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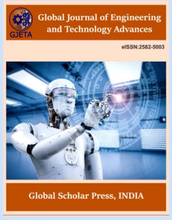

(Review Article)

Fiber incorporation and crack control: A synergistic approach to improving serviceability of RC concrete

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Abstract

This research elaborates on how cracking affects RC fiber concrete serviceability. It describes the different forms of fibrous concrete and how they function under cracking impact, enhancing concrete structure serviceability. Practical mechanical behavior language is often used to assess materials' performance. Historical assessment should help create experiences using RC fiber concrete, which reduces cracking and enhances concrete structures' serviceability. The issue is chronologically linked through early and modern author references. However, fibrous concrete's construction path is desirable worldwide. Fibrous concrete is employed in many building applications, from rehabilitation to new construction, due to its advantages over conventional construction materials. Lightness, high mechanical performance, the ability to manufacture in any form, ease of assembly, and a reduced need for supporting structures, controlled anisotropy, high specific strength, and specific stiffness all improve the serviceability of concrete structures. Fibrous concrete's many properties are opening new construction industry pathways. Thus, this research reviews the present use of fibrous concrete on cracks to improve concrete structure serviceability.

Keywords: Fibrous Concrete; Cracking Impact; Construction Industry; Serviceability Enhancement.

1. Introduction

Reinforced concrete constructions are extensively employed in the construction sector due to their cost effectiveness, durability, and strength. However, these structures are susceptible to cracking and deflection, which may negatively impact their safety, serviceability, and appearance. When cracks occur in these structures, they can lead to moisture and chemicals infiltrating the concrete, resulting in corrosion of the reinforcement and damage to the concrete. The cracks can also reduce the structure's lifespan and detract from its aesthetic appeal. Moreover, cracks can compromise the structure's safety by lowering its load-bearing capacity, increasing deflection and vibration, and heightening the risk of collapse. Consequently, it is vital to comprehend the factors contributing to cracking and deflection and to formulate methods to mitigate these issues.

The roots of cracks in reinforced concrete structures can be generally classified into two groups: external and internal factors. External factors comprise changes in temperature, variations in moisture, and environmental loads, like wind, earthquakes, and traffic. On the other hand, internal factors consist of concrete shrinkage, creep, and thermal deformation, as well as inconsistencies in the characteristics of the concrete and reinforcement [1].

The loss of moisture during the concrete hardening process causes concrete shrinkage, which is a significant internal cause of cracks in reinforced concrete structures. Tensile stresses can form in the concrete due to shrinkage, resulting in cracking.

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Another contributor to cracking is concrete creep, which is the gradual deformation of concrete under constant loading, leading to long-term tensile stresses in the concrete.

Temperature fluctuations can also lead to cracking in reinforced concrete structures. High temperatures can cause concrete to expand and develop compressive stresses, while low temperatures can cause it to contract and develop tensile stresses. Cracking can occur if these stresses exceed the concrete's tensile and compressive strength. Environmental loads, like wind, earthquakes, and traffic, can also cause cracking in reinforced concrete structures by creating dynamic or cyclic loading conditions that can cause fatigue cracking or overload cracking in the structure [2]. There are a lot of likely problems that could arise if reinforced concrete buildings start cracking. Consequences can be felt immediately, or they can linger for a while. Reduced stiffness and strength are the most obvious immediate effects; corrosion, water seepage, and longevity issues are some of the longer-term implications. [3]. If cracking occurs in RC structures, it can cause a decrease in stiffness and strength, leading to greater deflections and deformations. This, in turn, can result in additional cracking, further diminishing the structure's stiffness and strength. When cracking becomes too severe, the serviceability and performance of the structure may be compromised [1].

Understanding the cracking behavior of concrete structures is crucial for evaluating their functional capabilities. Merely verifying that the steel and concrete do not experience excessive stress is inadequate in the design of reinforced concrete structures. It is also essential to ensure their resilience against environmental conditions and maintain their usability. The development of minor internal cracks due to volume changes can escalate into larger cracks, while cyclic cracking in concrete arises from its inherent vulnerability to tension. These factors can ultimately render concrete structures non-functional [4].

In RC concrete design and construction, it is crucial to prioritize cracking control in order to guarantee the longevity, functionality, and visual appeal of concrete structures. By employing an appropriate mix of design and placement techniques, the likelihood of cracking resulting from shrinkage and internal factors can be minimized. Additionally, the incorporation of reinforcement and meticulous detailing can effectively prevent or manage cracks caused by external factors like environmental loads. However, the efficacy of these methods is influenced by various factors, including the nature and intensity of the loads, the chosen design and construction approaches, and the prevailing environmental conditions. Thus, it is imperative to consider these factors when selecting and implementing cracking control measures [5]. Implementing crack control strategies, such as incorporating fiber reinforcement, can effectively mitigate the occurrence of cracking in RC structures. The utilization of fiber-reinforced concrete enhances the structure's ductility and toughness, thereby minimizing the likelihood of cracking resulting from external loads. Furthermore, the inclusion of steel reinforcement offers added strength and rigidity to the structure, consequently diminishing the risk of cracking [4].

Fiber-reinforced concrete (FRC) is a composite material composed of a cementitious matrix fortified with discrete fibers. FRC can incorporate metallic, synthetic, or natural fibers, which are included in the concrete mix to enhance its mechanical characteristics, such as its tensile strength, toughness, and durability. By adding fibers to the concrete, its flexural strength, toughness, impact resistance, and fatigue resistance are improved. The fibers act as a reinforcement, preventing the expansion of cracks in the concrete matrix. Compared to conventional concrete, the tensile strength of FRC is notably higher, and it also presents improved ductility, which enables it to withstand more deformation before reaching failure. [6].

FRC incorporates different types of fibers, including steel fibers, polypropylene fibers, glass fibers, and carbon fibers. Steel fibers are frequently chosen for FRC because of their excellent tensile strength and ductility. Polypropylene fibers are preferred due to their affordability, resistance to corrosion, and ease of handling. Glass fibers are utilized when a high modulus of elasticity is necessary, while carbon fibers are employed in applications that demand exceptional strength and stiffness [7,8].

Fiber-reinforced concrete (FRC) has found diverse applications owing to its superior mechanical properties in comparison to standard concrete. The inclusion of fibers elevates the tensile strength, toughness, and ductility of the concrete, resulting in improved resistance against cracking and deformation [9]. Bridge decks, airport pavements, industrial floors, and even tunnel linings are just some of the places where FRC has been put to use. FRC has been shown to lengthen the life of bridge decks and make them less prone to cracking. Airport pavements that use FRC have seen increased skid resistance and decreased rutting. FRC has been utilized to lessen the likelihood of cracking in industrial flooring caused by severe weights and impact loading. As a result of its high resilience to fire and blast stresses, FRC has also been employed in tunnel linings.

2. Advancements in Fiber Reinforced Concrete

Since the 1980s, numerous novel types of fibers and fiber configurations have been introduced, leading to notable changes in the production methods and performance measures of fiber-reinforced concrete (FRC), particularly in terms of strength and crack control. The availability of FRC component materials, along with advancements in admixtures and production techniques, has positively impacted the attainable fiber concentrations in real-world applications and the efficiency of fiber bonding. These factors significantly influence the mechanical properties of FRC. Consequently, with the advancements in technology, designers and suppliers of materials can now economically produce and specify a wide range of FRC formulations [10].

In recent decades, notable progress has been achieved in the realm of fiber-reinforced concrete (FRC), specifically in the exploration of novel fiber materials, refinement of fiber quantities, and comprehension of the material's response to diverse loads. These technological advancements have had a substantial influence on the domain of concrete technology. The incorporation of hybrid fibers and nanofibers has empowered engineers to create concrete structures with enhanced characteristics, including heightened toughness, ductility, and durability. These properties play a vital role in guaranteeing the prolonged functionality of concrete structures [9].

In recent investigations into fiber-reinforced concrete (FRC), the emphasis has been on enhancing its mechanical properties and discovering novel avenues for its application. One particular study conducted by [11] examined the impact of utilizing hybrid fibers on the mechanical characteristics of FRC. The findings indicated that the combination of steel and polypropylene fibers enhanced the concrete's toughness and ductility. Another study conducted by [12] delved into the integration of FRC in earthquake-resistant structures. The research revealed that FRC can significantly enhance the seismic performance of structures by augmenting their capacity for energy dissipation.

With the goal of improving several material properties, the science behind hybrid fiber reinforcement concrete (HyFRC) has recently advanced. Hybrid fiber-reinforced composites are made by mixing two or more fiber types in the right proportions to create a material with enhanced mechanical and physical properties [9]. Hybrid fiber-reinforced composites are reinforced constructions in which two or more types of fiber are used together to produce a single matrix structure [13]. Pre-treatment of fiber, the use of compatibilizers or additives in the matrix, and the hybridization of natural or synthetic nanofibers are just a few of the strategies that have been used to date to enhance the mechanical characteristics of natural fibers [14]. The hybridization of two or more natural fiber matrices can greatly improve the performance of concrete composites while cutting costs [15].

The use of nanotechnology to enhance FRC qualities is another recent development in this area of technology. The term "nanofiber" refers to fibers with a diameter of 100 nanometers or less. It has been discovered that FRC's mechanical properties are greatly enhanced by the incorporation of nanofibers. Because of their great surface area, nanofibers link more strongly with the cement matrix, increasing the strength and longevity of the final product [16].

Furthermore, self-healing FRC has been a major breakthrough in concrete technology. Cracks in self-healing FRC release healing ingredients contained in capsules, which can be bacteria or polymers. The cracks are sealed, and the concrete's strength is restored while the healing agents do their work. This innovation has the potential to greatly extend the useful life of buildings made of concrete. Self-healing FRC has the ability to completely alter the landscape of concrete engineering. Concrete structures may see a large increase in their service life and a decrease in the frequency of costly repairs or replacements if cracks could be repaired [16].

Properties of the fiber matrix, the volume of fiber inclusion, fiber geometry, fiber type, and orientation of fiber in the concrete mixture all play a role in how effective the fiber is [17]. Tensile strength for carbon and stainless-steel metallic fibers is in the 200-to-2600 MPa range. The qualities of concrete that have been reinforced with synthetic fibers depend significantly on the fibers' elastic modulus. When new fibers are added to FRC, the material undergoes a dramatic transformation in terms of its characteristics [18].

3. Steel fiber

Fibers are classified into three categories: metallic, polymeric, and natural. Among these categories, steel fibers are the most frequently employed for both structural and nonstructural applications [19]. Subsequently, polypropylene, glass, and other fibers are utilized to a lesser extent, particularly in structural concrete applications [20]. The preference for steel fibers can be attributed to various factors, such as economic considerations, availability of manufacturing facilities, reinforcing capabilities, and resilience to adverse environmental conditions [20].

Steel fibers are frequently employed; they are short, discrete lengths of steel with an aspect ratio (length-to-diameter ratio) of roughly 20 to 100, a range of cross sections, and dimensions of 25 to 60 mm in length and 0.4 to 1.3 mm in diameter [21,22]. These fibers can be sufficiently small to achieve a random distribution within the matrix when using conventional mixing methods. The manufacturing process of steel fibers is influenced by multiple factors, which include the material properties of the fibers (such as strength, stiffness, and Poisson's ratio), environmental conditions, the fiber geometry (including end-hooked, crimped, and twisted variations), the volume of fibers incorporated in the material, the properties of the matrix (such as strength, stiffness, and Poisson's ratio), and the characteristics of the interface (such as adhesion, frictional properties, and mechanical bonding). Figure 1 provides visual representations of different geometrical shapes of steel fibers [23].

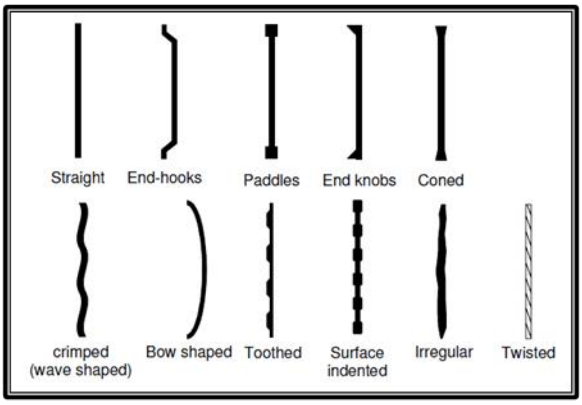

Figure 1 Steel fiber geometrical shapes, [24].

Researchers all across the world have looked into the effectiveness of steel fiber-reinforced concrete (SFRC). Mechanical characteristics and longevity are two areas where SFRC has been shown to outperform regular concrete in a number of investigations. It has been demonstrated that incorporating steel fibers into concrete increases its ductility, toughness, and flexural and shear strengths. Superior resistance to cracking, shrinking, and deformation across a wide range of loading situations is another benefit of SFRC [25].

The incorporation of steel fibers into concrete leads to a significant enhancement in its compressive strength. An effective increase in both compressive and flexural strength can be achieved by utilizing 3% steel fibers by volume of cement [6]. As the volume fraction of steel fibers increases, the shear strength of the concrete also increases. However, this increase in shear strength is accompanied by a notable decrease in the workability of the concrete. To mitigate this issue, the use of superplasticizers is necessary for fiber-reinforced concrete (FRC). Additionally, the presence of steel fibers contributes to an increase in the toughness of the concrete, leading to a different crack pattern compared to normal concrete. SFRC exhibits a ductile mode of failure, which differs from the crack pattern observed in ordinary concrete [8].

Unlike unreinforced composites, which fail in stress and flexure as soon as a single fracture occurs, steel fiber reinforced concrete can be repaired. Plastic and drying shrinkage cracks can be prevented and tracked with the help of steel fibers in concrete. Steel fibers integrated into concrete have been shown to improve its ductile performance prior to ultimate failure, cracking resistance, durability, and flexural resilience [26]. among other properties. Precast components, tunnel linings, ground slabs, raft foundations, and tunnels are only a few of the structural uses for steel fibers. In some structural applications, conventional reinforcement is used in tandem with steel fibers to either limit cracking or develop resistance to material degradation due to shrinkage, impact load, fatigue load, or thermal stresses [27].

Recent research studies have focused on various aspects of SFRC, including its mechanical properties, durability, and performance under different loading conditions. A study by [28] investigated the effect of steel fiber length and volume fraction on the mechanical properties of SFRC. The results showed that increasing fiber length and volume fraction improved the flexural and compressive strength of SFRC. Another study by [29] evaluated the performance of SFRC under freeze-thaw cycles. The results indicated that SFRC exhibited better resistance to freeze-thaw damage compared to plain concrete.

The flexure behavior of SFRC beams has been the subject of much research, with encouraging findings regarding the material's enhanced resistance to cracking, stiffness, ductility, impact, abrasion, and energy absorption. Steel fiber-reinforced concrete slabs performed better under impact loading compared to non-fibrous slabs, according to research [30]. The speed of crack propagation and severity of localized cracks were found to be significantly affected by the steel fiber content. Beams made of fiber-reinforced concrete can have a bond efficiency somewhere between 1.0 and 2.2 due to the steel fibers intertwining with the matrix in the tensile zone [7].

4. Fiber's Impact on Crack Development

Concrete cracking is a problem that can range from annoying to disastrous, according to professionals in the industry. No matter where they emerge, cracks are always caused for alarm. It's usually just as difficult and expensive to fix the cracking.

Concrete cracking has been proven to be a historical pattern. When strains exceed the strength of the concrete, cracks appear. Members of structures made of concrete are renowned for their great compression and low tension. Thus, when tensions exceed the tensile strength of the concrete or the tensile capacity of the concrete structural part, cracks form in the tension zone. When the tensile stress in a structural member is greater than its tensile strength, microfractures occur on the inside of the member. These microcracks enlarge into macrocracks that travel along the external fibers of the structural members [2].

Internal stresses pose a significant challenge in the concrete industry. These inherent stresses stem from the shrinkage of concrete, making them difficult to predict in terms of frequency and variation. Concrete shrinkage occurs due to internal settlement and rapid evaporation of water from the specimens, leading to the development of internal cracks. These cracks typically manifest within the first 24 hours after pouring the concrete. Conversely, Plastic Shrinkage cracks become visible at a later stage. Although these cracks do not affect the structural integrity, they persist until the concrete fully hardens, and they actually lengthen during the drying process. The presence of cracks allows water to permeate through the concrete, enabling the entry of salts and other harmful substances, which ultimately diminish the durability and lifespan of the concrete [31].

Prior to being subjected to any loads, concrete typically displays numerous microcracks. The weakest aspect of the composite concrete system is usually the interface between the aggregate and mortar [31]. When concrete is loaded, cracks typically emerge at the interfacial transition zone, which is often the weakest part of hardened concrete, and these cracks impact the mechanical characteristics of the concrete. Because cement-based materials possess low tensile strength and low tensile strain capacity, concrete is inclined to exhibit brittle behavior, and cracks are nearly unavoidable in any concrete structure. The primary reason for the formation of cracks is the application of a load that surpasses the low tensile strength of the concrete. These cracks propagate under loading and contribute to the nonlinear behavior at low-stress levels and volumetric expansion until the point of failure [32].

With the advent of fibrous concrete, the construction sector now has a tool at its disposal to prevent the spread of soft cracks. By introducing a variety of fibers into the matrix, fibers serve as secondary reinforcement for concrete. Since fibrous concrete has a higher tensile strain potential, it is far less likely to develop plastic shrinkage fractures during curing [33]. There is less of a chance for cracking due to plastic shrinkage, and the concrete is better able to strengthen for the long haul as a result. Concrete structures that include the fibers may theoretically exhibit improved cracking behavior. Fibers' influence on crack initiation is shown in Figure 2.

Figure 2 Influence of fibers on cracks development, [34].

When employed in accordance with an engineer's recommendations, fibrous concretes can provide an exceptional crack control mechanism throughout the concrete production process. The presence of fibers in advance of a crack's edge can also have a toughening effect, making the composite more robust. As a result, fibrous concretes may cause changes to the way concrete breaks. Simply altering the cracking process allows for the transformation of macro cracking into micro cracking. As a result, the cracks become smaller, reducing the penetrability of the concrete and increasing the overall cracking pressure of the structures [35]. Additionally, fibrous concretes have been useful in preventing fatigue damage in structures, extending fatigue life, enhancing fatigue load capability, decreasing fatigue damage gradation, and delaying the onset of structural damage. One of the most important benefits of employing fibrous concretes is that the addition of fibers improves the durability, or residual load-carrying capacity after the first fracture, hence reducing the penetrability and fatigue damage gradation. Therefore, fibrous concretes can fulfill the needs for structural strengthening and serviceability in impact performance despite cracking [36].

Fibers possess the capacity to transmit pressure from the matrix and withstand stretching forces during the breaking point. This ability of fibers leads to enhancements in the concrete's resilience after cracking and its ability to withstand impacts.

Consequently, incorporating fibers with an elastic modulus greater than that of the matrix can boost the concrete's strength. So, before macrocracks are formed, the matrix disperses some of the load throughout the fibers [37].

The principal effect of the fibers in FRC occurs after the matrix has cracked. Because of their flexibility, steel fibers can span fissures and distribute the load evenly. Steel fibers can prevent cracks from spreading too far [38]. When compared to cemented concrete, the tensile strength of steel fibers is much greater. If the bond between the concrete paste and the fibers fails, the FRC will collapse. The failure of FRC tensile testing revealed the fibers had been pulled out. [39] found that when deformed-end fibers (such as hook-end steel fibers) are used, a great deal of energy must be dissipated in order to straighten and plastically deform the fibers.

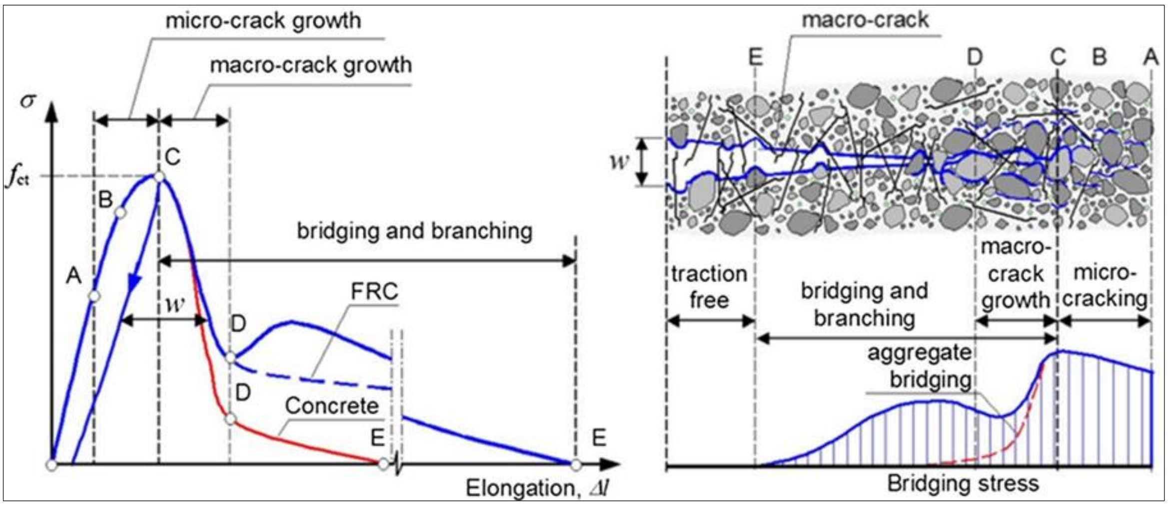

Figure 3 Schematic description of the stress-crack opening relationships for the plain concrete and FRC, [41].

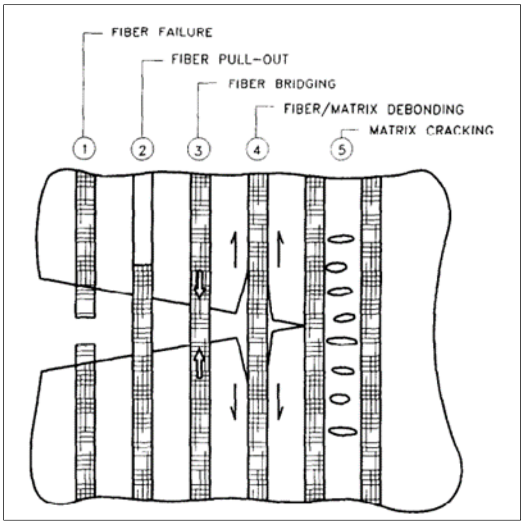

Figure 4 Energy-absorbing fiber/matrix mechanisms [10].

The aggregate and fibers will bridge together in FRC, creating a synergistic effect. Figure 3 illustrates how the bridging impact of steel fibers is much larger than that of aggregate. Microcracking and macrocrack growth zone; bridging zone; traction-free zone; failure zone; are the three zones that can be identified in the process from crack initiation to failure of the specimen [40]. The magnitude of post-crack stress depends on the number of fibers crossing the crack and the bonding between the fibers and matrix. In cases where the crack is crossed by a sufficient number of fibers with strong fiber-matrix bonding, the post-crack stress can exceed the cracking load, resulting in a phenomenon known as strain hardening, where multiple cracks develop. However, for typical fiber content (less than 1%), the behavior of the concrete is characterized by strain softening, where damage localizes immediately after the first crack initiates [41].

Figure 4 is a simplified graphic depicting the role fibers play in dampening impact and slowing the spread of cracks. Beginning with the fiber element on the far left and moving right along the crack, the figure depicts fiber rupture, fiber pull-out, fiber bridging by tension through the fiber, and debonding at the fiber/matrix contact. These mechanisms work, albeit to a negligible extent, even for a single fiber, and are independent of the distance between them. However, it has been shown that the aggregate impact of many fibers placed in the confined topography of the brittle paste phase of the typical concrete composite is considerable [10].

5. Fiber Impact on Serviceability Enhancement

Concrete structures are extensively utilized in construction due to their affordability, strength, and durability. Nevertheless, these structures are prone to cracking and deflection, which can have detrimental effects on their functionality, safety, and appearance. Cracks in concrete can result in a decrease in strength, durability, and waterproofing.

The designer's responsibility in serviceability design is to make sure the structure will function as intended while being subjected to normal, recurring stresses. The design must consider effective strategies for resisting cracks and deflection, and no part of the structure should be subjected to severe vibration. In an effort to increase the durability of concrete buildings, it is necessary to create more trustworthy design techniques. This calls for the construction sector to use reliable engineering input and for designers to pay closer attention to the specification of a suitable concrete mix, particularly with regard to the mix's creep and shrinkage properties [42].

Extensive research has been conducted over the past three decades to study the material properties of Fiber Reinforced Concrete (FRC) in both its fresh and hardened states. However, the exploration of FRC's structural response in elements has primarily emerged in the last fifteen years. Consequently, the absence of international Building Codes specifically for the structural design of FRC elements has contributed to the limited adoption of FRC among practitioners, despite the recent development of design guidelines [9].

Recognizing the improved understanding of FRC and the global progress in developing guidelines for structural design, the fib Special Activity Group 5 (SAG 5), responsible for the upcoming fib Model Code, has decided to incorporate sections on FRC. Working Groups 8.3 ("Fiber Reinforced Concrete") and TG 8.6 ("Ultra-High-Performance Fiber Reinforced Concrete") of fib are actively preparing these sections for the new fib Model Code. The aim is to provide engineers with comprehensive guidance for designing FRC structural elements that ensure both serviceability (SLSs) and ultimate limit states (ULSs), prioritizing safety and drawing upon the latest knowledge in the field [9].

- Concrete structures can experience various deflection problems that can impact their functionality. These issues can be categorized into three types:
- Extreme deflection leads to aesthetic or operational problems.
- Excessive deflection of a component can cause harm to either a structural or non-structural element connected to it.
- Inadequate stiffness can result in occupants being disturbed by dynamic effects.

Due to the fact that fibers can be viewed as a dispersed form of reinforcement, Fiber-Reinforced Concrete (FRC) can be effectively employed to ensure a more desirable distribution of cracks and restrict crack width within acceptable limits during Serviceability Limit States (SLS). Additionally, fibers can serve as a partial replacement for traditional reinforcement methods such as rebars or welded mesh. In certain structures, fibers have the potential to completely replace rebars. These particular structures typically exhibit a significant level of structural redundancy, making fibers a more efficient reinforcement system. Moreover, utilizing fibers can lead to cost savings in such applications [9].

Fiber-reinforced concrete is one of many technologies that can be used to increase the durability of concrete structures. Cracking and deflection can be minimized with the use of FRC because it increases the tensile strength of the concrete. By increasing the concrete's compressive strength, modulus of elasticity, and durability, FRC can aid in minimizing cracking and deflection. Pre-stressing the concrete with PT can increase its flexural stiffness, which in turn decreases deflection [43]. It is important to note that the type and quantity of fibers employed, in addition to the qualities of the concrete itself, can significantly affect the efficiency of fiber reinforcement and the serviceability of concrete. Adding steel fibers to concrete, for instance, can make the material more rigid and strong, but it also has the potential to make the material less workable and more prone to corrosion. Polypropylene fibers, on the other hand, can enhance concrete's workability but may only have a little effect on its strength and durability [44].

Several researchers have looked into how fiber content in concrete affects its practicality. An increase in fiber content in concrete, for instance, has been shown to increase its flexural strength and ductility [45] The study did find, however, that raising the fiber level past a certain point reduced workability, which could have implications for the efficiency with which the material was placed and compacted. Furthermore, the alignment of fibers within the concrete plays a significant role in its overall performance. Specifically, when fibers are oriented in the anticipated direction of cracking, they can enhance the behavior of concrete after cracking occurs. A study conducted by [46] demonstrated that aligning fibers along the primary tensile stress direction improved the resistance to cracking and increased the ductility of the concrete.

The serviceability of concrete can also be influenced by the aspect ratio of fibers, which refers to the ratio of their length to diameter. Fibers with a high aspect ratio can offer enhanced reinforcement to concrete by bridging larger cracks. According to a study conducted by [47], increasing the aspect ratio of steel fibers in concrete resulted in improved post-cracking behavior and increased resistance to cracks. Moreover, the type of fibers used can have varying effects on the serviceability of concrete. For instance, research by [48] discovered that synthetic fibers exhibited superior crack resistance compared to natural fibers like sisal and jute. In addition, [49] found that steel fibers outperformed glass fibers in terms of crack resistance.

6. Conclusion

Fibrous concrete's recent advancements in serviceability have been discussed, as have its methods for reducing the effects of cracking and deflection in concrete buildings. One of the most intriguing and promising technologies for improving the strength and serviceability of concrete structures under a wide range of loading circumstances is fibrous concrete, which makes use of a wide range of fibers as innovative materials.

Fibrous concrete is one of the most effective strategies for preventing cracks from spreading, which improves the durability of concrete buildings. Therefore, enhancing the strength and usability of concrete through the use of fibrous concrete is one of the primary concerns today. Therefore, the use of fibrous concrete is trending as a new generation technology of concrete structures to reduce the influence of cracks on long-term durability and serviceability.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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