FRP INTERNATIONAL

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IIFC Lecture Series

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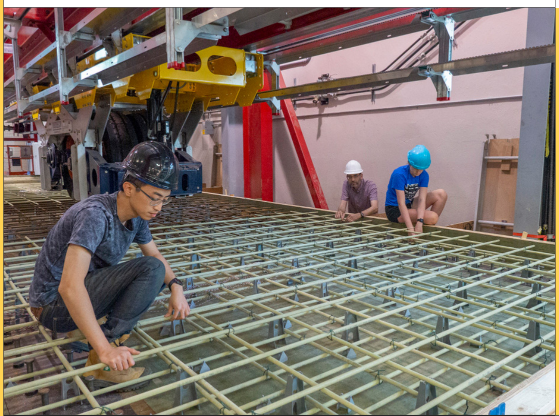

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Message from the Editor

The IIFC community had much to celebrate in 2025: a memorable gathering in Lisbon for the CICE conference, significant global engagement with our webinar series, increasing adoption of FRP composites in construction projects around the world, and many new individual and patron members that have joined our growing network, to name a few highlights. As we look ahead to 2026, this momentum shows no signs of slowing down; IIFC continues to produce meaningful educational content, support high-quality conferences and workshops, develop new strategic partnerships, and showcase the great work of our members for the benefit of our community. Stay tuned for more exciting announcements this year about future events and new initiatives for our diverse membership. I encourage all members to take some time this year to explore all that IIFC has to offer through our many online resources as well as in-person events.

This newsletter begins with the announcement of a new distinguished lecture series in honour of Professor Sami Rizkalla, a true pioneer of IIFC whose impact in our field cannot be overstated. The upcoming FRPRCS-17 conference in Girona, Spain—already a can't-miss event—will now carry even more significance as the site for the inaugural lecture from this series and a special session dedicated to Prof. Rizkalla. See you in July!

IIFC Task Groups are also ramping up their activities this year, and we are pleased to feature the first in a series of articles on their work. In this issue, we highlight natural textile reinforced mortars, one of several emerging areas with potential to improve the sustainability of construction materials.

A personal highlight for me is the Meet the People feature, which recognizes the remarkable career and contributions of Professor Carol Shield. Dr. Shield's service to the profession and leadership of ACI Committee 440, which grew to be the largest and most prolific of all ACI committees, were instrumental in supporting the emerging FRP-in-construction industry in North America.

We also spotlight an impressive research project by 2025 IIFC Best PhD Thesis Award winner Chongxi Gao, and two field case studies: the Changtai Yangtze River Bridge in China and the NEOM South Statcom SEC Substation Project in Saudi Arabia. Finally, be sure not to miss the overview of the new ACI PRC-440.14-25 design guide for concrete-filled FRP tubes in our "Codes and Standards" section.

As always, I invite you to reach out with any ideas for future issues.

Thanks for reading!

Prof. **Martin Noël**
Editor

IIFC NEWS & EVENTS

IIFC News

Sami Rizkalla - Lecture Series

Prof. **Sami H. Rizkalla**
Distinguished Professor Emeritus

The International Institute for FRP in Construction (IIFC) is proud to announce the establishment of the **Sami Rizkalla IIFC Lecture**, recognizing one of the true pioneers in the field of FRP in civil engineering.

Professor Sami H. Rizkalla, Distinguished Professor Emeritus at North Carolina State University, has tremendously helped shaping the global landscape of FRP composites in construction for almost four decades through his scholarship and leadership in the field.

From founding FRP International, the forerunner of the IIFC Newsletter, years before establishing the Institute itself, to mentoring generations of engineers and researchers worldwide, Professor Rizkalla's influence has defined both the field advancements and the community of FRP in construction.

This new lecture to be delivered at every FRPRCS conference reflects the continued leadership of IIFC in shaping the global conversation on innovative, sustainable, and resilient construction using FRP technologies, and pays tribute to the remarkable contributions of Prof. Sami Rizkalla — a pioneer, mentor, and visionary whose work continues to inspire the global FRP community.

We are especially pleased to share that the **inaugural Sami Rizkalla IIFC Lecture** will be delivered by **Prof. Jin-Guang Teng**, President of The Hong Kong Polytechnic University, at the upcoming **FRPRCS-17 Conference**, to be held in **Girona, Spain**, from **July 6–8, 2026**.

Featured IIFC patron member

Dextra Group:
Building the Future with GFRP Rebar

At the heart of Saudi Arabia's new Dammam Stadium, Dextra and ICSC are driving innovation and localized manufacturing of advanced GFRP reinforcement solutions. This landmark project, set to host the 2027 AFC Cup, reflects our commitment to Saudi Vision 2030 by producing locally and sourcing raw materials within the Kingdom.

Innovating today for a stronger tomorrow.

Why Dextra GFRP rebar?

- **Corrosion-resistant** for harsh environments
- **Lightweight** for easier handling
- **Lower carbon footprint** for sustainable construction
- **Long-lasting durability** to reduce maintenance costs
- **Locally manufactured** speeding up delivery times

For the stadium's massive slab-on-grade, Dextra supplied 900,000 meters of GFRP rebar, backed by engineering support, precision drawings, and seamless coordination, delivering speed, reliability, and sustainability.

Dextra: Your trusted partners for mega-projects, combining global standards with local strength and speed.

For more information on membership, visit iifc.org/membership

IIFC NEWS & EVENTS

IIFC Events

FRP workshop at American University of Sharjah

The American University of Sharjah (AUS) recently hosted the workshop "Towards Enhanced Structures and Sustainable Construction: FRP Solutions for Strengthening, Rehabilitation, and Internal Reinforcement" on December 9–10, 2025. The event was organized by Dr. Farid Abed, a professor at AUS, and covered externally bonded FRP systems for structural strengthening and rehabilitation, as well as the use of FRP bars as internal reinforcement for sustainable and corrosion-resistant concrete structures. The workshop brought together academics, designers, contractors, and industry professionals to exchange knowledge and bridge the gap between research, design codes, and practical implementation.

Professor Tao Yu participated in the workshop as the representative of the International Institute for FRP in Construction (IIFC), one of the supporting organizations of the event. Dr. Yu is the Senior Vice President of IIFC and a Professor of Structural Engineering at The Hong Kong Polytechnic University.

In his presentation, Dr. Yu introduced the IIFC, highlighting its organizational structure, international conferences, awards, and ongoing initiatives that support innovation and excellence in FRP research and practice.

He then delivered a technical lecture on FRP-reinforced seawater sea-sand concrete structures, demonstrating how the integration of FRP reinforcement with seawater sea-sand concrete offers a dual sustainability solution by enhancing corrosion resistance while enabling the use of locally available materials unsuitable for conventional steel-reinforced concrete. His contribution aligned closely with the workshop's emphasis on durable and sustainable alternatives to traditional reinforcement systems.

Last call for FRPRCS17, Girona, Spain

17th International Symposium on Fiber-Reinforced Polymer (FRP) Reinforcement for Concrete Structures I Girona, Spain – July 6-8, 2026

The 17th International Symposium on Fiber-Reinforced Polymer Reinforcement for Concrete Structures (FR-PRCS17) is just months away. Join us on July 6 to 8, 2026 in the beautiful and historic city of Girona, Spain.

With more than 330 abstracts received, the symposium is set to be the premier platform for leading researchers, engineers, industry practitioners, and students to present research advancements and exchange ideas on the use of FRP reinforcement in concrete and masonry structures.

The symposium will feature a rich and diverse program, covering a wide range of topics, as well as 18 Special Sessions dedicated to specialized research aspects.

Prof. **Jin Guang Teng**
Keynote Speaker

Prof. **Lijuan Cheng**
Keynote Speaker

Prof. **Marco di Ludovico**
Keynote Speaker

KEY DATES

- Deadline for submission of full papers: extended to February 20, 2026
- Notification of approval/revision of full papers: March 30, 2026
- Deadline for revised version of full papers: April 10, 2026
- Early bird registration: April 15, 2026

CONFERENCE HIGHLIGHTS

- The conference proceedings will be indexed in Scopus and published by Springer. Selected contributions will be invited for Special Issues in the Journal of Composites for Construction and Construction and Building Materials.
- Inaugural Sami Rizkalla IIFC Lecture: Prof. Jin Guang Teng will deliver the series' first keynote "FRP Composites in Construction: A Personal Journey of Three Decades and the Potential of FRP as a Mainstream Structural Material."
- Engaging keynote lectures: Prof. Lijuan (Dawn) Cheng on "Enhancing Fatigue Service Life of Aging Concrete Bridges Using FRP", and Prof. Marco di Ludovico on "Advanced Solutions Using Composites for Seismic Loss Reduction".
- Exclusive "Meet the Editors" event: Gain in-depth knowledge on the publication process. Editors from the Journal of Composites for Construction, Construction and Building Materials, Journal of Building Engineering, Structural Concrete and Advances in Structural Engineering will share tips and tricks for successful academic writing.
- 1st edition of "Women in the IIFC": A landmark plenary session featuring notable speakers and a roundtable discussion to celebrate and promote the contribution of women in the field of FRP.
- Young Researchers plenary session and RILEM award: a dedicated session exploring career perspectives and trajectories for the next generation of experts on FRP. The RILEM best paper award will be presented to the best paper authored and delivered by a young researcher or PhD student.

Beyond the technical programme, the participants can immerse themselves in the beautiful city of Girona, explore the historic Jewish Quarter, walk along the ancient city walls, and sample Catalonia's world-famous cuisine. The program also includes a technical visit to Barcelona, easily accessible by high-speed train.

The Organizing Committee of FRPRCS17 looks forward to welcoming all participants to Girona on 6-8 July 2026!

APFIS 2026 & ISSCI 2026

BEIJING, CHINA

Asia-Pacific Conference on FRP in Structures (APFIS) is an international conference series that is open to researchers, academics, students, manufacturers, consultants, contractors and policy makers. Its aim is to showcase research, development and application of fibre-reinforced polymer (FRP) composites in the built environment. The inaugural APFIS conference was held in Hong Kong in 2007, and the most recent one was successfully held in Adelaide, Australia in 2024. The APFIS 2026 is being jointly organized by University of Science and Technology Beijing and Tsinghua University on **2-5 August 2026** in Beijing, China.

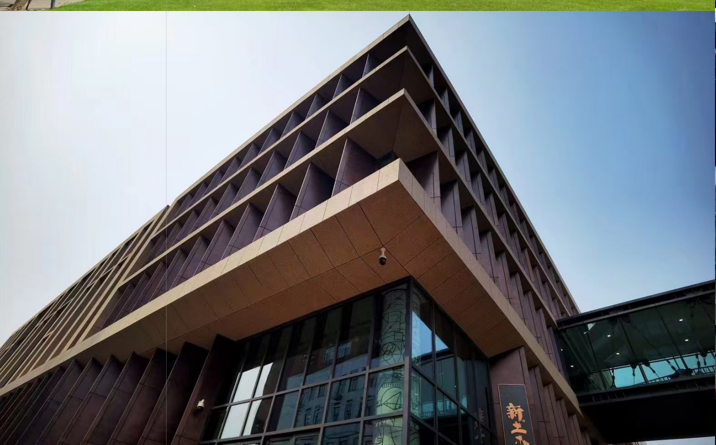
The International Summer School on Composites in Infrastructure (ISSCI) is an official activity of the International Centre for Composites in Infrastructure (ICCI) established at University of Wollongong, Australia.

The inaugural ISSCI was held at University of Wollongong in 2016. Following the success of the previous summer schools, the 7th ISSCI will be held on the Tsinghua Campus on **5-7 August 2026** preceded by the APFIS 2026. Students participating in the summer school are encouraged to present their research at the young researcher's forum during the conference.

On behalf of the organizing committee, we offer you a very warm welcome to Beijing and we look forward to seeing you at APFIS 2026 and ISSCI 2026.

Details & registration
www.apfis2026.scimeeting.cn

Enquiry
apfis2026@cribc.com



IIFC NEWS & EVENTS

IIFC Task group updates

IIFC TG-1: Sustainable fibre composite materials

NTRMs: bridging strength and sustainability in existing building retrofitting (G. Misseri, A. Monaco, F. Roscini)

Natural Textile Reinforced Mortar (NTRM) systems can be considered a sustainable advancement in structural strengthening [1-3]. The search for more sustainable reinforcement systems has never been more critical in a world grappling with energy crises, resource scarcity, and the urgent need to decarbonise construction practices [3]. Natural fibre composites have been studied for decades as a promising alternative to conventional composite systems in structural and infrastructural applications [4,5]. For instance, Fibre Reinforced Polymer (FRP) systems, though effective, come with high embodied energy, production complexities, and a series of shortcomings connected to the compatibility with historic construction materials and damaged substrates.

NTRMs offer a paradigm shift as they reduce carbon emissions, leverage locally available materials, and support low-energy production processes [6]. These systems constitute a viable retrofitting technology that uses natural fibre textiles embedded in an inorganic mortar. Natural fibres offer low cost, renewability, and biodegradability, and studies show promising mechanical performance [7,8]. Those include plant-based fibres such as flax, jute, hemp, and sisal, as well as mineral-based fibres like basalt, which can be woven or nonwoven into a fabric mesh. The bio-based origin and then, the reduced carbon-footprint make NTRMs a compelling alternative in a sector striving for circularity and long-term environmental responsibility.

In addition to lower energy emissions for production, natural fibre meshes are also less expensive. Across low-income and non-industrialised countries, the demand for cost-effective, accessible strengthening techniques is growing rapidly. NTRM systems can often be locally manufactured, requiring reduced industrial facilities and simpler workmanship, especially compared to synthetic fibre composites. This makes them an ideal solution for developed contexts seeking greener solutions and resource-limited settings, where high-tech imports are often unaffordable or unsustainable.

At the same time, high-income countries face the challenge of preserving historic structures since this positively affects their economies.

One of the most compelling advantages of NTRMs is the chemical and mechanical compatibility of their inorganic mortars with substrates such as masonry and stone [9]. This makes them particularly well-suited for historic building retrofits, where preserving material integrity and aesthetic authenticity is paramount. Their reversible and minimally invasive application methods align closely with international restoration principles, offering a respectful yet robust path to seismic upgrading and structural rehabilitation.

In this framework, NTRMs respond to both realities since these systems enable structural strengthening that is affordable and heritage-compatible.

Insights on the mechanical response

The primary mechanical difference between externally bonded FRP systems and Textile Reinforced Mortar (TRM) systems is their interaction with the substrate. Debonding at the FRP–substrate interface is the typical limit state in FRP-strengthened structures, often resulting in a fracture that resides within the substrate. Conversely, in TRM systems, failure typically occurs within the composite (fibre-matrix interaction), and with proper installation in NTRM, the substrate remains intact.

Driven by sustainability concerns, research is increasingly focused on using NTRM systems as an eco-friendly alternative to synthetic fibres for structural rehabilitation, especially masonry. While the mechanical behaviour of TRMs is extensively studied, there is less research on NTRM, particularly for masonry strengthening [10-22]. Considering the literature studies in this reference list, some of them explore flax- and jute-based TRM (see Figure 1a), with some showing significant increases in the capacity of masonry walls strengthened with flax-TRMs.

Experimental shear bond tests were conducted [11,23,24], in a limited number of cases (Figure 1b) to evaluate the adhesion strength and failure modes of NTRMs, and these results were correlated with tensile tests to assess stress transfer (Figure 2).

This allowed for the derivation of a bond-slip law characterising the interface response. The findings aim to demonstrate the mechanical compatibility of NTRM with historical substrates, support its use as an effective and minimally invasive reinforcement technique, and contribute to predictive models for interface behaviour in heritage conservation.

One of the foremost challenges that must be addressed in this field is the significant variability in mechanical properties [25-27], alongside the methods and effectiveness of fibre treatment techniques [12,28-31]. These factors are particularly important in enabling the reliable assessment of accelerated conditioning effects on the TRMs mechanical properties [13, 32-35], essential for predicting long-term performance and durability (Figure 3).

In conclusion, NTRMs are more than just a sustainable alternative: they represent an opportunity to rethink the strengthening of structures as smarter and greener.

They are a versatile solution for various structural contexts, especially where resources or access to advanced materials are limited. They technical performance and environmental responsibility, with the added benefit of being locally sourced and compatible with historic buildings.

However, there is still work to be done, especially in understanding their durability performance and refining fibre treatments, but the foundation is promising [36]. With the right investment in research and innovation, NTRMs could reshape the future of structural rehabilitation, offering that respects both the planet and the preservation of our architectural heritage.

Finally, NTRMs could be key in shaping a more sustainable, inclusive future for structural rehabilitation worldwide.

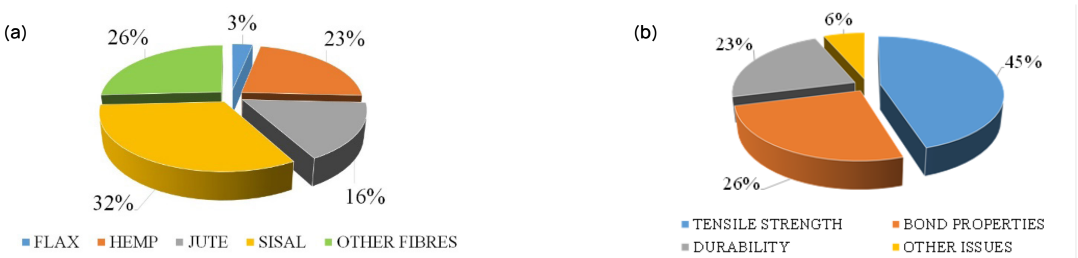


Figure 1: a) percentage distribution of fibre type and b) structural issues considered through the reported references.

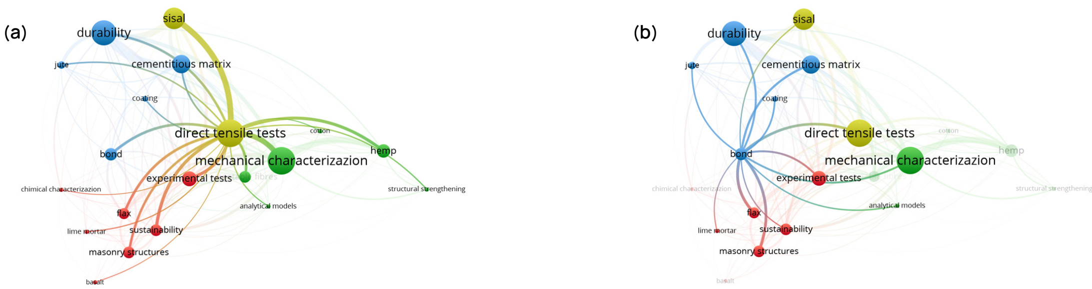


Figure 2: Keywords with higher co-occurrence with a) "direct tensile tests" and b) "bond".

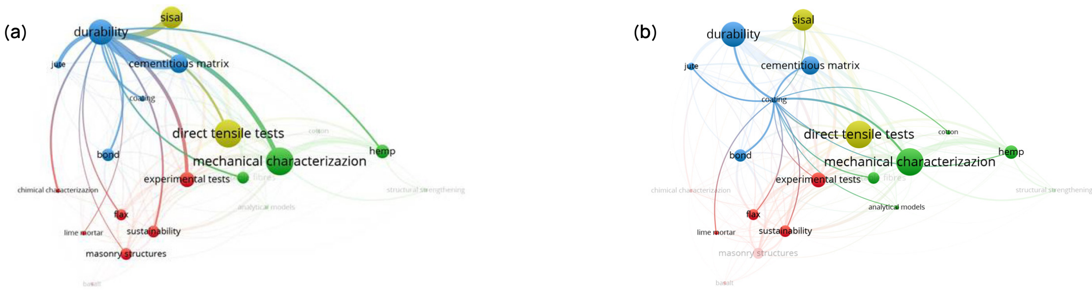


Figure 3: a) Keywords with higher co-occurrence with a) "durability" and b) "coating".

EDITOR'S NOTE

IIFC launched six new task groups in March 2025 to promote research and collaboration on emerging topics with widespread interest among research and industry members.

This article is part of a new regular series in which the various task groups will highlight key trends and opportunities in the field of FRP composites for construction.

For more information, see https://www.iifc.org/publications-resources/task-groups/ or contact Chao Wu.

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MEET THE PEOPLE

Prof. Carol Shield

1984 BA Mathematics, BS Engineering Swarthmore College

1986 MS Mechanical Engineering Rensselaer Polytechnic Institute

1991 PhD Theoretical and Applied Mechanics, University of Illinois

Current Affiliation: Department of Civil, Environmental, and Geo-Engineerings, University of Minnesota, Professor Emeritus

Key Roles

Faculty, University of Minnesota 1991-2020

Director, MAST Laboratory, University of Minnesota 2004-2015

Chair ACI Committee 440 (2009-2015)

Vice Chair ACI Committee 440C (2023-current)

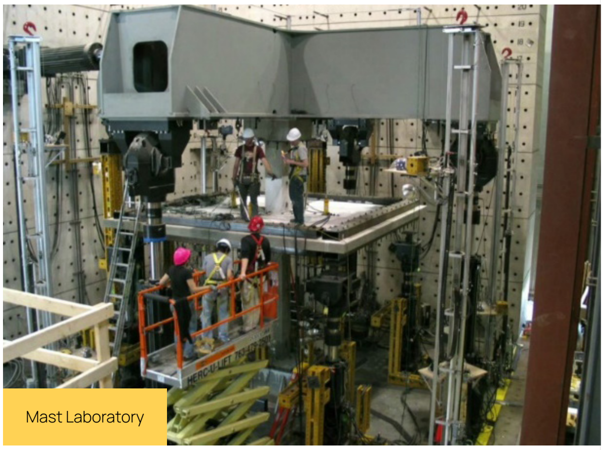
Chair, Seventh International Symposium on Fiber Reinforced Polymer Reinforced Concrete Structures (FRPRCS-7) 2005.

Dr. Shield's research focused primarily on the use of fiber reinforced polymers (FRP) in civil infrastructure, the behavior of prestressed concrete girders, and the development of testing methods. Her work contributed to improved understanding of how innovative materials can enhance the durability, performance, and longevity of critical structures. From 2004 to 2015, she served as director of the Multi-Axial Subassemblage Testing (MAST) Laboratory, one of the leading facilities in the United States for large-scale structural testing. In this role, she oversaw experimental programs that supported academic research, informed industry practice, and advanced the state of knowledge in seismic simulation.

Dr. Shield has held significant leadership roles within the American Concrete Institute (ACI). She is a past chair of ACI Committee 440 Fiber Reinforced Polymer Reinforcement, served as co-chair of ACI Subcommittee 440H, the group responsible for developing the GFRP Bar Code and is currently vice chair of ACI 440C FRP Reinforced Building Code. Her long-standing service to ACI reflects her dedication to strengthening design standards, improving material guidelines, and supporting the safe implementation of emerging FRP technologies.

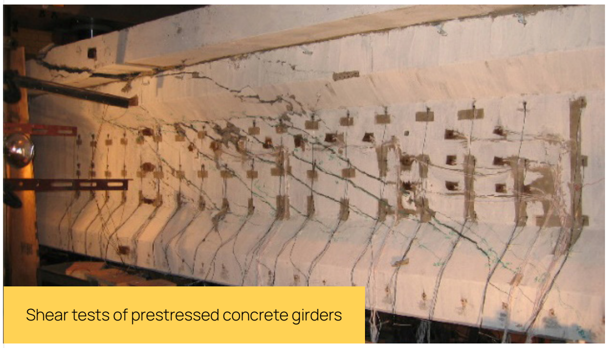
Her most impactful contribtion to FRP reinforced concrete design is the development of equations for bond of GFRP rebars to concrete.

Her contributions have been recognized through notable honors, including the ASCE Norman Medal and the ACI Delmar L. Bloem Award. She is also a Fellow of the American Concrete Institute, reflecting her sustained impact on the structural engineering profession.



Mast Laboratory

MEET THE PEOPLE › CAROL SHIELD


Shear tests of prestressed concrete girders

When and how did your interest on FRP composites first develop?

My first job out of college in 1984 was with the United Technologies Research Center in East Hartford, CT. There I worked on developing methods of nondestructive evaluation. One of the larger projects I worked on was developing these methods for composite rocket motor cases. This was my first interaction with composite materials and I got intrigued. I liked the notion that you could engineer a material to have different properties in different directions, and potentially optimize material use for function.

In your view, what are the main current and future challenges regarding the application of composites in civil engineering?

Structural engineers tend to be very conservative and resistant to change. They don't like to take chances when it comes to safety. So, getting those people to accept that composite materials can be used to reinforce concrete is truly a challenge. I often end up talking with engineers after I give a presentation and they don't like the idea of using a material that is brittle as a reinforcement for concrete, often liking it to using cast iron for bridge construction. It takes sitting down with these people to open their minds to the fact that not all brittle materials are the same and that as long as you take material properties into account in writing design standards these types of materials can not only be used safely, but also cost efficiently. I also think the industry is hurting itself. Currently producers seem to want to compete with each other based on who produces the best bar. This also provides a hurdle for adoption, as designers don't necessarily want the best bar, they want a bar that reliably meets a set of standards, and then among those bars they want the least expensive one. If we could get FRP bar manufacturers to realize that standardization across the industry helps with adoption, and all build bars to meet (but not necessarily exceed) ASTM specs, so that designers don't have to think about what producer bar they are going to use when designing, that will really open up more doors.

Can you share the most rewarding moments or achievements in your professional career?

This is a particularly easy question for me to answer. Without a doubt, the most rewarding achievement in my career was the publication of ACI CODE-440.11-22, but I'll talk more about that in my response to question 4. Outside of 440.11-22, I've really enjoyed helping people realize their goals. In particular, I loved teaching, and especially loved teaching undergraduate students their first class in structural design. At the University of Minnesota, that first design class covers both the design of steel structures and the design of reinforced concrete structures. It has a reputation for being a very challenging course, so most students when they show up for the class are not looking forward to it, especially the ones who are not currently on a path to becoming structural engineers. To me, the most rewarding moments are when those students realize that structural design is unlike any other engineering class they've taken, that there are many correct answers and that they have the ability to put some of their personality into their designs. So many students end that class with a new found interest in structural design.

Can you describe a particularly impactful project or initiative you've been involved related with FRP composites and its outcomes?

I hope the most impactful project that I've been involved with will be ACI CODE-440.11. When I chaired ACI Committee 440 from 2009-2015 it was clear to me that to move FRP reinforced concrete forward there needed to be a ACI 318-like design code for FRP reinforced concrete. I worked with ACI staff during that time to build support for the idea and ultimately got permission for the committee to start work on the code around 2014. In preparation for creating that document, the committee produced a construction specification ACI SPEC-440.5 and a materials specification ACI SPEC-440.6. The materials specification ultimately morphed into ASTM D957. With materials and construction specifications in hand, the committee had the tools it needed to be able to write a design code, and so began the long path to the publication of ACI CODE-440.11. Because ACI 318 underwent substantial revision in 2014, it was decided that the committee would not start work on the GFRP design code until after the publication of ACI CODE-318-14. Vicki Brown and I took the lead at drafting many of the chapters for the new code and by the fall of 2015 we started balloting chapters at the subcommittee level. With the help of many great committee colleagues, we were able to produce an ACI 318-like document that provided designers the option to design concrete structures with GFRP reinforcement. In 2022, that document was published by ACI and later that year it was adopted by IBC.

I do believe that this monumental step will have a large impact on the use of GFRP reinforced concrete in the built infrastructure. The adoption of this document by IBC means that designers don't have to jump through extra hoops in order to design GFRP reinforced concrete members. The publication of this document, through a rigorous ANSI standard process also gives the designers confidence that this isn't just a document slapped together by a few people without much thought. I'm hopeful that it will help to ease away some of the angst that structural engineers have when venturing into a new space.

What motivates you to continue working and contributing to the FRP composites area, even after so many achievements?

There is always more to be done in making it easier for designers to use FRP for civil infrastructure. If the corrosion problem can be tackled, which is one of the main points of using FRP reinforcement, then structures will last longer and be better for the environment. Longer lasting structures also means less disruption to society, as infrastructure will have to get replaced less frequently. So thinking that I can be a part of this little bit of making the world better keeps me motivated to keep on contributing in the composites area.

If you were starting your career today as a young engineer/researcher, what advice would you give yourself?

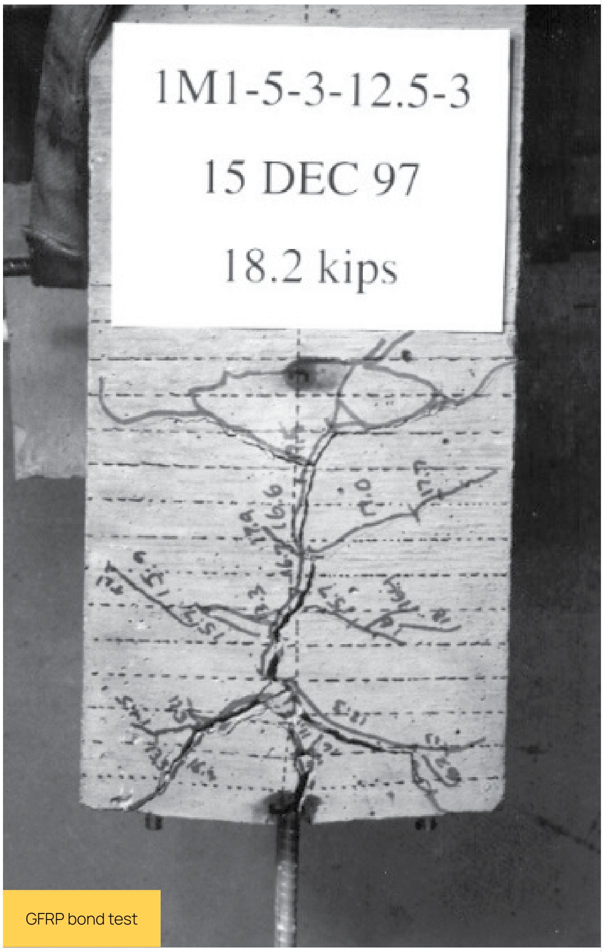
My advice would be to get involved in something professional that you are passionate about. At ACI, it's easy to join committees and get involved. Don't be afraid to offer your help on whatever the committee is working on, even if it's as simple as offering to do an editorial review on something that you might not be "the expert" at. Involvement helps to build a network, which helps to promote your career as you develop more and more contacts that you can ask questions of and bounce ideas off of.

What is your favorite hobby outside of work?

I'm an avid sailor. My husband and I have raced a 20ft long scow for the past 30+ years. I've also crewed on a 38 ft long scow (with 3 other women and 2 men). I love sailing with a purpose (to win). I also think that sailing is an engineers sport. If you don't think like an engineer and figure out how to tune the boat and understand the wind, you will not be a great racer.

What is your favorite food?

This one's also easy – dark chocolate.



GFRP bond test

What is/was your favorite trip?

My favorite trip of all time was going to Egypt with my Dad when I was in high school. I will always remember being awed by the ancient structures, like the pyramids, but probably even more spectacular was approaching Abu Simbel by boat.

COMPOSITES AROUND THE WORLD

Research

Experimental and Numerical Investigations of a Full-Scale Steel- and GFRP-Reinforced Concrete Bridge Deck under Pulsating and Rolling Load Fatigue

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2025 IIFC Best PhD Thesis Award Winner

INTRODUCTION

Bridges are crucial components of today's transportation infrastructure system, yet hundreds of thousands of bridges around the globe are in critical condition due to the combined effects of fatigue loading and environmental exposure conditions. Across North America, Europe, Asia, and Australia, aging assets under heavy traffic and corrosive exposures make deck fatigue a shared concern, motivating improved design, assessment, and rehabilitation.

In order to prolong the expected service life of rehabilitated and newly designed bridges, researchers have extensively studied the possibility of using fibre-reinforced polymer (FRP) materials as corrosion-resistant reinforcement of concrete bridge decks[1,2]. While fatigue behaviour of glass fibre-reinforced polymer (GFRP) rebar and GFRP stay-in-place (SIP) form reinforced bridge deck has been investigated, the traditional fixed-point pulsating load (PL) was adopted rather than the more realistic rolling wheel load (RL). Existing research on steel rebar reinforced bridge deck has found that one cycle of RL is equivalent to 80 to 1800 cycles of fixed-point PL upon failure of specimens[3,4].

The difference between PL and RL on the fatigue behaviour of concrete bridge deck reinforced with GFRP material is yet to be determined. Moreover, none of the existing research have investigated the fatigue behaviour of a concrete bridge deck reinforced purely with GFRP SIP form and GFRP rebar using RL.

This PhD thesis is the first of its kind to assess fatigue behavior of GFRP-reinforced bridge decks under RL in a laboratory.

A full-scale slab-on-girder type bridge with a concrete bridge deck incorporating three different reinforcement setups at various portions has been designed, assembled, and tested. The fatigue behaviour of concrete bridge deck reinforced with GFRP rebar under both PL and RL was investigated and compared. The residual punching shear strength of GFRP rebar reinforced bridge deck after fatigue experiment was also studied. Rolling load was used to evaluate the fatigue performance of three reinforcement setups. A finite element modeling (FEM) strategy was created for the specimen bridge deck and validated using experimental data. In addition to the experimental and numerical analysis, a thorough state-of-the-art review is also presented in this thesis regarding the RL fatigue behaviour of reinforced concrete bridge decks.

METHODOLOGY

Bridge specimen: A full-scale concrete bridge deck was tested under RL fatigue using Canada's only Rolling Load Simulator (ROLLS) at Queen's University. The bridge deck was a slab-on-girder design measuring 15.24 m in length, 3.89 m in width, and 210 mm in depth. Resting on two steel I-beams, spaced 3.05 m apart center-to-center (Fig. 1(a)). The girders' top flanges have 29 mm diameter bolt holes, spaced 152 mm apart, located 89 mm from the mid-width of the flange. These holes accommodate 19 mm thick sacrificial steel plates with two rows of welded shear studs spaced at 305 mm (Fig. 1(b)), preserving the girders for future use, and were torqued to the flanges. Cross bracings bolted to the girders provide lateral support at both ends and at mid-span of the bridge. Two concrete pedestals at each end supported the steel girders.

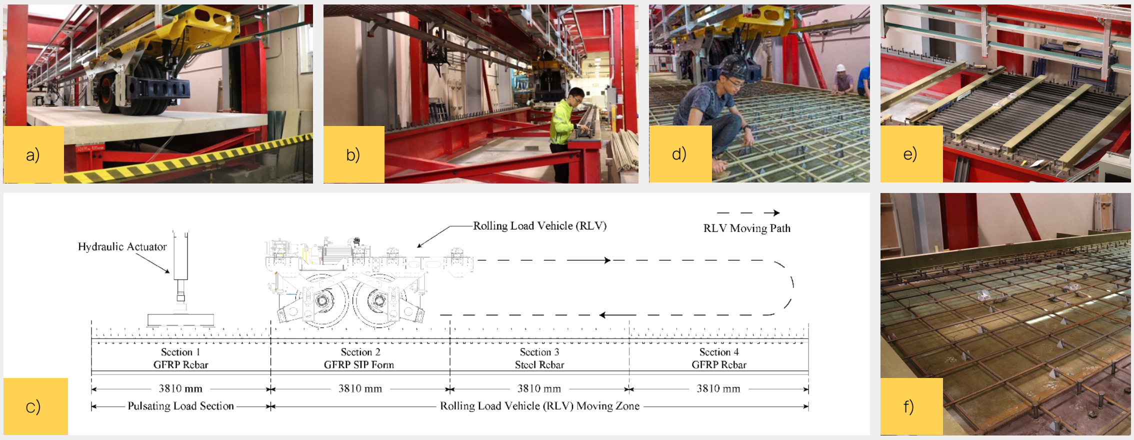

Figure 1. (a) Overview of bridge specimen and rolling load simulator, (b) Shear studs plate installed on steel supporting girder, (c) schematic plot of deck segmentation with label and loading setup in elevational view, and photos of (d) GFRP rebar grid, (e) GFRP SIP form, as well as (f) steel rebar grid.

Reinforcement design: The full deck is monolithically cast but was conceptually segmented into four equal sections, each 3.81 m long and 3.89 m wide, labeled 1 to 4 as shown in Fig. 1(c). The sections are not isolated from each other. Instead, they are all part of the integrated bridge deck. Sections 1 and 4, located at the deck's ends, feature orthotropic GFRP rebar grids(Fig. 1(d)) consisting of 15M GFRP rebar spaced at 152 mm and 300 mm in the transverse and longitudinal directions, respectively. Isotropic rebar grids with 15M GFRP rebar spaced at 300 mm serve as top reinforcement. Section 2 incorporates a novel GFRP SIP form (Fig. 1(e)). The transverse reinforcement consists of five GFRP I-beams, each 152 mm tall and wide, with 9.5 mm thick flanges and webs. These I-beams are positioned on the top flange of steel I-beams, spaced at 905 mm. GFRP planks with T-up ribs are placed between the I-beams on their bottom flanges, and serve as longitudinal reinforcements. Section 3 uses isotropic conventional steel reinforcement top and bottom which is 15M rebar spaced at 300 mm in both directions (Fig. 1(f)). All three reinforcement setups were designed in accordance with the CHBDC[5]. Longitudinal reinforcement of each section would extend into the neighbouring section to create splices, designed to ensure the continuity of bridge deck by satisfying the development length required by rebars.

Experiment setup: The fatigue experiment was setup to have section 1 tested under PL, while the other three sections were tested under RL as shown in Fig 1(d). Each section underwent 3 million (M) fatigue cycles, except the steel-reinforced section, which experienced 6M due to its position within the travel path. The base fatigue load level was determined to be 90 kN/half-axle applied on two half-axles spaced at 1.2 m.

The fatigue experiment was periodically paused to conduct monotonic tests up to the base design load to establish the stiffness degradation, deflection progression, and strain development.

After the fatigue experiment concluded, the two end sections reinforced with GFRP rebar were tested to failure with a single loading pad. Linear potentiometers (LP) were installed to monitor the deflection of the bridge deck and the supporting girders along the longitudinal centre line of each section. Strain gauges were mounted onto reinforcement at the centre of each section, as well as on top reinforcement near the supporting girder.

Loading apparatus: The PL was applied with a hydraulic actuator, while the RL was applied with the ROLLS. The Rolling Load Simulator (ROLLS), which is the only one in Canada and likely one of only 3 or 4 worldwide at that scale and capability, comprises two half-axles spaced at 1.2 m, equipped with air-inflated truck size dual rubber tires (Fig. 1(a)). The apparatus features a running load vehicle (RLV) equipped with an onboard hydraulic system and one independently controlled 125 kN actuator on each half-axle. The RLV is driven by a 400 hp electric motor, utilizing specialized timing belts, and can achieve a maximum speed of 6 m/s. The residual strength test of two GFRP rebar reinforced section was conducted using hydraulic press.

Numerical analysis: A nonlinear FEM was created using LS-Dyna and validated by experimental data to simulated deck behavior under single cycle of PL and RL.This model can capture accumulated damage and can be used in the feature to simulate fatigue behaviour. The FEM was also used to simulate the punching shear behaviour of the GFRP rebar reinforced section.

A parametric study was also conducted to investigate the influence of loading pad amount, and loading location on the punching shear strength of GFRP rebar reinforced concrete bridge deck.

RESULTS

PL vs. RL: RL resulted in significantly greater fatigue damage than PL, with a 71% and 54% reduction in normalized stiffness (k/k_o) for the GFRP-reinforced sections, indicating that one R-cycle equates to 120 P-cycles. Live load deflection limit of span/800 was reached in the RL section after 0.78M equivalent cycles, and at 3M equivalent cycles was exceeded by 15%, but the PL section remained below the limit. The strain measured from the top transverse reinforcement near the supporting girder barely changed for the PL section, where it increased by 1035% for the RL section. The transverse cracks created by rolling load could have led to moment redistribution resulting in load concentration at the centre of the section. The RL section showed far more extensive and denser grid-pattern cracking with concrete pitting at the soffit after fatigue experiment, while the PL section showed minor longitudinal and some radial cracks. Longitudinal cracks were discovered at the top surface of RL section along the supporting girders, where no crack was observed on the top surface of the PL section. A conversion factor (ξ) was established to enable researchers and designers convert (k/k_o) from readily and easily available PL to an equivalent RL of GFRP-reinforced deck at any number of cycles, since PL is not conservative, and RL capabilities are not easily available. In this study, ξ is 0.59 at 3M equivalent cycles.

Reinforced setups under rolling load: After 3M cycles of RL, the live load deflection for section 2, 3, and 4 increased by 240%, 207%, and 224%, respectively. The normalized stiffness reduction for sections 2, 3, and 4 are 73%, 69%, and 71%, respectively. Despite the difference in reinforcement stiffness, GFRP-reinforced sections experienced very similar reduction in stiffness to that of the steel-reinforced section at 3M cycles. The live load deflection limit of span/800 was reached at 2.2M, 4.47M, and 0.78M cycles for section 2, 3, and 4 respectively. The number of cycles it takes to reach live load deflection limit is directly correlated with the reinforcement stiffness of each section.

At 3 million cycles, the residual deflection of section 3 and 4 are 3.87 mm and 3.95 mm respectively, where the residual deflection for section 2 is only 2.41 mm.

The small residual deflection of section 2 can be contributed to higher reinforcement ratio combined with a maximized contact surface area between GFRP SIP form and concrete, which possibly led to enhanced tension stiffening.

Residual strength: The two GFRP rebar reinforced sections were tested under single point loading to failure after fatigue experiment. Despite the difference in stiffness degradation, both GFRP rebar reinforced sections exhibited similar residual punching shear strength (V_u), with only a 4% difference. Failure occurred by punching shear of the concrete deck slab, with average cone angles of 15° and 19° for the PL and RL sections, respectively. At failure, the GFRP rebar maximum tensile stress did not exceed 27% of its ultimate strength. Parametric study based on FEM revealed Vu under two loads spaced at 1.2 m, representing the two half axles of CL-625 in close proximity, is only 34% higher than V_u under a single load due to the interaction between the two punching shear cones, reducing the net surface of resistance. The parametric study also revealed translational offset of load has little effect on V_u.

CONCLUSION

This PhD thesis included a thorough state-of-the-art review on research related to rolling load fatigue studies of bridge decks. A full-scale slab-on-girder type bridge with sophisticated reinforcement design was tested using both pulsating and rolling load fatigue. A comparison study was conducted to investigate the difference between rolling and pulsating fatigue load on GFRP rebar reinforced bridge decks. Experiment results reveal that bridge deck RL experiences more fatigue damage than PL in terms of stiffness degradation, deflection progression, crack propagation, and strain development. Punching shear experiment was carried out on GFRP rebar reinforced bridge decks to study the post-fatigue residual strength. The fatigue behaviour of concrete bridge decks with three different reinforcement setups, namely GFRP rebar, GFRP SIP form, and steel rebar was investigated. Despite the smaller reinforcement stiffness, all three sections have similar stiffness degradation after 3 million cycles of rolling load. Non-linear FEMs were created and validated with experiment data. This PhD thesis has yielded six journal papers, four of which have been published.

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COMPOSITES AROUND THE WORLD

Case Studies

Development and Large-Scale Application of Ultra-Long CFRP Cables for Temperature-Adaptive Restraint System in Changtai Yangtze River Bridge in China

Principal Investigator: Prof. Shunquan Qin, Academician of the Chinese Academy of Engineering

Partner Institutions: Faersheng Group, Zhongfu Shenying Carbon Fiber Co., Ltd., along with the bridge design and construction entities responsible for the Changtai Yangtze River Bridge project.

Period of Development: The project commenced with the official start of main structural construction in October 2019. A key milestone was achieved in January 2021 with the precise final sinking of the caissons, setting a record for the fastest sinking rate of large caissons in silty clay strata at 25 cm per day. The main girder was successfully joined with millimeter-level precision in June 2024. By August 31, 2024, the installation of vertical supports was completed. On September 9, 2025, the Changtai Yangtze River Bridge was officially opened to traffic.

INTRODUCTION

The Changtai Yangtze River Bridge, holding the record as the world's longest-span cable-stayed bridge (main span 1208 meters), presented extraordinary engineering challenges. Key among these was managing longitudinal deformation and internal forces caused by temperature variations and the unique asymmetric loading from its combined highway and railway deck layout. Conventional steel components are susceptible to thermal expansion, which can adversely affect structural performance and serviceability in such mega-structures.

The primary motivation was to innovate a restraint system that could accommodate necessary longitudinal movements while drastically reducing thermal stress.

The core objective centered on designing and implementing a **temperature-adaptive longitudinal restraint system (TARS)** utilizing materials with minimal thermal expansion.

This led to the focus on **CFRP cables** as the system's critical component, necessitating the development of ultra-long, high-strength CFRP cables on a scale unprecedented in civil engineering.

The major challenges included:

1. Designing a reliable CFRP cable system with sufficient capacity for the bridge's loads while being inherently insensitive to temperature changes.
2. Manufacturing CFRP cables of record length (approximately 560 meters) with consistent, high-quality properties at an industrial scale.
3. Successfully integrating the novel TARS with the conventional bridge structure and ensuring its long-term durability and performance.

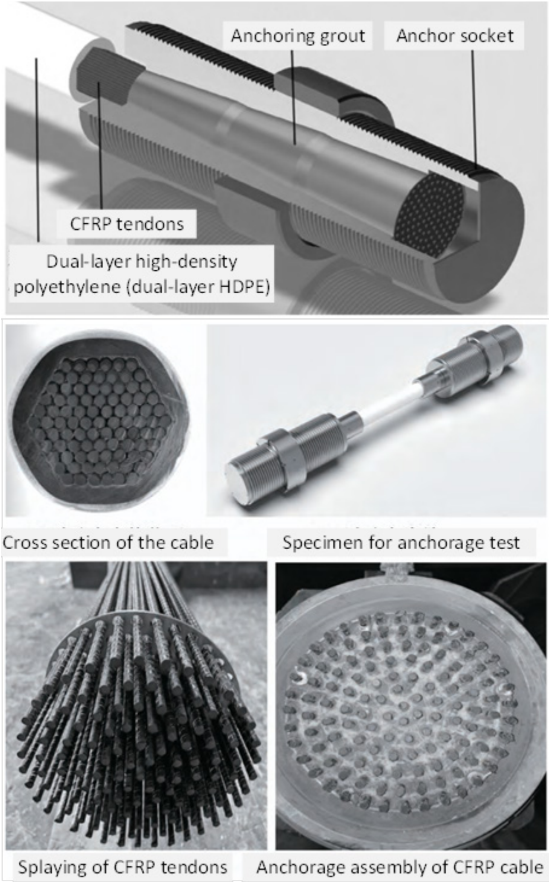
METHODS / WORK PACKAGES

1. **Material Development & Cable Production**: A collaborative effort between Faersheng Group (responsible for system design and cable technology) and the carbon fiber producer (e.g., Zhongfu Shenying) to specify and manufacture the T700-grade carbon fiber composite. This work involved optimizing material properties—notably high tensile strength and a low coefficient of thermal expansion—and adapting the pultrusion or similar process for producing continuous 559-meter cable elements.
2. **Novel Anchorage Design**: The CFRP cables of the bridge employ a **bond-type anchorage system** featuring a multi-step conical design to ensure secure and durable load transfer. This system consists of CFRP tendons, anchoring grout, and a precision-engineered anchor socket (Fig. 4). The multi-step conical structure progressively transforms axial tensile forces into radial and circumferential pressures, which are transmitted through bonding, compression, and friction between the grout, tendons, and socket. This innovative design specifically addresses the challenge posed by CFRP's low transverse strength, effectively mitigating stress concentration at the narrow end of the anchor and preventing potential clamping damage. The anchor socket and nut are manufactured from high-strength alloy steels (42CrMo and 35CrMo, respectively) and are protected against corrosion by a uniform powder zinc coating with a minimum thickness of 90 μm. Each cable comprises 127 CFRP tendons, twisted at an angle of 2.5°–3.5° and sheathed in a dual-layer high-density polyethylene coating for enhanced durability and environmental protection. The anchorage assembly follows the same specifications and processes as those used in the actual bridge structure, ensuring performance reliability and consistency.

3. **TARS System Design**: Engineering the complete TARS framework, where CFRP "connecting rods" (horizontal stay cables) are installed at the mid-span, linking the steel truss girder to the pylon's crossbeam. This system provides controlled longitudinal restraint and facilitates a low-elevation transfer of longitudinal forces.
4. **Testing, Installation & Performance Validation**: Stages include the development and rigorous testing of cable samples, couplers, and anchorage systems to verify mechanical properties (including the target tensile strength of 2600 MPa), fatigue resistance, and long-term behavior. Mass production of 28 identical CFRP cables (each 559m long, with a total system weight of 130 tons). Execution of precise installation, anchorage, and tensioning procedures within the constructed bridge framework. Incorporating the TARS/CFRP system into the overall structural analysis and construction sequence. Implementing health monitoring systems to track the in-service performance of the cables and the TARS under live loads and environmental cycles.

OVERVIEW OF MAIN RESULTS

- **Record-Setting CFRP Cable Application**: Successful deployment of the world's **longest (559m) and largest-scale** CFRP cable system in a bridge project. A total of 28 cables with a combined weight of 130 tons were installed.
- **Realization of the TARS**: The innovative temperature-adaptive longitudinal restraint system was successfully built and integrated. It effectively controls longitudinal displacement, reducing the deck's potential longitudinal movement from an estimated 1 meter to approximately 80 centimeters.
- **Enhanced Structural Performance**: The TARS significantly optimized internal force distribution. The bending moment at the pylon base was reduced from 1.1 million tonne-meters to 760,000 tonne-meters, representing a **31% reduction**. This improvement enhances safety, allows for more efficient structural design, and contributes to long-term durability.
- **Material Performance Achievement**: The project utilized CFRP cables with a reported tensile strength of **2600 MPa**, setting a new benchmark for strength in bridge cable materials.
- **Validation of Innovative Design**: The project successfully translated the novel asymmetric design and the TARS concept from theoretical design to practical implementation, demonstrating the viability of advanced composites in critical, large-scale civil infrastructure.



CONCLUDING REMARKS

The development and full-scale application of CFRP cables in the TARS of the Changtai Yangtze River Bridge constitute a pioneering achievement in modern bridge engineering. This project marks a significant leap in utilizing advanced composite materials for primary structural components in large-span bridges, moving beyond traditional metallic solutions.

It exemplifies a successful collaborative innovation model, integrating the expertise of bridge designers, specialist cable manufacturers, and advanced materials producers. The outcomes—including improved structural efficiency, superior temperature adaptation, and promising reductions in long-term maintenance—establish a new standard for future mega-bridges globally. This breakthrough is not only a technical milestone but also strengthens the "Chinese Bridge" brand, showcasing a high level of capability in mastering core technologies and pushing the boundaries of intelligent, sustainable, and resilient infrastructure development.

COMPOSITES AROUND THE WORLD

Case Studies

Non-Metallic Innovation for Energy Infrastructure: GFRP Rebar in the NEOM Mountain South Statcom SEC Substation Project

Project: NEOM South Statcom SEC Substation Project
Owner: NEOM
Client: Saudi Electricity Company (SEC)
Contractor: Al Gihaz Contracting Company
Location: NEOM Mountain, Saudi Arabia
Year: 2024
By: Eid Bader, Deputy General Manager – IKK Mateenbar

INTRODUCTION

Glass fiber-reinforced polymer (GFRP) reinforcement is increasingly utilized in bridges, tunnels, and marine structures; its application within electrical infrastructure is of particular importance. Globally, utilities and power providers are adopting GFRP in transformer pads and foundations, switchyard slabs, cable trenches, and power plant structures subject to elevated electromagnetic fields, owing to its non-conductive and non-magnetic properties. In this context, Saudi Arabia, through initiatives led by the Saudi Electricity Company (SEC) and NEOM, is emerging as an advocate of GFRP reinforcement for critical power infrastructure, demonstrating its technical, operational, and long-term advantages to the broader international energy sector.

THE PROJECT

The NEOM Mountain Bulk Supply Point (BSP) is a 380/132 kV Gas-Insulated Substation (GIS) located within the NEOM urban development zone and forms an integral component of the SEC's broader strategy to modernize the national power grid, expand transmission capacity, and advance NEOM's renewable energy goals. The project encompasses the construction of an advanced indoor GIS substation; the installation of power transformers along with associated control and protection systems; and the execution of civil, electro-mechanical, and telecommunications works.

GFRP reinforcement was used for the NEOM South Statcom SEC Substation Project, marking a significant step in the increasing adoption of non-metallic materials within Saudi Arabia's energy infrastructure and, in particular, within NEOM— the Kingdom's flagship development envisioned to operate entirely on renewable energy. The project involved key stakeholders, including the SEC as the client, and Al Gihaz Contracting Company as the main contractor.

The specification of GFRP was not optional; SEC mandated its use for critical transformer foundation structures due to its non-magnetic and non-conductive properties, which prevent interference with transformer performance by mitigating stray electromagnetic effects. These foundations, or transformer pads, are engineered to support substantial transformer loads while ensuring precise alignment, structural integrity, and full compliance with the SEC's Standard Distribution Materials Specifications (SDMS). Transformer pads are subjected to harsh environmental conditions, including high humidity, temperature fluctuations, and potential chemical exposure; the use of GFRP reinforcement provides exceptional resistance to corrosion and chemical attack, ensuring long-term durability with minimal maintenance requirements. The project, therefore, illustrates the role of GFRP reinforcement in enhancing technical reliability, operational safety, and sustainability across the Kingdom's rapidly developing power infrastructure.

GFRP BARS

10 mm and 22 mm GFRP bars were used, including both straight and pre-bent configurations, along with technical support to ensure proper installation and full compliance with project design specifications. These reinforcements were incorporated into the transformer pad foundations, providing the structural capacity required to support substantial transformer loads while maintaining the non-magnetic and non-conductive characteristics essential for mitigating electromagnetic interference and ensuring optimal transformer performance. The SEC's SDMS guidelines mandate strict design criteria for transformer foundations. The use of GFRP rebar was in direct alignment with these specifications to avoid electromagnetic interference.

PERFORMANCE OF GFRP BARS

The adoption of GFRP reinforcement in the NEOM Mountain substation project yielded several significant benefits, including enhanced electromagnetic efficiency of the transformers and the elimination of field losses typically associated with conductive steel reinforcement. Additionally, the corrosion-resistant nature of GFRP contributes to reduced lifecycle costs by minimizing long-term maintenance requirements. The use of GFRP also ensured full compliance with SEC's technical mandates, thereby establishing a performance benchmark for future substation developments across the Kingdom.

SUSTAINABILITY IMPACT

GFRP reinforcement supports sustainability by reducing embodied carbon compared to steel, extending service life through its resistance to corrosion and electro-magnetic field degradation, minimizing energy losses in transformer operations, and contributing directly to NEOM's renewable and sustainable energy agenda. This sustainability dimension aligns with both the SEC's innovation goals and NEOM's ambition to become the world's first mega-city powered entirely by renewable energy. The NEOM development is envisioned as a global hub for clean energy and sustainable living, with its infrastructure designed to rely exclusively on solar, wind, and hydrogen resources. Substations such as the NEOM Mountain BSP are essential to this vision, as they integrate renewable generation sources into the grid, stabilize power supply through advanced control systems, and ensure long-term reliability by incorporating non-conductive and non-magnetic foundation materials such as GFRP. As a result, the project contributes not only to Saudi Arabia's Vision 2030 but also to emerging international best practices in sustainable energy infrastructure.

KEY LESSONS

The NEOM Mountain Substation project offers several important lessons for industry stakeholders. First, mandating the use of non-metallic materials such as GFRP ensures compliance with stringent electromagnetic requirements while enhancing overall system performance. Second, effective collaboration between clients, contractors, and suppliers is essential for the successful implementation of innovative solutions in complex infrastructure projects. Finally, the advantages of GFRP extend beyond durability and corrosion resistance; in electrical applications, its non-magnetic and non-conductive properties provide unique technical benefits that conventional steel reinforcement cannot achieve.

CONCLUDING REMARKS

The NEOM SEC South Statcom Project represents a significant milestone in Saudi Arabia's energy infrastructure, exemplifying the integration of advanced non-metallic reinforcement into the foundations of the NEOM Mountain 380/132 kV GIS substation. Using 10 mm and 22 mm GFRP bar in both bent and straight configurations facilitated the construction of transformer pads that are non-magnetic, non-conductive, durable, and sustainable. This innovation ensured full compliance with the SEC's technical specifications, enhanced transformer efficiency and operational safety, reduced long-term maintenance and lifecycle costs, and supported NEOM's vision of a fully renewable and sustainable energy system. This project illustrates how collaboration and innovation can deliver world-class outcomes. As NEOM continues to establish global benchmarks in sustainability and technological advancement, the NEOM Mountain Substation project provides a clear demonstration of how GFRP reinforcement is shaping the future of energy infrastructure worldwide.

COMPOSITES AROUND THE WORLD

Codes and Standards

ACI PRC-440.14-25: Design of Circular Concrete-Filled Fiber-Reinforced Polymer Tubes – Guide

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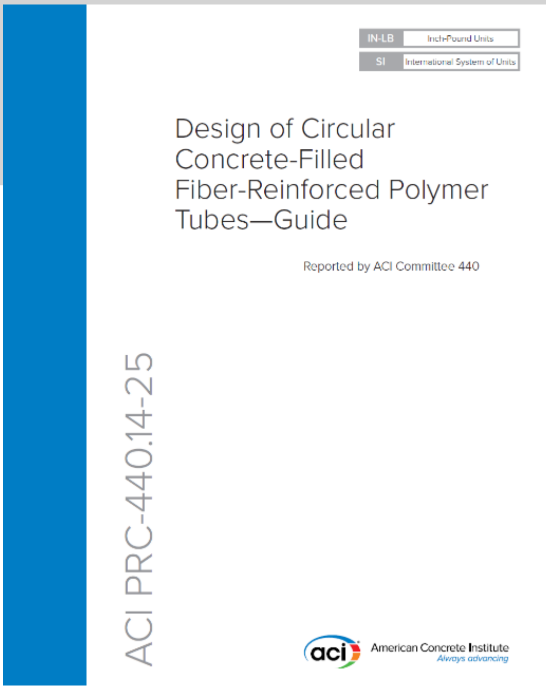

ACI PRC-440.14-25 Design of Circular Concrete-Filled Fiber-Reinforced Polymer Tubes – Guide was published in August 2025. This is the first dedicated ACI document providing comprehensive design guidance for circular concrete-filled fiber-reinforced polymer (FRP) tube (CFFT) members, which are a high-performance alternative to conventional reinforced concrete construction and are particularly suited for harsh environments. Developed by ACI Subcommittee 440-J (FRP Stay-in-Place Forms) under ACI Committee 440 (Fiber-Reinforced Polymer Reinforcement), the guide consolidates decades of experimental research, analytical modeling, and field application experience into a unified resource for practitioners.

THE CFFT SYSTEM

CFFTs consist of a pre-cured FRP tube and a concrete core that is typically cast in place. However, the concrete core may also be placed off-site to form a precast CFFT system. The FRP tube serves multiple structural and construction functions:

- Functions as stay-in-place formwork, enabling rapid construction without the need for stripping forms.
- Acts as corrosion-resistant reinforcement, replacing traditional longitudinal bars, ties, and stirrups.
- Provides confinement and environmental protection for the concrete core, improving strength, ductility, and durability.

The fiber orientations within the FRP tube are engineered to deliver strength and stiffness in desired directions. Fibers aligned along or near the longitudinal axis provide resistance under bending and combined axial–bending loads, while fibers aligned along or near the hoop (circumferential) axis provide concrete confinement. This common configuration, known as a cross-ply or near-cross-ply laminate, may be tailored to the application. Alternative designs include angle-ply laminates, with fibers at large angles to the longitudinal axis, or hybrid laminates combining angle-ply and cross-ply layers for enhanced performance.

SCOPE OF THE GUIDE

ACI PRC-440.14-25 provides recommendations for the design of circular CFFTs used as structural components such as beams, arches, columns, load-bearing piles, and monopoles. Other shapes, such as rectangular sections, are beyond the scope of this document. The design methodologies allow CFFTs to be proportioned as flexural members, axial compression members, or members subjected to combined flexure and axial compression.

The recommendations are based on research conducted on FRP tubes composed of continuous glass or carbon fibers embedded in vinyl ester or epoxy resins and are limited to these materials. The guide does not address the contribution from chopped strand mat (CSM) materials due to their relatively low influence on CFFT stiffness and strength, although CSM layers may be present in some commercial tubes.

Recommendations are also limited to normal weight concrete. The contribution of internal steel reinforcement exceeding the minimum needed to compensate for accidental FRP tube damage is not considered.

LIMITATIONS

The provisions of this guide are derived from experimental data on circular CFFTs with laminate architectures that satisfy prescribed fiber-orientation limits and are applicable only within these bounds. Specifically, the guide requires that at least one-third of the fibers be oriented within ±35 degrees of the longitudinal axis to provide flexural resistance, and at least one-third be oriented within ±35 degrees of the hoop (circumferential) axis to provide adequate confinement. Members acting as beam-columns must satisfy both requirements simultaneously. FRP tubes that do not meet these fiber-orientation criteria exhibit pronounced nonlinear stress–strain behavior, rendering the provisions of this guide inapplicable.

In addition, minimum hoop-direction capacity is required to mitigate longitudinal splitting, and tubes lacking hoop reinforcement, such as some pultruded sections with fibers oriented primarily in the longitudinal direction, are beyond the scope of this document.

The guide is further limited to circular CFFTs with diameters not exceeding 36 in. (914 mm) and does not address members subjected to axial tension, seismic loading, moment redistribution, disturbed regions, or torsion beyond negligible threshold levels. Applicability also assumes adequate bond between the FRP tube and concrete core, verified through push-off testing to provide a minimum push-off bond strength of 72 psi (0.5 MPa) at 28 days of concrete age.

The guide also excludes systems with internal reinforcement exceeding the minimum required for structural integrity and limits axially loaded members to unconfined concrete strengths not exceeding 10,000 psi (69 MPa). Although local buckling did not govern failure in the experimental database used to calibrate the design equations, designers are cautioned when applying the provisions outside the validated diameter-to-thickness ratio range.

TECHNICAL PROVISIONS

In addition to background information on CFFT technology, covering material properties, laminate configurations, and bond behavior at the tube–concrete interface, the guide provides provisions for flexural strength, axial load capacity, shear resistance, combined loading, connection detailing, and mitigation of accidental tube loss. The organization of the guide is summarized in Table 1.

Table 1: Chapter organization of ACI PRC-440.14-25

Chapter 1	Introduction
Chapter 2	Notation and Definitions
Chapter 3	Material Properties
Chapter 4	Limit States
Chapter 5	Design for Flexure with No Axial Compression
Chapter 6	Design for Axial Compression
Chapter 7	Design for Combined Flexure and Axial Compression
Chapter 8	Design for Shear
Chapter 9	Minimum Internal Reinforcement
Chapter 10	Connections
Chapter 11	References

SIGNIFICANCE

CFFTs have been applied successfully for piles, bridge piers, building columns, and utility poles, especially in aggressive environments where corrosion of steel reinforcement is a major durability concern. By integrating primary reinforcement in both longitudinal and hoop directions into a single continuous membrane, CFFTs offer a streamlined, durable, and efficient solution for a variety of structural applications.

ACI PRC-440.14-25 fills a long-standing gap by providing a tailored design guide for these unique members, which are not covered in conventional reinforced concrete codes. While non-mandatory, it is anticipated that this document will inform agency specifications and may form the technical foundation for future code provisions.

Looking ahead, continued advancements in FRP manufacturing, material specifications, and analytical modeling are expected to broaden the applicability of CFFT systems. This guide provides a solid technical base to support these future innovations while enabling engineers to take full advantage of this durable and high-performance technology.

ACKNOWLEDGMENTS

The development of ACI PRC-440.14-25 reflects the sustained efforts of many dedicated volunteers. Special recognition is extended to the past Chair of ACI 440J, Dr. Amir Fam, and the Vice Chair, Mr. John Busel, who led and guided the development of this document over more than 12 to 15 years. The technical contributions of Dr. Douglas Tomlinson, along with those of the current Chair, which played an important role in shaping the guide, are also acknowledged. In addition, the collective contributions of the members of ACI 440-J and the broader ACI 440 committee are gratefully acknowledged for their support, technical input, and commitment to advancing the development of this guide.

FUTURE STEPS

Future efforts are expected to focus on the development of detailed design examples to facilitate implementation by practitioners and to promote consistent application of the provisions. In addition, ongoing research and industry feedback are anticipated to support the extension of the design guide to other cross-sectional shapes beyond circular members, building on the framework established in this document. Related future work is also expected to include the development of a new ASTM test method to evaluate the bond behavior between concrete and FRP tubes, which would provide a standardized basis for characterizing tube–concrete interaction and support future refined design provisions.

The continued evolution of this guide will rely on the active engagement of the research and practitioner communities. Subject matter experts in FRP materials, structural design, testing, and construction are encouraged to participate in the work of ACI 440J and contribute to future enhancements and expansions of the design guide by contacting the Chair.

PUBLICATIONS

European Composite Bridges Database

Bridging the Data Gap: New European Database Paves the Way for Industry Growth

As the global composites community anticipates the publication of the upcoming Composite Eurocode, the industry stands before a historic opportunity to establish a firmer foothold in the construction sector. However, widely adopting Fiber-Reinforced Polymer (FRP) composites in infrastructure has long faced a significant barrier: the lack of comprehensive, accessible data.

To address this challenge, the Norwegian Circular Materials Technology (NCMT) cluster has launched the **European Composite Bridge Database**. This initiative aims to strengthen the industry's position by collecting and sharing data on existing composite bridges across Europe.

FOR MORE INFORMATION PLEASE CONTACT: **VIDAR NYHAMMER ↗**

↗ ACCESS THE **DATABASE**

THE APPROVAL PARADOX

For many practitioners and researchers within the IIFC community, the struggle to get innovative projects approved is familiar. Alf Egil Jensen, chair of the NCMT board and CEO of FiReCo, captures this frustration perfectly: "Paradoxically, a composite bridge can be installed in one hour, but the approval process can take up to ten years".

This database serves as a direct response to that challenge. By making knowledge and experience available to everyone, NCMT aims to provide the evidence-based information decision-makers need to make informed choices. When regulatory authorities can view documentation from similar successful projects across Europe, uncertainty is significantly reduced, accelerating approval processes.

WHAT IS IN THE DATABASE?

The database is designed to be a comprehensive resource for engineers, researchers, and manufacturers. It is organized to allow easy navigation between high-level statistics and granular project details. Key contents include:

- **Technical Specifications**: Detailed bridge specifications and engineering metrics crucial for approval processes.
- **Materials & Methods**: Information on the specific composite materials and manufacturing methods utilized.
- **Stakeholder Data**: Details on the varied stakeholders involved in each project, fostering networking and collaboration.

A COLLECTIVE EFFORT: YOUR CONTRIBUTION MATTERS

The European Composite Bridge Database is not just a repository; it is a tool for collective growth. The more companies and researchers that contribute data, the stronger the entire industry stands when engaging with construction firms and authorities. A solid database of documentation allows composites to finally compete on equal terms with steel and concrete in tenders.

NCMT emphasizes that the success of this initiative relies heavily on industry participation. The database will be updated regularly as new data is shared.

HOW TO PARTICIPATE

We encourage all IIFC members—whether academic researchers or industry practitioners—to contribute to this initiative. You can support the database by:

- **Submitting Data**: Share details about your composite bridge projects through the NCMT online form.
- **Using the Data**: Utilize the database as a concrete reference in your own customer dialogues and tenders.
- **Networking**: Connect NCMT with other bridge constructors and engineers in your professional network.

All data usage will strictly comply with relevant privacy and data protection regulations.

Together, by sharing knowledge and experience, we can seize this opportunity to strengthen the position of composites in the building and construction sector.

PUBLICATIONS

ASCE Journal of Composites for Construction – Recent issues

The American Society of Civil Engineers (ASCE) Journal of Composites for Construction (JCC) is published with the support of IIFC. As a service to IIFC members and through an agreement with ASCE, FRP International provides an index of ASCE JCC.

The ASCE JCC may be found at the following website: www.ascelibrary.org/cco

ASCE JCC subscribers and those with institutional access are able to obtain full text versions of all papers. Preview articles are also available at this site.

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