



# Innovating for a Greener Future: Steel Fiber Reinforcement as a Key to Low-Carbon Concrete Construction

Ahmad Mandalawi

Structural Engineering Specialist Dubai, United Arab Emirates

## ARTICLE INFO

### KEYWORDS

Steel Fiber Reinforced Concrete (SFRC)  
Embodied Carbon Sustainable  
Construction Foundation Systems  
Structural Optimization Low-Carbon  
Concrete

### HOW TO CITE

Mandalawi, A. (2026). Innovating for a Greener Future: Steel Fiber Reinforcement as a Key to Low-Carbon Concrete Construction. Emirati Journal of Civil Engineering and Applications, 4(1), 28-33.  
<https://doi.org/10.54878/1959z822>

## ABSTRACT

The construction sector is under increasing pressure to reduce embodied carbon while maintaining structural safety and durability. Concrete structures, particularly those relying on conventional steel reinforcement, contribute significantly to global greenhouse gas emissions due to the energy-intensive production of steel and cement. In rapidly developing regions such as the Gulf Cooperation Council (GCC) countries, including the United Arab Emirates, national sustainability agendas are encouraging the adoption of innovative construction materials and design approaches to reduce environmental impact. Steel fiber reinforced concrete (SFRC) has emerged as a promising solution capable of enhancing structural performance while contributing to lower embodied carbon in concrete construction. Steel fibers improve tensile strength, flexural behavior, ductility, and crack control by bridging cracks and providing post-cracking resistance. When used either as a partial or full replacement of conventional reinforcement in structural elements such as slabs-on-grade, isolated footings, strip footings, and raft foundations, steel fibers allow structural optimization and reduction of reinforcement congestion. In hybrid systems combining fibers and rebars, improved punching shear resistance and crack control can be achieved with lower material consumption. This paper investigates the structural and environmental benefits of steel fiber reinforcement and evaluates its contribution to sustainable construction through a comparative embodied carbon assessment. Additionally, a practical case study involving residential slab-on-grade construction in the Expo City “The Valley” townhouse development in Dubai is presented to illustrate the practical implementation of SFRC in residential projects. The findings demonstrate that steel fiber reinforcement can significantly reduce reinforcement quantities, simplify construction processes, and contribute to lower embodied carbon, making it a viable pathway toward low-carbon concrete construction.



Double-blind peer review by independent reviewers.

Received: 23 Jan 2026, Accepted: 09 May 2026, Published: 18 Jun 2026

\*Corresponding author: [ahmad.mandalawi@bekaert.com](mailto:ahmad.mandalawi@bekaert.com)

Copyright: © 2026 by the author. Licensee Emirates Scholar Center for Research & Studies, UAE.

Open access under the Creative Commons Attribution (CC BY) license

<https://creativecommons.org/licenses/by/4.0>

## 1. Introduction

The construction industry is responsible for approximately 37% of global energy-related carbon emissions, with concrete production accounting for a substantial share of this environmental impact. The embodied carbon associated with concrete structures originates mainly from cement production and steel reinforcement manufacturing. As the demand for infrastructure and residential developments continues to grow, particularly in rapidly developing regions such as the Gulf States, reducing the environmental footprint of construction materials has become a priority.

In response to global climate commitments and sustainability agendas, countries such as the United Arab Emirates have introduced initiatives aimed at reducing the carbon intensity of construction materials. These initiatives promote the adoption of innovative technologies that maintain structural performance while reducing environmental impact.

Traditional reinforced concrete relies heavily on steel reinforcing bars to resist tensile stresses. Although this system has proven effective for more than a century, it often results in high reinforcement quantities, complex detailing, reinforcement congestion, and increased embodied carbon.

Steel fiber reinforcement represents an alternative reinforcement mechanism capable of improving the mechanical performance of concrete while potentially reducing the reliance on conventional reinforcing bars. By distributing discrete fibers throughout the concrete matrix, the material gains enhanced tensile capacity, ductility, and post-cracking behavior.

Unlike conventional reinforcement that resists tensile stresses primarily in specific directions, steel fibers provide multidirectional reinforcement throughout the concrete matrix. This behavior improves crack distribution, increases structural resilience, and enhances the overall performance of concrete elements.

Beyond structural performance, steel fibers also offer environmental advantages. Due to their efficient reinforcement mechanism and relatively lower environmental impact per unit of structural performance achieved, steel fibers can contribute to significant reductions in embodied carbon.

This paper investigates the role of steel fiber reinforcement in reducing embodied carbon while maintaining structural integrity in concrete structures. The research also explores the application of steel fibers in residential slab-on-grade systems through a practical case study.

## 2. Literature Review

### 2.1 Development of Steel Fiber Reinforced Concrete

Steel fiber reinforced concrete (SFRC) has been widely studied since the 1970s. Early research demonstrated that the inclusion of discrete steel fibers in concrete significantly improves its post-cracking behavior and energy absorption capacity.

According to ACI 544, steel fibers enhance concrete performance by providing crack bridging mechanisms that allow the material to sustain tensile stresses after cracking. This residual tensile strength is critical in controlling crack widths and improving structural durability.

The fib Model Code also recognizes the structural contribution of fibers through residual tensile strength parameters derived from standardized flexural testing procedures.

### 2.2 Structural Design Frameworks

Several international standards provide guidance on the design of fiber reinforced concrete structures:

ACI 544 provides guidelines for specifying, proportioning, and designing fiber reinforced concrete systems.

fib Model Code 2010 introduces design methodologies based on residual tensile strength parameters derived from flexural tests.

Eurocode EN 1992 acknowledges the use of fiber reinforcement for crack control and structural applications when supported by appropriate testing data.

These frameworks demonstrate the increasing acceptance of steel fibers as structural reinforcement in modern design practice.

### 2.3 Mechanical Benefits of Steel Fibers

Steel fibers improve several key mechanical properties of concrete:

Tensile strength

Flexural strength

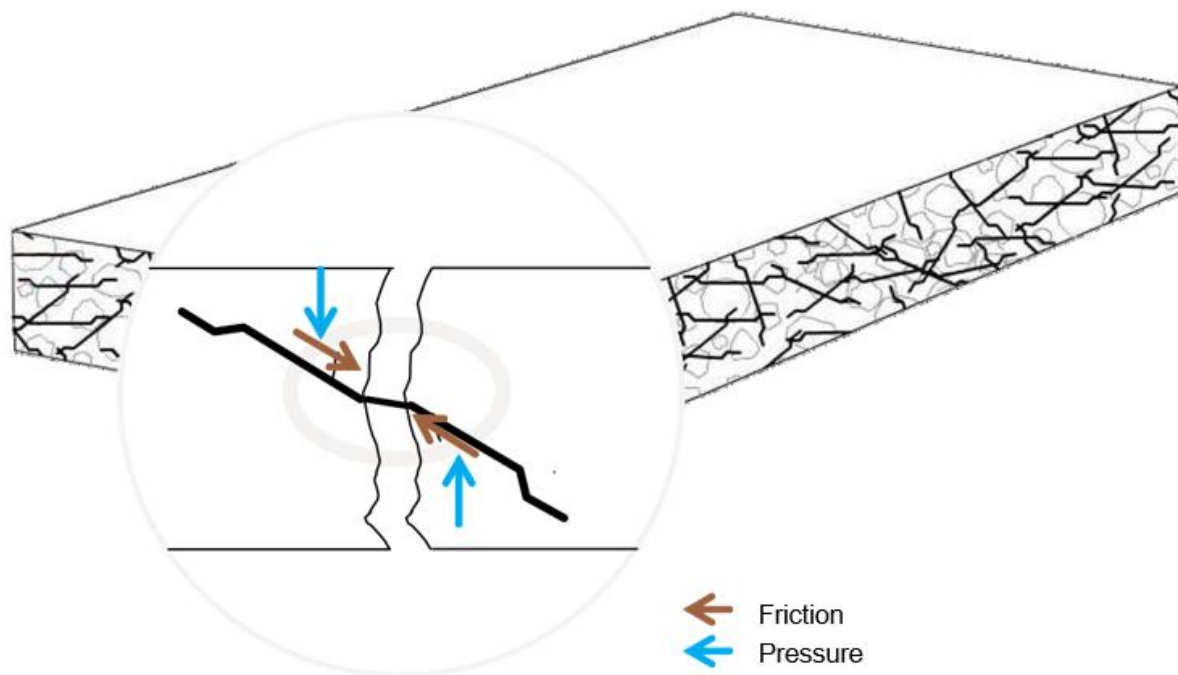
Ductility

Impact resistance

Crack control

Post-cracking load carrying capacity

The primary mechanism behind these improvements is the fiber bridging effect, illustrated conceptually below.



**Figure 1.** – Crack Bridging Mechanism of Steel Fibers

Steel fibers bridge cracks and transfer tensile stresses across the crack plane, allowing the concrete to sustain loads after cracking.

### 3. Purpose and Objectives of the Study

The primary objective of this research is to evaluate the potential of steel fiber reinforcement to reduce embodied carbon in concrete construction while maintaining structural performance.

The specific objectives include:

Investigating the structural benefits of steel fiber reinforcement.

Evaluating the environmental impact of steel fibers compared to traditional reinforcement.

Demonstrating the practical application of steel fibers in residential slab-on-grade construction.

Assessing the potential carbon reduction achievable through hybrid reinforcement systems.

### 4. Methodology / Research Approach

The research methodology includes three primary components:

#### 1. Literature Review

Review of international design standards and research publications related to fiber reinforced concrete.

#### 2. Embodied Carbon Assessment

Comparison of embodied carbon between conventional reinforcement systems and steel fiber reinforcement using Environmental Product Declaration (EPD) data.

#### 3. Case Study Analysis

Evaluation of a residential slab-on-grade system in the Expo City “The Valley” townhouse development in Dubai where steel fibers from Ms.Bekaert were considered as part of the structural solution.

### 5. Findings / Results

#### 5.1 Structural Performance

Steel fibers significantly enhance the post-cracking behavior of concrete. Residual tensile strength enables the concrete to maintain load-carrying capacity after cracking, improving structural reliability.

#### 5.2 Carbon Comparison

A comparative embodied carbon assessment was conducted between conventional reinforcement and steel fiber reinforcement.

**Table 1.** – Embodied Carbon Comparison

| Material    | Typical Dosage       | Embodied Carbon (kg CO <sub>2</sub> /kg) | Carbon Impact per m <sup>3</sup> |
|-------------|----------------------|------------------------------------------|----------------------------------|
| Rebar Steel | 35 kg/m <sup>3</sup> | 1.7                                      | 59.5 kg CO <sub>2</sub>          |

|                                                                               |                      |                                                                                       |                      |
|-------------------------------------------------------------------------------|----------------------|---------------------------------------------------------------------------------------|----------------------|
| Steel Fibers                                                                  | 10 kg/m <sup>3</sup> | 0.6                                                                                   | 6 kg CO <sub>2</sub> |
| Estimated Carbon Reduction: ~90% reduction in reinforcement-related emissions |                      | This comparison illustrates the environmental advantage of steel fiber reinforcement. |                      |

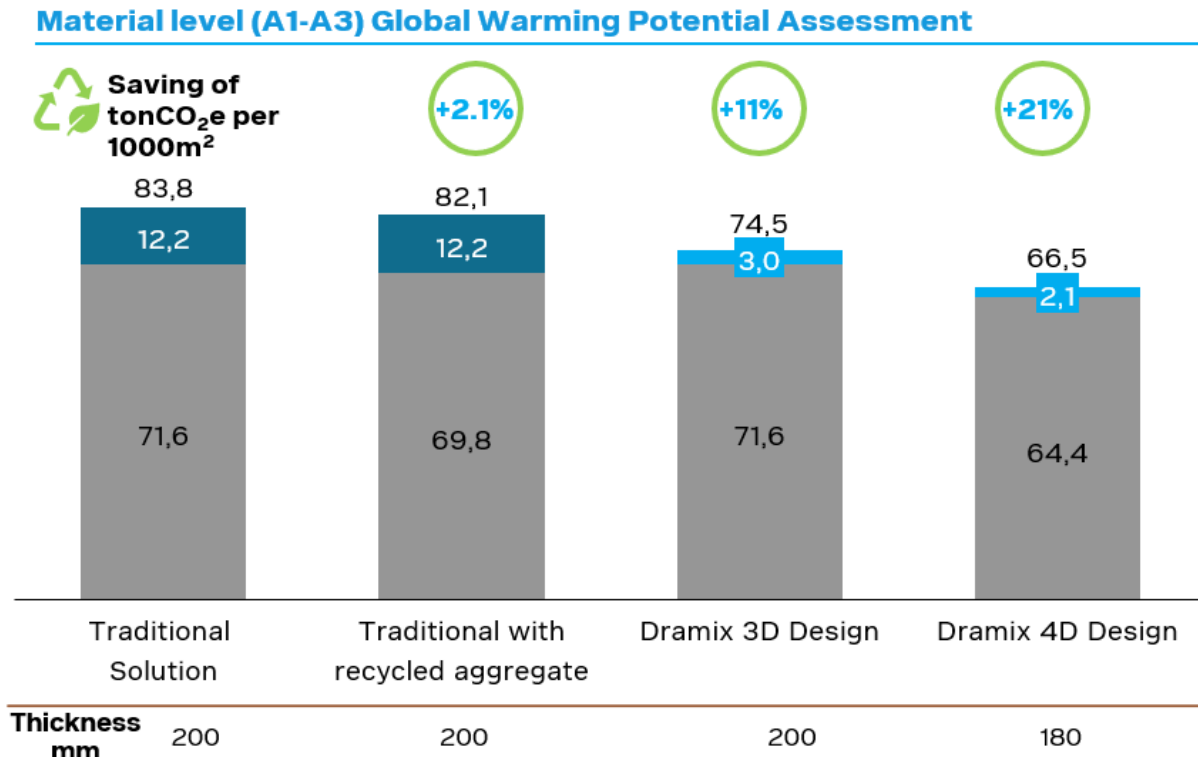


Figure 2. – Carbon Reduction Potential

Comparison of the Carbon emissions in concrete mix reinforced with traditional mesh compared to steel fiber concrete mix reinforced with Dramix® steel fiber 3D and 4D.

6. Case Study: Residential Slab-on-Grade – Expo City “The Valley”

Project Overview

The Valley is a large residential development consisting of low-rise townhouse communities located in Expo City Dubai.

Typical townhouse construction includes:

Ground floor slab-on-grade

Reinforced concrete strip footings



Block masonry superstructure

Conventional Design

Typical slab design:

Concrete strength: C<sub>30</sub>/37

Thickness: 150mm with edge thickening of 200mm

Reinforcement: BRC normal mesh

Steel Fiber Alternative

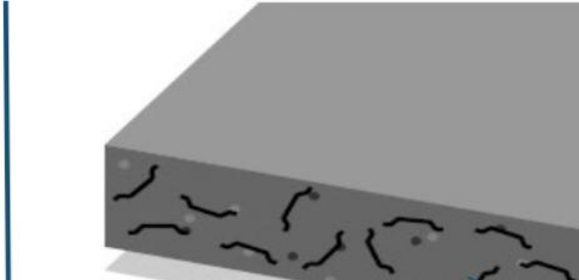
Steel fiber reinforced concrete was proposed as an alternative reinforcement system.

Typical mix:

Concrete strength: C<sub>30</sub>/37

Steel fiber dosage: 10 kg/m<sup>3</sup> Dramix® 4D 8060BGE

Thickness : 100mm without edge thickening.



**Figure 3.** – Conventional vs Steel Fiber Slab

Observed Advantages

Elimination of reinforcement mesh installation.

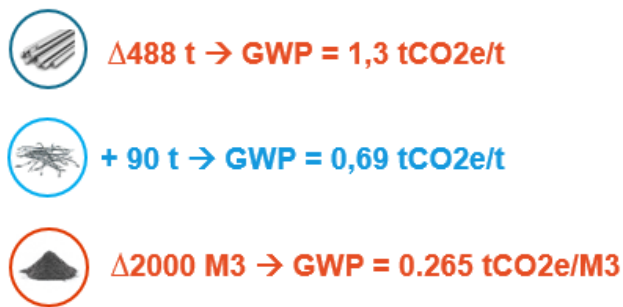
Faster construction time.

Reduced labour requirements.

Lower reinforcement carbon footprint.

Improved crack control.

### Material and GWP for A1-A3



**Figure 4.** – Conventional vs Steel Fiber Slab Life Cycle Assessment. Material and GWP for A1-A3

## 7. Discussion

The results demonstrate that steel fiber reinforcement can significantly reduce or replace fully the reinforcement quantities while improving structural performance. The carbon comparison indicates that replacing conventional reinforcement with steel fibers can reduce reinforcement-related emissions by up to 80-90%.

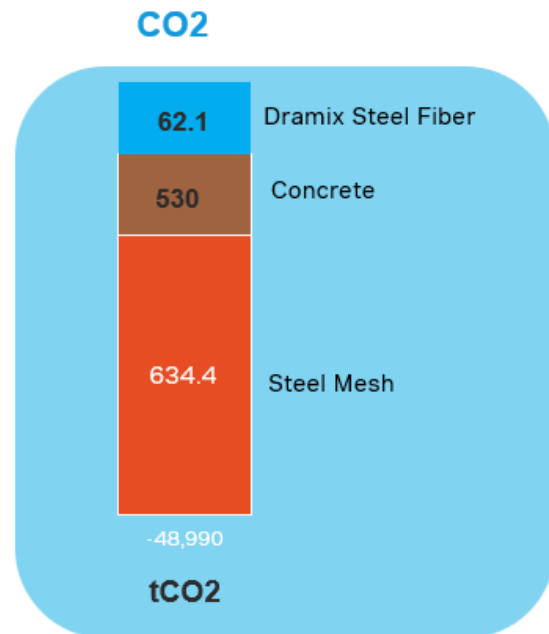
The hybrid reinforcement approach—combining fibers with limited traditional reinforcement—offers a balanced solution that ensures structural safety while minimizing environmental impact.

Furthermore, the simplified construction process associated with steel fiber concrete reduces labour and construction time, contributing to additional sustainability benefits.

## 8. Conclusion, Implications and Recommendations

Steel fiber reinforcement represents a promising technology for reducing embodied carbon in concrete construction while enhancing structural performance.

The study leads to the following conclusions:



Steel fibers improve tensile strength, ductility, and crack control in concrete structures.

Fiber reinforcement enables structural optimization and reduced reliance on conventional reinforcement.

Embodied carbon associated with reinforcement can be significantly reduced through the use of steel fibers.

Practical implementation in residential slab-on-grade systems demonstrates feasibility and construction efficiency.

The construction industry should continue developing design guidelines and regulatory frameworks to facilitate the wider adoption of fiber reinforced concrete in structural applications.

## References

- ACI Committee 318. (2025). Building Code Requirements for Structural Concrete.
- ACI Committee 544. (2018). Guide for Specifying, Proportioning, and Production of Fiber Reinforced Concrete.
- fib. (2010). fib Model Code for Concrete Structures.
- fib. (2013). fib Bulletin 55: Model Code 2010 – First Complete Draft.

European Committee for Standardization. (2004).  
Eurocode 2: Design of Concrete Structures – EN 1992.