

A Study on Strength and Durability of Geo-Polymer Fiber-Reinforced Concrete

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Abstract : Portland cement is highly workable but tends to be weak under stress and prone to cracking. These weaknesses can be mitigated by incorporating standard steel reinforcements, along with the partial addition of various specialized fibers. The inclusion of fibers enhances the strength of the fiber-matrix composite and significantly alters its post-failure behavior. The objective of this paper is to present insights into the quality and compatibility of commonly used fibers and their application in producing concrete with improved properties. This study provides an overview and discussion of related research on fiber-reinforced concrete, specifically focusing on the use of different types of geo-polymer fibers in the preparation of concrete samples.

IndexTerms – Fiber, Concrete, Geo-Polymer, Cement, SRF.

I. INTRODUCTION

Portland cement is widely used in construction due to its high workability and ease of molding into various shapes. However, despite its versatility, it is inherently brittle and prone to cracking and failure under tensile stress or dynamic loading. These mechanical limitations reduce its long-term durability and structural reliability, especially in applications exposed to heavy loads, temperature variations, or shrinkage effects.

To mitigate these issues, conventional reinforcement techniques involve the incorporation of steel bars or meshes. Additionally, the inclusion of discrete fibers such as steel, glass, synthetic, or natural fibers has emerged as an effective strategy to improve the mechanical performance of concrete. When added to the cementitious matrix, these fibers form a fiber-reinforced composite, which enhances strength, toughness, and post-cracking behavior by bridging cracks and delaying their propagation.

This paper aims to provide an in-depth overview of the types, properties, and compatibility of commonly used fibers in concrete, with a particular focus on their application in producing concrete with enhanced strength, ductility, and durability. A newer development in this area is the use of cellulose fibers, which are derived from renewable natural sources and offer a sustainable alternative to synthetic reinforcements.

Fibers used in concrete can vary in terms of material composition—ranging from steel, plastic (polypropylene), and glass, to carbon and natural fibers (such as hemp, coconut, and cellulose). They also differ in size, aspect ratio, geometry (e.g., hooked, straight, crimped), and surface treatment, all of which significantly influence the performance of the fiber-reinforced concrete (FRC).

The integration of such fibers transforms traditional cementitious materials into smart composites with tailored mechanical behavior, making them suitable for a wide range of structural and non-structural applications. These include

pavements, industrial floors, tunnel linings, precast elements, and even 3D-printed construction components, where improved crack resistance and mechanical resilience are critical.

II. FIBER REINFORCED CONCRETE (FRC)

Fiber-reinforced concrete is a cementitious mixture, aggregate or compact, mixed with suitable, discrete, well-defined and well-dispersed fibers. There are many types and levels of fiber, each with its own benefits. The various fibers do not include continuous nets, braids, cables or long bars. Fibers are little things that make them strong with special properties [2]. They can be round or flat and come in a variety of shapes and sizes. Aspect ratio is a useful parameter commonly used to characterize cables. The diameter of a fiber is the ratio of its length to its diameter. The proportions are generally between 30 and 150. FRC is a type of concrete with fibrous material to increase its strength properties. It is made up of small insulating fibers that continuously distribute and rotate randomly. Fibers include metallic fibers, glass fibers, synthetic fibers and natural fibers. The properties of fiber reinforced materials depend on the materials used, the fiber materials, the shape, distribution, orientation and density of these different fibers. Shotcrete supports multiple threads and can be used with a normal computer. Traditional concrete floors are often used for flooring and walkways, but can be used for a variety of other building materials. (Beams, fixtures, foundations, etc.) Alone or in combination with hand-bonded rebar, fiber concrete (usually steel, glass, or "plastic") is ten times cheaper than rebar. The shape, size and length of the fiber are important. Short fibers, such as short-hair glass fibers, are only effective in the first few hours after the concrete is poured (reducing shrinkage as the concrete hardens), but they do not increase the concrete's tensile strength.

Fibers are widely used in concrete to prevent shrinkage cracking due to resin shrinkage and drying shrinkage. It also prevents water seepage by reducing the permeability of the concrete. Concrete containing certain fibers is more resistant to impact, abrasion and spalling. Fiber generally does not increase the flexural strength of concrete, so it can also be used as a substitute for flexural or structural reinforcement. Certain fibers reduce the strength of concrete.

2.1. Advantages of Fiber Reinforced Concrete (FRC)

- Increase the tensile strength of the material.
- Reduces air and water pockets in the natural pores of the gel.
- Longevity is good.
- Most resins have low creep resistance, but graphite and glass have high creep resistance. Therefore, the orientation and number of fibers has a significant effect on strengthening / stretching muscle performance.
- Reinforcement material is a complex material that uses reinforcing steel as a reinforcing material and as a matrix. Both are important
- The material behaves similarly under thermal stress, reducing the different deformations between the material and the reinforcement.
- It is known that a fine, thick and smooth fiber with a material will make it anti-crack and improve the elastic properties and strength of the material.

2.2. Disadvantage of Fiber Reinforced Concrete (FRC)

- Rain exposes the fibers.

- One of the disadvantages of the fiber enhancer is that it interferes with the specific function of the fiber enhancer.
- The problem is one of the network servers on the computer. In addition, fiber balls are produced during the blending process.
- Another disadvantage is that fiber-reinforced concrete is heavier than non-fibrous concrete. There is also a risk of corrosion when using steel fibers.
- Finally, fiber-reinforced concrete is usually more expensive than regular concrete, but other factors can offset the cost.

2.3. Use of Fiber Reinforced Concrete (FRC)

- It was used for refractory lining, road overlays with explosive-resistant construction, and airport overlays.
- It is used to create precast items like pipelines, boats, beams, stairways, wall panels, roof panels, manhole covers, etc.
- Doors and door frames, pressure pipes, permanent and temporary formwork, bus shelters, and park benches are all constructed with glass fibre.

III. LITERATURE REVIEW

Mortada et al. (2025) investigated steel fiber-reinforced 3D-printed geopolymer concrete (GPC), finding significant improvements in flexural and tensile strength, ductility, and interlayer bonding, especially using 1.2% recycled steel fibers [1]. Sharma et al. (2024) reviewed fiber-reinforced GPC (FRGC), emphasizing the environmental benefits and mechanical enhancements offered by steel, glass, polypropylene, and basalt fibers [2]. Waqas

et al. (2024) studied GPC with quarry rock dust and steel fibers in circular columns, noting enhanced load capacity and ductility compared to OPC, supporting its structural application [3]. Laxmi et al. (2024) examined hooked-end steel fibers in ambient-cured GPC, achieving optimal strength and durability at 1% fiber content [4]. Qin et al. (2023) provided a comprehensive review of FRGC, highlighting improved toughness and chemical resistance, while identifying research gaps in interface behavior and fiber treatment [5]. Chandrashekhar et al. (2022) analyzed prestressed synthetic fiber-reinforced beams, showing improved ductility and strength at higher fiber content, supported by finite element modeling [6]. Karimipour et al. (2022) tested RC beams with up to 2% steel fibers, developing predictive models for flexural performance [7]. Garg et al. (2022) used sawdust and brick waste as partial aggregates, producing cost-effective lightweight concrete with acceptable strength for non-structural applications [8]. Mansoor et al. (2022) found that replacing cement with up to 15% waste brick powder improved strength and reduced permeability, enhancing durability [9]. Chandar et al. (2022) reviewed cementitious alternatives like fly ash, slag, and silica fume, affirming their effectiveness in improving concrete sustainability and durability [10].

IV. CONCLUSION

This study highlights the potential of fiber-reinforced geopolymer concrete (FRGC) as a sustainable and high-performance alternative to conventional Portland cement concrete. By incorporating various types of fibers such as steel, glass, synthetic, and natural fibers into geopolymer binders, significant improvements in mechanical properties, particularly tensile strength, ductility, impact resistance, and durability, can be achieved. The literature survey confirms that optimal fiber content, geometry, and

distribution are critical factors influencing the performance of fiber-reinforced composites. Furthermore, the use of industrial by-products like fly ash, slag, and waste brick powder as partial replacements for cement or aggregates not only enhances sustainability but also contributes to mechanical and durability gains. Although fiber-reinforced concrete does present challenges such as mixing complexity, increased cost, and potential corrosion in the case of steel fibers, its advantages especially in structural integrity and longevity outweigh the limitations for many applications. From pavements and precast products to 3D-printed and high-performance structures, FRGC offers a viable path toward eco-friendly and resilient construction practices. Future research should focus on optimizing fiber types and treatments, understanding fiber–matrix interfacial behavior, and developing standardized design guidelines for field applications to fully realize the potential of fiber-reinforced geopolymer concrete in modern infrastructure.

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