Cracking Impact on the Serviceability Enhancement of RC Fibrous Concrete: A Review

Mahmoud Abo El-Wafa

King Abdulaziz University, Faculty of Engineering at Rabigh, Department of Civil Engineering, 21911 Rabigh, Kingdom of Saudi Arabia
masayed[at]kau.edu.sa

Abstract: ***This paper presents an elaborative discussion on the issue of cracking impact on the serviceability enhancement of RC fibrous concrete. It is proposed as an outline of the different types of fibrous concrete available and how they perform under cracking impact, thereby improving the serviceability of concrete structures. It frequently discusses practical mechanical behavior terminology that procedure a fundamentals for recognizing materials performance. Historical assessment is expected to aid in building experiences for what is currently known about RC fibrous concrete, which has a direct impact on cracking and thus improves the serviceability of concrete structures. References from both early and contemporary authors are included to help tie the issue together chronologically. However, the construction path is one of the major desirable paths for fibrous concrete globally. Because of the advantages it has over conventional construction materials, fibrous concrete is used in a wide range of building applications, from the rehabilitation of existing structures to the full-scale use of new projects. Such advantages include, but are not limited to, lightness, high mechanical performance, and 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 of which contribute to the improved serviceability of concrete structures. All of these diverse characteristics of fibrous concrete are knocking on the doors of new paths of myriad requests in the construction industry. As a result, this paper attempts to review specific areas of the current utilization trend of fibrous concrete on cracks impact for improving the serviceability of concrete structures.***

Keywords: Fibrous concrete, cracking impact, construction industry, serviceability enhancement

1. Introduction

Cracking must be controlled and deflections must not be excessive for a concrete structure to be serviceable. It also shouldn't vibrate too much. Fibrous concrete is essential in each of these aspects of concrete structure service load behavior [1].

The fibrous concrete are increasingly being used in engineering applications, particularly for civil engineering structures, with entering a new era when the construction industry faces an additional challenge: how to control concrete cracking to build concrete structures that are environmentally more sustainable and have a good serviceability [2, 3].

It needs to understand not only the reasons for the serviceability failures that involving by excessive cracking and/or excessive deflection, but also how to develop the fibrous concrete that produce sustainable and serviceable structure.

A wide variety of the fibrous concrete are available today for applications as advanced composite materials, which have been emerged as the most exciting and promising composite materials in strengthening and serviceability of concrete structures.

Cracking behavior of concrete structures is of interest for evaluation of serviceability performance. In designing reinforced concrete, it is not enough just to ensure that the steel and concrete are not over stressed. The structure must remain serviceable under environmental conditions. Volumetric change generates internal micro cracking, which may develop into full cracking, as well as, the growth of cyclic cracking in concrete is attributed to the inherent weakness of concrete in tension, which lead to losing the serviceability of concrete structures [4].

Thus, the cracking of concrete under restrained conditions and cyclic loading is considered a major serviceability problem of concrete structures.

The fibrous concrete are believed to be one of the most effective ways of controlling such cracking, due to sufficient bridging forces to suppress crack opening and redistribute the stress to the nearby matrix.

Moreover, the fibrous concrete when uniformly distributed within concrete play an active role in improving the serviceability problem of concrete structures.

Therefore, this new generation technology utilizes fibrous concrete, which have a great impact on all concrete structures under different loading manners for strengthening and serviceability development.

The fibrous concrete are introducing revolutionary changes in the structural application of concrete structures. These fibrous concrete are excellent candidates for strengthening and serviceability of highways, bridges, airfields, tunnels, explosion resistant structures, and earthquake resistance construction.

The new generation of fibrous concrete is being developed, which can be used at higher addition rates to bring about major improvements in the characteristics of composites. In current construction practice, discontinuous metallic and non-metallic fibers are added to matrices at relatively low volume fractions (usually ≤ 1.0 %), mostly in order to improve the toughness and the post cracking ductility of the composite and hence improve the serviceability of concrete structures under all modes of loading [5,6].

Therefore, the intending to be as brief as is consistent with the goals of the discussion is divided into three parts: Technology of fibrous concrete, Performance of cracking impact, and serviceability enhancement.

2. Technology of Fibrous Concrete

Today, a wide range of fibers are available for use as advanced composite materials in fibrous concrete, which have emerged as the most exciting and promising materials for improving the strength and serviceability of concrete structures under various loading conditions.

Cracks do not propagate as much in the fibrous concrete, and it is considered to be one of the most powerful strategies for managing cracking, improving the serviceability of concrete structures. As a result, one of the most pressing problems today is to improve the strength and serviceability of fibrous concretes.

Consequently, the use of discrete steel fibers and synthetic polypropylene fibers is regarded as a new generation technology of fibrous concrete for achieving concrete structure sustainability and serviceability.

In contrast to conventional concrete, the most distinguishing characteristic of fibrous concrete is its ability to stabilize the broken matrix locally by transferring stresses around the ruptured surface.

Unlike standard concrete, which only transfers a small amount of stress through cracks due to aggregate interlock, the presence of fibers allows for substantial tensile load transfer across cracks before the fiber either pulls out or splits.

In both historic and modern situations, the general standard is to apply fibers to an inherently fragile and brittle matrix to increase tensile strength and reduce brittleness, resulting in increased ductility and durability. This quality has largely remained unchanged in recent years, but the range of fiber forms, shapes, and sizes available to enhance matrix characteristics has greatly increased.

In general, adding fibers to a matrix (paste, mortar, or concrete) can have two major effects. They improve the ductility and toughness of an otherwise inherently brittle matrix in two ways: first, they tend to reinforce the composite under all modes of loading that induce tensile stress, such as direct tension, bending, and shear, and second, they improve the ductility and toughness of an otherwise inherently brittle matrix.

The improvements in these properties that a specific fiber imparts are dependent on a variety of fiber parameters, including the type of fibers used and their material, which is typically expressed as a percentage by volume of composite concrete, as well as the mode of loading.

Consequently, adding fibers to concrete, which is a quasi-brittle material, improves post-cracking efficiency by increasing ductility. The fibers transmit tensile forces across cracks, reducing crack width and improving the concrete post-cracking efficiency as compared to unreinforced concrete.

There are two types of fibers: those with a high modulus of elasticity and low elongation properties, and those with a low modulus of elasticity and high elongation properties. Steel, glass, asbestos, and carbon fibers belong to the first group, while synthetic organic fibers like nylon, polypropylene, and polyethylene belong to the second.

Steel fibers are the most common type of fiber used in concrete composites. Steel fibers are commonly used and are characterized as small, discrete lengths of steel with an aspect ratio (length-to-diameter ratio) of about 20 to 100, various cross sections, lengths between 25 and 60 mm, and diameters between 0.4 and 1.3 mm.

They're insignificant enough to be distributed randomly in the matrix through standard mixing processes. Steel fiber output is affected by a variety of factors, including fiber material properties (fiber strength, stiffness, and Poisson's ratio), as well as environmental factors, fiber geometry (end-hooked, crimped, and twisted fibers), fiber volume material, matrix properties (matrix power, stiffness, and Poisson's ratio), and interface properties are all factors to consider (adhesion, frictional and mechanical bond). Figure 1 depicts several steel fiber geometrical shapes.

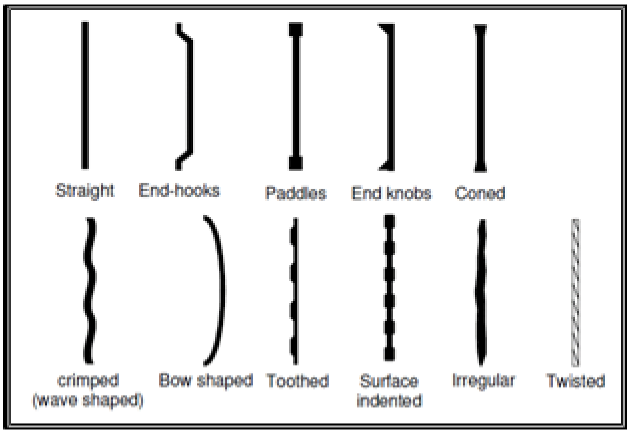

Figure 1: Steel fiber geometrical shapes

Since they are lightweight and cost-competitive, polypropylene fibers are perhaps the most common synthetic fibers. Polypropylene fibers, like other synthetics, require a large design volume. Because of its outstanding resistance to moisture, acids, and alkalis, and the raw material's low cost per volume compared to steel or glass fibers, polypropylene fibers are considered attractive fibers among synthetic fibers.

Polypropylene fibers have proved to be effective materials for controlling unsightly and problematic cracking in concrete structures, and they are commonly used in all forms of concrete construction. Figure 2 portrays several polypropylene fiber geometrical shapes.

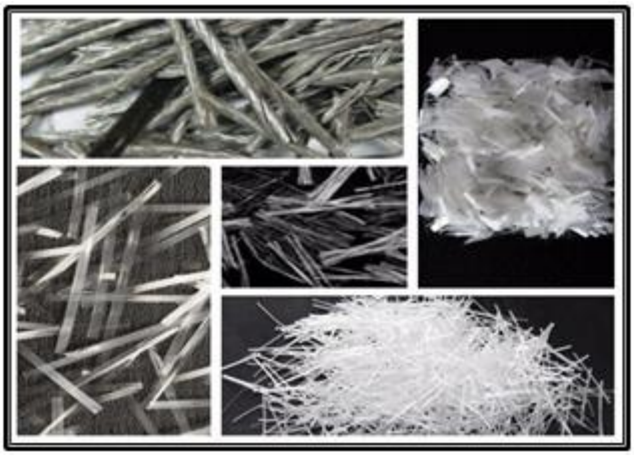

Figure 2: Polypropylene fiber geometrical shapes

Clearly, the type and quantity of fibers in each matrix are important parameters that affect steel fiber performance and cost. The presentation of steel fibers, on the other hand, can be improved to the point that it shows a deflection toughening comeback in flexure. Steel fiber reinforced concrete has a higher ductility than unreinforced composites, which fail in stress and flexure when a single crack appears. Steel fibers are used in concrete to avoid and monitor plastic and drying shrinkage cracking. Additional research and development revealed that integrating steel fibers into concrete enhances flexural resilience, energy absorption potential, ductile performance prior to ultimate failure, cracking resistance, and longevity. Steel fibers are used in structural applications such as supported pile slabs, ground slabs, raft foundations, tunnel linings, and various precast components. Steel fibers are used in a complementary capacity in some structural applications to either constrain cracking, develop resistance to material degradation as a result of shrinkage, impact load, fatigue load, or thermal stresses, alternatively, conventional reinforcement may be used.

3. Performance of Cracking Impact

Internal stresses are a significant issue in the concrete industry. These intrinsic stresses are caused by concrete shrinkage, and they are difficult to monitor due to their unpredictability of frequency and variety. Due to internal settling and rapid water evaporation from the specimens, concrete shrinkage induces intrinsic cracking. These cracks will appear within the first 24 hours after the concrete has been cast. They may or may not be visible right away.

Shrinkage cracks are not visible until much later. These cracks aren't structural, but they also don't go away until the concrete hardens. They actually grow longer as the drying process continues. Cracks allow water to diffuse through the concrete, allowing salts and other harmful compounds to enter, decreasing the concrete's longevity and service life. In the concrete structural members are well known for having a high compression but a low tension. Thus, cracks form in the tension zone of concrete structural members when the concrete's stress exceeds its tensile strength or when stresses surpass the concrete structural member's tensile capacity. Internal micro cracks form when the tensile stress in structural members exceeds its tensile strength at a specific position. These cracks develop into macro cracks that spread to the structural members' external fiber regions.

On the other hand, heavyweight traffic on major highways and bridges, as well as heavy machinery used in industrial services, can all cause cracking. Engineers perform a serviceability test of concrete structures assuming a cracked section and build structural members to withstand the multiple stresses from external loads to combat structural cracking.

Concrete fabricators, architects, builders, and construction experts all agree on one thing: concrete cracking can be anything from a minor annoyance to a nightmare. Cracks are a concern no matter where they appear. Repairing the cracking is usually just as difficult and costly. Historically, the cracking of concrete has been verified as a predictable trend. Cracks form as a result of stresses that exceed the concrete's strength at a given time.

Although the end result of these three acts is the formation of cracks, the mechanisms by which cracks form cannot be compared. Internal micro cracking is caused by volumetric change and can progress to full cracking, while internal micro cracking can be caused by direct internal or external stress or applied loads, such as the cyclic cracking caused by reversible load or flexural macro cracking resulting in fully formed cracking.

As a result, both of these tendencies necessitate earlier cracking performance regulation in order to meet the serviceability requirements of concrete structures.

Consequently, crack management has become critical for maintaining the structural integrity and aesthetics of concrete structures. When describing the role of fibrous concrete in concrete crack regulation, it's important to differentiate between situations where cracking is primarily controlled by macroscopic tensile or compressive stresses.

The construction industry now has a controlling tool in the form of fibrous concrete to limit the formation of soft cracks. Fibers provide secondary reinforcement to concrete by inserting various fibers into the matrix.

By increasing the tensile strain potential of concrete, the fibrous concrete will significantly reduce the formation of plastic shrinkage cracks. Plastic shrinkage cracks are minimized, allowing the concrete to develop its maximum long-term integrity.

Incorporating the fibers into concrete structures may theoretically enhance the cracking behavior of the structure. Figure 3 depicts the effect of fibers on the formation of cracks.

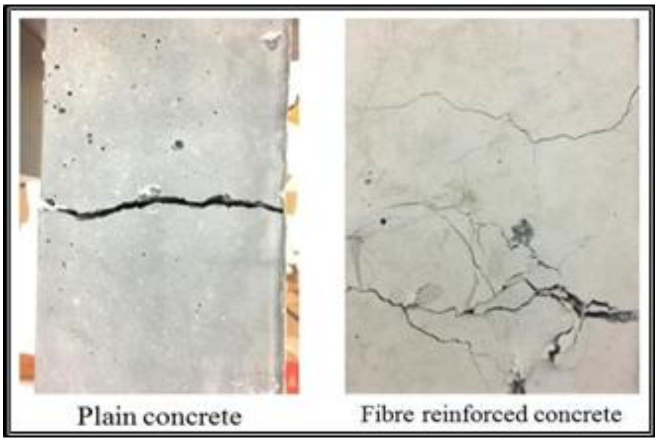

Figure 3: Influence of fibers on cracks development

Fibrous concretes are a stand-alone material technology that, when used in conjunction with an engineer's recommendations, can provide a superior crack control mechanism at any stage of concrete production. Furthermore, due to the toughening impact of the fibers in front of the crack edge, the composite can become tougher and stronger. Consequently, fibrous concretes have the potential to alter the cracking process. Macro cracking can be converted to micro cracking by changing the cracking process. The cracks are thinner, which decreases the penetrability of concrete and increases the overall cracking pressure of the structures. Furthermore, fibrous concretes have played an important role in extending fatigue life, increasing fatigue load capability, reducing fatigue damage gradation, and delaying the onset of structural damage. Aside from minimizing penetrability and fatigue damage gradation, one of the most significant advantages of using fibrous concretes is that fibers addition improves the durability or residual load carrying capacity after the first crack.

As a result, fibrous concretes are capable of meeting the structural strengthening and serviceability requirements in performance of cracking impact.

4. Serviceability Enhancement

When designing for serviceability, the designer must ensure that the structure can perform its intended purpose under the day to day service loads.

Deflection must not be excessive, cracks must be properly managed and no portion of the structure should experience excessive vibration.

Shrinkage causes time-dependent cracking, reducing the stiffness of a concrete structure, and is therefore a negative factor in all aspects of serviceability design.

There are three types of deflection problems that can affect the serviceability of concrete structures:

1) Extreme deflection results in cosmetic or functional issues.
2) When a member's excessive deflection causes damage to a structural or non-structural feature attached to it.
3) Where occupants are bothered by dynamics caused by inadequate stiffness.

Excessively large cracks can be unsightly and detract from the appearance of an exposed concrete surface; they can allow moisture in, hastening reinforcement degradation and durability failure; and, in rare cases, they can reduce the concrete's contribution to a concrete member's shear strength. Excessively large cracks in floor systems and walls can also be avoided by using strategically spaced contraction joints, which relieve some of the shrinkage restraint and lower internal stress.

When cracking does occur, sufficient amounts of well-distributed and well-anchored reinforcement must be used at any position where substantial stress can exist to ensure that crack widths remain acceptable.

The maximum crack width that can be considered suitable in a given situation is determined by the structure, the surrounding environment, and the effects of excessive cracking.

Crack widths do not exceed 0.1-0.2 mm in corrosive and hostile conditions.

A maximum crack width of 0.3 mm should be appropriate for members of one or more exposed surfaces.

Larger crack widths may be sufficient in the sheltered interiors of most houses, where the concrete is not exposed and architectural considerations are secondary (say 0.5 mm or larger).

As a result, the development of more reliable design procedures is needed in the search to improve the serviceability of concrete structures.

It also necessitates that designers pay more attention to the specification of an acceptable concrete mix, especially with regard to the mix's creep and shrinkage characteristics, and that the construction industry employs sound engineering input.

High-performance concrete structures necessitate the use of high-performance concrete (not necessarily high-strength concrete, but concrete with low shrinkage and resistance to plastic shrinkage cracking) as well as a high level of construction, including sufficient propping, successful curing processes, and strict on-site supervision, all of which contribute to the serviceability enhancement of concrete structures.

5. Conclusions

Recent improvements to the serviceability enhancement of fibrous concrete, as well as their strategies for cracking impact and deflection control of concrete structures, have been addressed.

A variety of fibers are available for use as advanced materials in fibrous concrete, and they have emerged as one of the most exciting and promising technologies for improving the strength and serviceability of concrete structures under various loading conditions.

Cracks do not spread as much in fibrous concrete, and it is thought to be one of the most effective methods of controlling such cracking, thereby increasing the serviceability of concrete structures.

As a result, one of the major challenges today is to improve the strength and serviceability of concrete using fibrous concrete.

Consequently, the utilization trend of fibrous concrete on cracks impact for enhancing the long-term durability and serviceability is considered as a new generation technology of concrete structures.

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