

RCC [Reinforced Cement Concrete] and Fabric

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ABSTRACT

Reinforced cement concrete (RCC) is a basic material in modern infrastructure, yet it encounters serious durability problems, especially because of the corrosion of the steel reinforcement. This corrosion causes increased maintenance expenses and may lead to early failure. Textile or fabric reinforcement has appeared as a promising alternative or supplement to conventional steel bars, allowing the production of thin, lightweight, and corrosion-resistant concrete components. Textile-reinforced concrete (TRC) is made up of continuous fabrics composed of high-performance fibres such as carbon, alkali-resistant (AR) glass, basalt, and polymeric fibres, which are incorporated into a cementitious matrix, usually a fine-grained mortar. Many studies have demonstrated that fabric reinforcement can greatly improve tensile and flexural performance, help to control cracking, and enhance resistance to impact and fatigue. Furthermore, it provides the possibility of reducing both the cover thickness and the amount of material used (Wu et al., 2023; Nivetha et al., 2023).

The review presents an overview of the present state of fabric-reinforced cementitious composites, with a focus on their possible use in conjunction with conventional RCC in both structural and pavement applications. Having first explained the reasons for incorporating fabrics into RCC, the paper goes on to examine different types of fabric materials and their configurations, the properties of the matrix, and the bond behaviour. It then looks at the mechanical performance of TRC under conditions of tension, flexure, shear, impact and fatigue, as well as its durability with respect to environmental factors such as freeze-thaw cycles, chloride ingress and elevated temperatures (Wu et al., 2023; Venigalla et al., 2022). Special attention is paid to hybrid systems that involve

the combination of steel bars, dispersed fibres and fabrics, as well as to the findings relating to fabric- and fibre-reinforced roller-compacted concrete (RCC) pavements, in which synthetic and steel fibres have led to considerable reductions in slab thickness (Vairagade & Dhale, 2023; Ozturk et al., 2022). Lastly, the review points out the existing research gaps and future areas to be explored, such as the development of design guidelines, large-scale field validation for RCC structures and pavements, and the modelling of long-term performance.

KEYWORDS: *Reinforced cement concrete (RCC); textile-reinforced concrete (TRC); fabric reinforcement; hybrid reinforcement; roller-compacted concrete; durability; pavements.*

INTRODUCTION

Reinforced cement concrete has been the dominant structural material for over a century due to its versatility, relative cost-effectiveness, and favorable compressive strength. However, the incorporation of steel bars in an alkaline cementitious matrix introduces inherent durability vulnerabilities, particularly corrosion caused by carbonation and chloride ingress in aggressive environments. These challenges are particularly critical in thin-walled elements, bridge decks, marine structures, and pavements where cover thickness is limited or exposure to harsh conditions is severe.

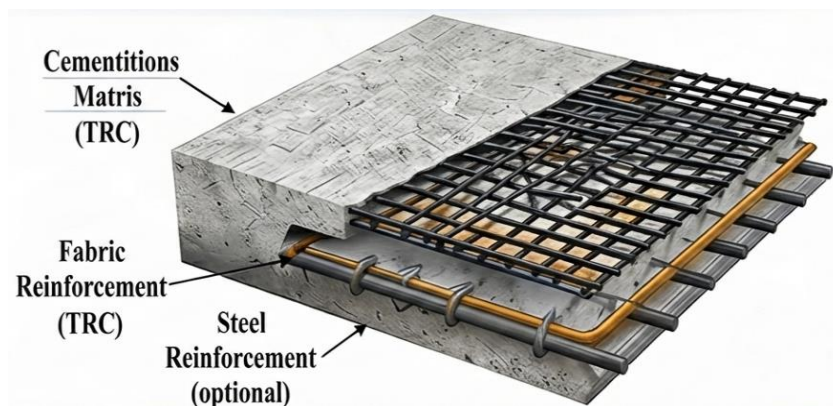


Figure 1: Reinforced Cement Concrete with Fabric Reinforcement

To mitigate corrosion and enhance structural efficiency, considerable research has focused on alternative or complementary reinforcement systems. Fiber-reinforced concrete (FRC), which

utilizes short steel, polymer, glass, or natural fibers, has been shown to improve toughness and reduce crack widths, already finding application in structural members and pavements (Vairagade & Dhale, 2023). More recently, continuous textile or fabric reinforcement has evolved into textile-reinforced concrete (TRC)—a class of thin, non-corrosive composite systems featuring high tensile capacity and multiple cracking behavior (Wu et al., 2023; Nivetha et al., 2023).

Although TRC has primarily been developed for fine-grained mortars and thin elements, its underlying principles—continuous non-metallic reinforcement, minimal cover requirements, and effective crack control—are highly applicable to traditional RCC, including cast-in-place members and roller-compacted concrete pavements. This review explores how fabric reinforcement concepts can be integrated into RCC systems, either as a replacement for steel in specific zones or as part of hybrid reinforcement strategies.

MATERIALS AND CONFIGURATIONS OF FABRIC-REINFORCED RCC

1. Textile/Fabric Types

Textile reinforcement typically consists of:

- Carbon fabrics: High tensile strength and stiffness, non-corrosive, but more expensive; often used where high performance and thin sections are required (Wu et al., 2023; Mansur De Castro Silva & De Andrade Silva, 2020).
- Alkali-resistant (AR) glass fabrics: Good tensile strength and cost-effective, but susceptible to long-term alkali attack if not properly protected. AR formulations improve durability (Nivetha et al., 2023).
- Basalt fabrics: Intermediate in performance and cost between glass and carbon, with good temperature resistance.
- Polymeric fabrics (e.g., AR-PBO, polypropylene, PET): Lightweight, non-corrosive materials with varying stiffness; commonly used where deformability and impact tolerance are desired (Wu et al., 2023).

Fabrics can be produced as unidirectional, bidirectional, or multi-axial meshes, with parameters such as yarn spacing, filament count, and coating type significantly influencing mechanical behavior and bond characteristics.

2. Cementitious Matrix for Fabric Reinforcement

Most TRC systems use fine-grained mortars or self-compacting fine-grained concrete to ensure good impregnation of textile yarns and limited voids. (Wu et al., 2023) Key characteristics include:

- Low maximum aggregate size to allow proper embedding of yarns.
- Adequate flowability or self-compaction to encapsulate the fabric networks.
- High tensile strain capacity (e.g., modified with polymer dispersions, silica fume, or supplementary cementitious materials).

Table 1: Types and Properties of Fabric Reinforcements

Fabric Type	Tensile Strength (MPa)	Modulus (Gpa)	Durability	Applications
Carbon Fabric	200-600	7-80	High	Paveenents
Glass (AR)	1650-1-500	7-80	Very	Fecade, roerofts
Polymeric Fabric	Polvmeric	50-60	Very	Infrastructure
Basalt Fabric	500-meric	50-60	High	Infrastructure

For integration with conventional RCC, two approaches are envisaged:

- Localized TRC layers on RCC substrates, e.g., TRC overlays or laminates bonded to RCC beams, slabs, or pavements for strengthening and crack control. (Venigalla et al., 2022)
- Hybrid RCC with embedded fabrics and conventional aggregates, where fabric layers are placed within standard RCC or roller-compacted concrete, provided that adequate workability and compaction procedures are ensured.

3. Bond and interface behavior

Bond between fabric and matrix is a primary driver of composite performance. Studies indicate that:

- Polymer coatings and surface treatments (e.g., epoxy with sand, silica particles) significantly enhance fabric–matrix bond and increase tensile strength and stiffness of the composite. (Wu et al., 2023)(Mansur De Castro Silva & De Andrade Silva, 2020)
- Multi-layer arrangements and smaller mesh spacing refine crack patterns and reduce crack widths, but may lead to bond-related failure modes if the interface is weak. (Venigalla et al., 2022)
- The internal filament distribution within yarns can lead to non-uniform strain, with outer filaments engaging more effectively than inner ones, which affects stress transfer and durability. (Nivetha et al., 2023)

For RCC, these findings highlight the need to carefully design compaction procedures and surface textures of fabrics to maintain a strong bond despite lower paste content or more heterogeneous matrices, particularly in roller compacted systems.

MECHANICAL PERFORMANCE

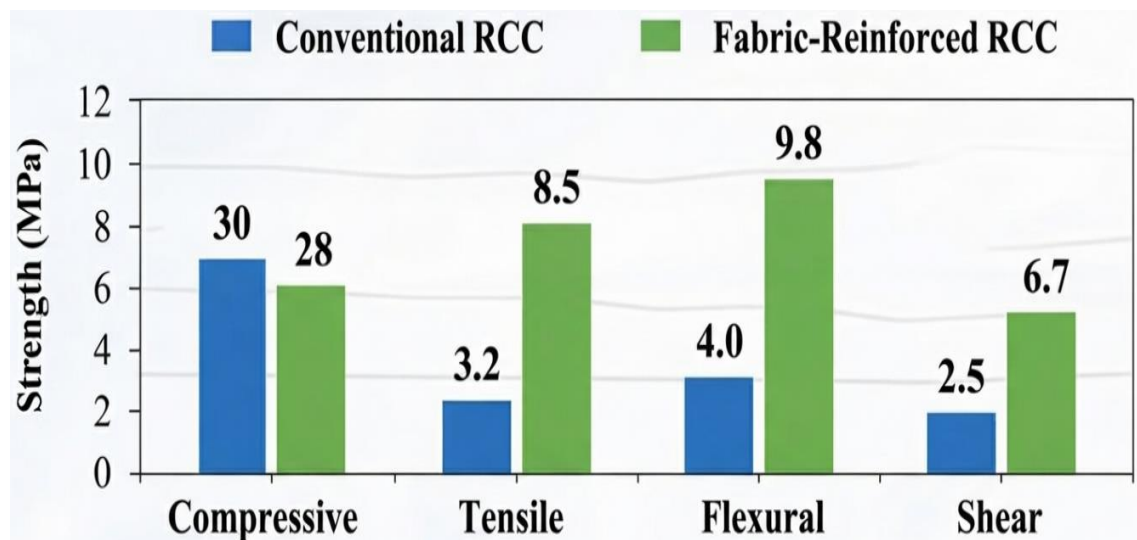


Figure 2: Mechanical Performance: RCC vs Fabric-Reinforced RCC

1. Tensile behavior

TRC and fabric-reinforced composites exhibit strain-hardening tensile behavior characterized by:

- An initial crack at low strain, followed by the formation of multiple fine cracks as the fabric progressively engages.
- A pseudo-ductile response where load is maintained or slightly increased after cracking, in contrast with the brittle post-cracking behavior of plain concrete. (Wu et al., 2023)(Venigalla et al., 2022)

Increasing the number of fabric layers, optimizing yarn orientation, and improving bond via coatings all contribute to higher ultimate tensile strength and ductility. (Wu et al., 2023) Such multiple cracking behavior is particularly advantageous when fabrics are combined with conventional reinforcing bars in RCC, since the fabric can limit crack widths and spacing, improving serviceability and delaying bar corrosion.

2. Flexural and shear performance

Experimental studies on beams and plates reinforced with textiles show:

- Significant increases in flexural capacity and stiffness compared with unreinforced or only short fiber reinforced concrete, especially for carbon and AR glass fabrics. (Nivetha et al., 2023)
- Flexural behavior is strongly governed by bond, fabric layout, and textile volume fraction; better bonding and more layers yield higher moment capacity but can reduce ductility if failure transitions to sudden yarn rupture. (Mansur De Castro Silva & De Andrade Silva, 2020)
- In hybrid beams combining TRC layers with steel reinforcement or dispersed fibers, the load–deflection behavior can be comparable to conventional RC beams at serviceability levels, even when overall reinforcement is reduced. (Mansur De Castro Silva & De Andrade Silva, 2020)(Venigalla et al., 2022)

These results suggest that RCC beams and slabs can exploit fabric layers near the tension face to achieve crack control and flexural strength, possibly allowing reduced bar diameters or cover thickness.

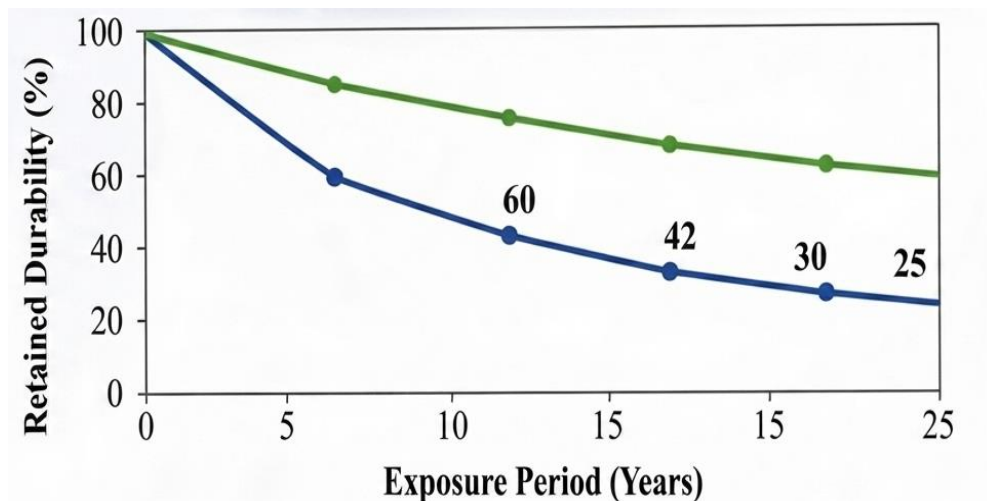
3. Impact, fatigue, and cyclic behavior

TRC systems have been investigated under dynamic and cyclic loading:

- Addition of polymer fibers (e.g., PVA) in the matrix together with textile fabrics improves cyclic tensile behavior and crack stability. (Wu et al., 2023)
- Textile-reinforced elements exhibit improved impact resistance and energy absorption due to multiple cracking and continuous reinforcement paths. (Venigalla et al., 2022)
- Fatigue performance is enhanced relative to plain concrete, as the fabric stabilizes microcracks and delays macro crack propagation.

In parallel, studies on fiber-reinforced roller-compacted concrete pavements show that synthetic and steel fibers can reduce slab thickness requirements by up to about 25% for certain load and support conditions. (Ozturk et al., 2022) This provides a strong conceptual basis for extending fabric reinforcement to RCC pavements, where continuous textile layers could further refine crack patterns and decrease slab thickness or joint spacing.

DURABILITY AND LONG-TERM PERFORMANCE



Fabric-reinforced RCC shows better long-term durability compared to conventional RCC.

Figure 3: Durability Comparison

1. Environmental actions

Durability is one of the primary motivations for using fabric reinforcement. Review studies on TRC report:

- Under elevated temperatures and fire exposure, the thermal response of TRC is broadly similar to that of ordinary Portland cement concrete, with fabrics exerting limited influence on thermal conductivity. However, high temperatures may degrade polymer coatings and certain fibers, particularly polymeric and some glass types. (Wu et al., 2023)
- Freeze–thaw and chloride wet–dry cycles can influence the tensile and bond properties of TRC; appropriate matrix composition and coatings are required to maintain durability in aggressive environments. (Venigalla et al., 2022)
- Accelerated aging of commercial textile reinforcements indicates that many fabric systems can retain substantial tensile capacity after environmental exposure, though long-term data are still developing. (Usability of Textile Reinforced Concrete: Structural ..., n.d.) For RCC structures and pavements, the use of non-corrosive fabrics offers the potential to significantly reduce or replace steel in zones where corrosion risk is high, thereby extending service life and reducing maintenance expenditures.

2. Durability compared with steel-reinforced RCC

In conventional RCC, corrosion of steel bars and cracking due to shrinkage, thermal movements, or traffic loading are dominant durability concerns. Fabric reinforced systems mitigate these issues by:

- Eliminating or reducing steel content in specific regions, thereby removing the electrochemical corrosion mechanism.
- Providing closely spaced reinforcement that limits crack widths, reducing ingress of chlorides and moisture to any remaining steel. (Wu et al., 2023)(Venigalla et al., 2022)

However, new durability questions arise regarding:

- Alkali resistance and chemical stability of glass and basalt fabrics.
- Long-term integrity of resin or polymer coatings in alkaline, wet–dry, and high-temperature environments.
- Compatibility between fabric layers and conventional RCC mixtures, particularly in roller compacted systems with lower paste content.

Addressing these issues is essential before large-scale adoption in RCC infrastructure.

APPLICATIONS AND IMPLICATIONS FOR RCC AND PAVEMENTS



Figure 4: Applications of Fabric-Reinforced RCC

1. Structural members

TRC systems have been used in thin façade panels, shells, pedestrian bridges, and strengthening overlays. For example, carbon concrete composite pedestrian bridges have demonstrated significant material savings and high stiffness in slender elements. (Nivetha et al., 2023)(Mansur De Castro Silva & De Andrade Silva, 2020)

For RCC beams, slabs, and shells, potential application strategies include:

- Externally bonded TRC laminates for flexural strengthening of existing RCC beams or slabs.
- Near-surface-mounted fabrics in grooves cut into RCC surfaces and filled with fine-grained mortar.
- Integral hybrid reinforcement, where steel bars provide primary flexural capacity and fabrics near the cover control crack widths and contribute to tensile resistance.

2. Roller compacted concrete (RCC) pavements

RCC pavements are widely used in industrial yards, ports, and low-speed roads due to their cost-effectiveness and rapid construction. Research on fiber-reinforced RCC has shown that:

- Synthetic fibers can reduce the required pavement thickness by up to about 25%, mainly by enhancing post-cracking load capacity and limiting crack widths. (Ozturk et al., 2022)

- Steel fibers improve fatigue resistance and load-carrying capacity of RCC pavements but are susceptible to corrosion in aggressive environments. (Ozturk et al., 2022)

While direct studies on fabric-reinforced RCC pavements are limited, extrapolation from TRC and fiber-reinforced RCC results suggests that incorporating textile layers at specific depths within an RCC slab could:

- Provide continuous crack control across slab panels.
- Allow for thinner slabs or larger joint spacing while maintaining performance.
- Potentially reduce reliance on dowel bars and tie bars in certain applications, though this requires rigorous verification.

Pilot projects and full-scale field trials will be critical to validate these hypotheses.

CHALLENGES, DESIGN ISSUES, AND RESEARCH GAPS

Table 2: Economic and Enviromental Comparison

Aspect	Conventional RCC	Fabric-Reinforced RCC
Initial cost	Lower	Moderate
Maintenance Cost	Higher	Lower
Service Life	Moderate	Longer
Carbon Footprint	Higher	Lower
Material Usage	High	Reduced

Despite significant progress in TRC research, several challenges remain before fabric reinforcement can be routinely adopted in RCC and RCC pavements:

1. Design codes and guidelines: Current reinforced concrete design standards are predominantly steel-centric and do not explicitly address textile reinforcement, multiple cracking behavior, or hybrid systems. There is a need for simplified yet accurate design models and code provisions for fabric-reinforced and hybrid RCC members. (Wu et al., 2023)(Venigalla et al., 2022)

2. **Scale-up and constructability:** Much of the existing work is at coupon or small-element scale, often using fine mortars. Integrating fabrics into RCC roller-compacted concrete, with realistic placing and compaction procedures, requires process innovations and detailed constructability studies.
3. **Bond and anchorage detailing:** Reliable anchorage of fabric layers, especially near member ends and discontinuities, is essential to develop tensile capacity. Anchorage strategies (mechanical anchorage, overlaps, end hooks with short bars, surface roughening) need further systematic investigation.
4. **Durability and lifecycle assessment:** Long-term performance data under field conditions are limited. Comprehensive lifecycle assessments comparing steel-reinforced RCC, FRC, and fabric-reinforced systems are required to justify adoption on economic and environmental grounds. (Wu et al., 2023)(Usability of Textile Reinforced Concrete: Structural ..., n.d.)
5. **Hybrid reinforcement optimization:** Optimal combinations of steel bars, short fibers, and fabrics in RCC members are not yet well established. Multi-objective optimization (strength, ductility, crack control, cost, sustainability) is an open research area. (Vairagade & Dhale, 2023)
6. **Standardized testing:** While test methods exist for FRC and for TRC coupon testing, standardized procedures specifically tailored to fabric-reinforced RCC (including roller-compacted systems) are still evolving.

CONCLUSIONS

Fabric or textile reinforcement represents a significant evolution in the design and construction of cementitious composites. By embedding non-corrosive, continuous fabrics within a cement matrix, TRC systems achieve high tensile capacity, multiple cracking, and improved durability compared with plain concrete and, in many cases, with conventional steel-reinforced RCC in aggressive environments.(Wu et al., 2023)(Nivetha et al., 2023)

For reinforced cement concrete and roller compacted concrete pavements, fabric reinforcement offers several promising pathways:

- As a supplement to steel bars, fabrics can refine crack patterns, reduce crack widths, and thus enhance durability and serviceability.

- As part of hybrid systems with dispersed fibers, they can enable thinner, lighter, and more resilient slabs and structural members, with evidence from fiber-reinforced RCC pavements pointing to substantial thickness reductions. (Vairagade & Dhale, 2023)(Ozturk et al., 2022)
- As a corrosion-resistant alternative in highly aggressive environments, fabrics could replace steel in specific zones, extending service life and reducing maintenance.

However, widespread adoption requires further work on design models, codification, long-term durability assessment, constructability in RCC and RCC pavements, and comprehensive cost–benefit analyses. Collaborative efforts among researchers, practitioners, and code-writing bodies will be essential to translate the promising results of textile and fabric-reinforced concrete research into robust, standardized solutions for RCC infrastructure.

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