buildings. The study highlighted the significance of carefully choosing suitable types of fibres and optimising the quantities of the mixture in order to attain the appropriate mechanical properties in high-strength concrete (HSC) with hybrid fibre reinforcement.

Deng et al. (2016) investigated the mechanical characteristics of High-Strength Concrete (HSC) that was strengthened using a combination of steel and glass fibres. According to their study, the incorporation of both steel and glass fibres led to a synergistic improvement in the tensile strength, toughness, and impact resistance. The researchers determined that the use of hybrid fibre reinforcement presents a promising method for enhancing the performance of high-strength concrete in structural applications.

Holschemacher et al. (2018) examined how the addition of hybrid fibre reinforcement affects the ability of high-strength concrete (HSC) to withstand harsh climatic conditions over time. Their research showcased that the amalgamation of steel and synthetic fibres enhanced the durability of high-strength concrete (HSC) against freeze-thaw cycles and chemical degradation. The researchers determined that the use of hybrid fibre reinforcement improves the long-term durability of high-strength concrete (HSC) in challenging conditions.

In their 2014 study, Kanda et al. examined the fracture behaviour of High-Strength Concrete (HSC) that was reinforced with hybrid fibres. The study focused on both static and dynamic loading situations. Their study shown that the incorporation of steel and polypropylene fibres augmented the ability of high-strength concrete (HSC) to absorb energy and resist impact. The researchers determined that the use of hybrid fibre reinforcement enhances the structural integrity of high-strength concrete (HSC) under dynamic loading conditions.

Li et al. (2017) examined the bond characteristics of hybrid fiber-reinforced high-strength concrete (HSC) and steel reinforcing bars. Their research showed that the integration of steel and synthetic fibres increased the adhesive strength and resistance to extraction of high-strength concrete (HSC). The researchers determined that the use of hybrid fibre reinforcement enhances the structural integrity and load-bearing capability of high-strength concrete in reinforced concrete components.

Oliveira et al. (2019) conducted a study that examined the characteristics of high-strength concrete (HSC) reinforced using a combination of different types of fibres, focusing on both its fresh and hardened qualities. Their research shown that the use of steel and synthetic fibres enhanced the manipulability, compressive strength, and longevity of HSC. The researchers determined that the use of hybrid fibre reinforcement is a practical method for improving the performance of high-strength concrete in construction applications.

Pereira et al. (2015) examined the impact of hybrid fibre reinforcement on the propagation of cracks and the behaviour of high-strength concrete (HSC) after cracking. Their research showcased that the amalgamation of steel and synthetic fibres led to diminished crack widths and enhanced ductility in High Strength Concrete (HSC) samples. The researchers determined that the use of hybrid fibre reinforcement improves the ability of High Strength Concrete (HSC) to resist cracking and enhances its overall structural performance.

In 2018, Razak et al. did a study to investigate the impact resistance of High Strength Concrete (HSC) reinforced with hybrid fibres. Their study demonstrated that the incorporation of both steel and synthetic fibres enhanced the ability of High-Strength Concrete (HSC) to absorb energy and withstand impact when subjected to dynamic loading conditions. The researchers determined that the use of hybrid fibre reinforcement improves the strength and resilience of high-strength concrete in applications that are prone to impact damage.

Singh et al. (2016) examined the impact of hybrid fibre reinforcement on the bending characteristics of high-strength concrete (HSC) beams. Their research showcased that the integration of steel and synthetic fibres led to improved flexural strength, ductility, and fracture management in high-strength concrete beams. The researchers determined that the use of hybrid fibre reinforcement enhances the structural integrity and functionality of high-strength concrete in bending situations.

Tan et al. (2019) conducted a study on the adhesive force of high-strength concrete (HSC) and hybrid fibre reinforcement. Their study demonstrated that the incorporation of steel and synthetic fibres enhanced the adhesive properties and interfacial bond strength of high-strength concrete (HSC). The researchers determined that the use of hybrid fibre reinforcement improves the structural integrity and load transfer mechanisms of high-strength concrete in reinforced concrete parts.

Wang et al. (2017) In their study, Wang et al. (2017) examined the impact of hybrid fibre reinforcement on the shrinkage and cracking characteristics of high-strength concrete (HSC). Their research showcased that the amalgamation of steel and synthetic fibres mitigated shrinkage-induced cracking and enhanced the overall durability of high-strength concrete (HSC). The researchers determined that using hybrid fibre reinforcement is an effective method for addressing shrinkage-related problems in high-strength concrete (HSC).

Xu et al. (2018) investigated the long-lasting properties of High-Strength Concrete (HSC) that was reinforced with a combination of different types of fibres. The study focused on how the HSC performed when subjected to harsh environmental circumstances. According to their research, the incorporation of steel and synthetic fibres improved the durability of high-strength concrete (HSC) by increasing its resistance to freeze-thaw cycles, chloride penetration, and sulphate corrosion. The researchers determined that the use of hybrid fibre reinforcement enhances the long-term resilience and lifespan of high-strength concrete (HSC) in challenging conditions.

Yang et al. (2015) examined how the addition of hybrid fibre reinforcement impacts the dynamic mechanical properties of high-strength concrete (HSC). Their research highlighted that the amalgamation of steel and synthetic fibres enhanced the ability of High-Strength Concrete (HSC) to withstand dynamic loading conditions by improving its impact resistance, energy absorption capacity, and ductility. The researchers determined that the use of hybrid fibre reinforcement improves the structural performance and resilience of high-strength concrete (HSC) in dynamic applications.

Zhang et al. (2016 In 2016, Zhang et al. conducted a study on the fatigue behaviour of High Strength Concrete (HSC) reinforced with hybrid fibres. Their study shown that the incorporation of steel and synthetic fibres enhanced the ability of High-Strength Concrete (HSC) to withstand fatigue and resist fracture propagation when subjected to cyclic loading conditions. The researchers determined that the use of hybrid fibre reinforcement improves the longevity and durability of high-strength concrete (HSC) in applications that are prone to fatigue.

In their study, Chen et al. (2020) examined the impact of hybrid fibre reinforcement on the fire resistance of high-strength concrete (HSC). Their research revealed that the amalgamation of steel and synthetic fibres enhanced the fire resistance and remaining durability of high-strength concrete (HSC) under high temperatures. The researchers determined that the use of hybrid fibre reinforcement improves both the fire resistance and structural integrity of high-strength concrete (HSC) when exposed to fire.

Gan et al. (2017) In 2017, Gan et al. conducted a study on the impact behaviour of High Strength Concrete (HSC) reinforced with hybrid fibres. Their study demonstrated that the integration of steel and synthetic fibres enhanced the ability of High-Strength Concrete (HSC) to withstand impact forces and absorb energy. The researchers determined that incorporating hybrid fibre reinforcement improves the strength and durability of high-strength concrete in applications that are susceptible to impact.

Huang et al. (2018) examined the impact of hybrid fibre reinforcement on the fracture toughness of high-strength concrete (HSC). Their study highlighted the synergistic effect of steel. In her 2014 paper titled "Mechanical Behaviour of Sisal Fibre Reinforced Cement Composites" published in the International Journal of Mechanical, Aerospace, Industrial, Techtronic and Manufacturing Engineering, M. Aruna investigated the hardness and tensile strength of cement composites reinforced with sisal fibres. The composites were made with varying weight percentages of sisal fibres, specifically 6%, 12%, 18%, and 24% by weight of cement. The study demonstrates enhancement in the tensile strength. Increasing the fibre volume fraction and length decreases the workability of the mix. The composite exhibited a heightened potential for absorbing high levels of energy, resulting in improved toughness and stress values. In their 2016 publication titled "Analysis of Self-Compacting Concrete Using Hybrid Fibres," Apoorva Chandak et al. conducted a comparative study between conventional concrete and self-compacting fibre reinforced concrete. The study specifically focused on the use of sisal fibre and hybrid fibre of banana. The objective of this study is to develop a self-compacting concrete by increasing the amount of coarse aggregate and enhancing its mechanical qualities, such as tensile, flexural, and compressive strength. Additionally, the compaction factor and slump values were verified. A concrete mixture with a grade of M30 was made. Hybrid fibre was added to the PPC cement at a ratio of 0.5% of the cement. The water cement ratio was maintained at 0.45, and an additive called sikacim was added at a ratio of 1%. Using Steel Fibre Reinforced Concrete (SFRC) results in a reduced slump, indicating a decrease in workability. In order to enhance the workability, a plasticiser was employed. The incorporation of fibre into concrete to enhance its compressive and flexural strength. Abdul Rahuman and colleagues [4].The author conducted a study titled "Study on properties of Sisal Fibre Reinforced Concrete with different mix proportions and different percentage of Fibre Addition" which was published in the International Journal of Research in Engineering and Technology in 2015. The study aimed to evaluate the workability and strength properties of a composite material made of sisal fibre reinforced with OPC cement. A Super plasticiser was included into the cement mixture at a concentration of 0.2% by weight. The sisal fibre content in the concrete mixes varied at 0.5%, 1%, and 1.5% relative to the weight of cement.

The study conducted by P. Sathish and colleagues [5], The paper titled "Experimental Study on Sisal Fibre reinforced concrete with partial replacement of cement by Ground Granulated Blast furnace Slag" was published in the International Journal of Science and Research in 2016. The research focused on replacing a portion of OPC cement with varying percentages of slag and analysing various mechanical properties. The construction material utilised was OPC cement of grade 53. Slag was incorporated at proportions of 10%, 20%, and 30% relative to the weight of cement. Additionally, 1% of sisal fibre was included based on the weight of the cement. A concrete mixture with a strength grade of M30 was created. The early stage of GGBS concrete exhibited a gradual rate of development in compressive strength. As the duration of the curing process extended, the level of strength likewise rose. The addition of GGBS resulted in an enhancement of compressive, tensile, and flexural strength, except when the cement was replaced by 30% with GGBS, which led to a drop in strength. The most effective dosage for partially replacing cement with 20% ground granulated blast furnace slag and 1% sisal fibre resulted in the greatest improvement in the mechanical characteristics of concrete. In their 1995 publication in Cement and Concrete Composites, A. M. Alhozaimy et al. investigated the impact of collated fibrillated polypropylene fibres on the compressive and flexural strength of concrete. The study focused on the mechanical properties of polypropylene fibre reinforced concrete and also examined the influence of pozzolanic materials. An evaluation was conducted to determine the impact resistance of Polypropylene fibre. The materials utilised included Portland cement type I, coarse aggregate, fine aggregate, water, and collated fibrillated polypropylene fibres. The study found that the addition of Polypropylene fibre does not have a notable impact on the compressive strength and toughness of ordinary concrete.H

3. CONCLUSION

The thorough examination of research articles in this paper clearly demonstrates that Hybrid Fibre Reinforced Concrete (HFRC) is an innovative material that provides numerous advantages and has a wide range of applications. Here is a more comprehensive understanding obtained from the analysed literature:

Reducing Negative Impact and Increasing Flexural Strength: The combined use of Nano-silica and hybrid fibres (steel and polypropylene fibres) not only successfully reduces the harmful effects caused by waste bottom ash (WBA), but also significantly enhances the flexural strength of Ultra-High Performance Fibre Reinforced Concrete (UHPFRC). This novel method represents a fundamental change towards the creation of environmentally-friendly concrete, while also obtaining exceptional mechanical characteristics.

Temperature-Dependent Behaviour: Studies have shown a significant reduction in both the tensile and compressive strength of hybrid fibre reinforced concrete as the temperature increases. This temperature-dependent behaviour highlights the importance of carefully considering thermal effects in applications exposed to high temperatures, in order to guarantee structural integrity and optimal performance in various environmental circumstances.

Impact of Fibre Type, Dosage, and Geometry on Workability: The workability and rheological qualities of concrete mixtures are influenced by several parameters, including the kind, dosage, and geometry of the fibres used. Furthermore, in hybrid mixtures, the complex interactions and combined effects between different types of fibres become crucial factors that shape the workability characteristics. This requires customised mix designs to provide maximum performance.

Improving Mechanical Properties through Fibre Blending: The use of both micro fibres and macro fibres in hybrid fibre concrete results in significant improvements in the modulus of rupture, deflection capacity, and energy absorption capacity. The selection of macro fibre type has a substantial impact on the extent and characteristics of these enhancements, emphasising the significance of a comprehensive approach to fibre blending techniques.

Criteria for Evaluating High-Performance HFRC: In order to achieve high-performance hybrid fibre concrete, it is necessary to conduct a comprehensive assessment that considers factors such as compaction capacity and a range of static qualities including compressive strength, modulus of rupture (MOR), and splitting strength. This comprehensive evaluation framework guarantees the achievement of exceptional mechanical properties that are crucial for challenging structural applications. The role of steel fibres in crack mitigation and enhanced durability is to strengthen the concrete and improve its ability to withstand cracking. By integrating steel fibres into the concrete matrix, it increases the concrete's ability to absorb energy, enhances its apparent ductility, and provides effective mechanisms to resist and control cracks. These reinforcements greatly enhance the overall strength, lifespan, and ability to withstand pressure of concrete constructions.

Enhancing Toughness by Synergistic Hybrid Fibres: By using hybrid fibres, the toughness indices of reinforced concrete structures are significantly increased, resulting in improved flexural toughness, stiffness, and overall performance. The combination of different fibres in reinforcing concrete enhances its strength and durability when subjected to dynamic loads and environmental stresses. To summarise, the analysis of information gathered from the literature research confirms that HFRC remains a cutting-edge material in the field of current concrete technology. HFRC, with its exceptional capacity to improve mechanical characteristics, reduce environmental impacts, and guarantee structural resilience, is leading the way for a new era of sustainable and high-performance concrete building.

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