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GFRP Misconceptions—Part 3

There are many design materials in a structural engineer’s toolbox that should be evaluated for the structural and environmental conditions under consideration—concrete, mild reinforcement, prestressing, and even structural steel and wood. As engineers, we know that not even concrete is ideal for all structures. And so, glass fiber-reinforced polymer (GFRP) reinforcing bars cannot be used in all reinforced concrete applications. We should not be afraid of innovation as it will expand possibilities, and more research is being done to that aim. Many advances have been made in coated and uncoated specialty steels for reinforcing concrete as well.

In this series of Q&A articles, we will attempt to clarify some common questions and misconceptions about GFRP reinforcing bars. They are compared to steel reinforcing bars to reference something that the reader is likely more familiar with currently.

Support for the series is graciously recognized from the American Composites Manufacturers Association (ACMA) FRP Rebar Manufacturers Council and NEx: An ACI Center of Excellence for Nonmetallic Building Materials.

Q1. Production and availability: Where are GFRP reinforcing bars manufactured and where can I find them?

A1. While some manufacturers are based internationally, there is significant production in North America, more specifically the United States. At the time of this issue’s publication, several manufacturers are exploring additional facility locations. Refer to the following industry associations for membership lists:

- NEx: An ACI Center of Excellence for Nonmetallic Building Materials at www.nonmetallic.org/member-companies; and
- The American Composites Manufacturers Association (ACMA) FRP Rebar Manufacturers Council at <https://tinyurl.com/md2bvpv7>.

GFRP reinforcing bars can typically be purchased from local and regional distributors. However, larger quantities can sometimes be purchased directly from the manufacturer. GFRP reinforcing bars have recently become available at “big-box” home improvement stores, making corrosion-free reinforcement more accessible and available for everyday jobsite adoption.

Q2. It is confusing to the design and construction community to have bars with different surface profiles. Should that make me hesitant to use them?

A2. Similar to the evolution of steel reinforcing bars in the early 1900s when there were many different and some patented surface deformations, GFRP reinforcing bars are evolving their surface profile. For steel, we have heard of Ransome bars that were square in cross section and twisted along the length; however, there were also lug bars, corrugated bars, twisted bars, and many more variations to gain the necessary surface profile to ensure bond and integral behavior with the surrounding concrete. An article in *STRUCTURE*¹ detailed a CRSI reference² summary that outlines more than 40 surface profiles commercially available throughout the early 1900s.

As stated in Part 1 of this Q&A series,³ ASTM International material specifications established a minimum bond strength according to ASTM International standard test methods. These material specifications do not specify or limit the surface profile of GFRP reinforcing bars. Currently, there are sand-coated bars, bars with a filament wound around the exterior to create an exterior surface with undulating deformations, wrapped bars, and helically grooved bars. These surface profiles were optimized for manufacturing by the producers of the respective bars. Over time, it is likely that the GFRP reinforcing bar industry can align around limiting allowable variations.

Q3. What should I know about the differences in material properties between GFRP reinforcing bar manufacturers?

A3. According to CSA Group material specifications,⁴ GFRP reinforcing bars are designated by grade (Grade I, II, and III); the grade is based on the modulus of elasticity. And, ASTM International material specifications, include ASTM D7957/D7957M⁵ and ASTM D8505/D8505M,⁶ the GFRP reinforcing bars are differentiated by the modulus of elasticity. This is similar to the grades of steel reinforcing bars, which are based on yield strength; however, GFRP reinforcing bars are based on modulus of elasticity because the GFRP material exhibits no yielding behavior under load.

Because the GFRP reinforcing bar manufacturer is likely not identified at the time of design, a conservative approach for designers is to design for the minimum properties in the material specifications. Then, depending on the element and degree of possible design refinement, rerun the calculations based on the specific manufacturer's properties because ACI CODE-440.11-22⁷ allows the use of a specific manufacturer's properties instead of ASTM D7957/D7957M minimums in the design of GFRP-reinforced concrete elements. It is recommended that designers become familiar with the GFRP reinforcing bar manufacturers that supply bars in their geographic area. The availability of specific bar sizes and bar details (for example, hooks and bends) may vary. It is important to understand what is available and feasible for any GFRP-reinforced concrete project, as with any construction material.

The industry is working to simplify this for designers, both with software programs currently in development and with further design guidance and assistance. Differences in material properties based on bar diameter should also be considered and could be simplified with design aids.

Q4. How much more GFRP reinforcement is needed compared to steel for a typical reinforced element design? I heard it is as high as 2:1.

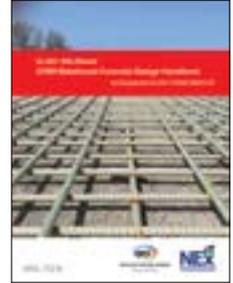
A4. In general, GFRP-reinforced concrete designs are governed by serviceability, and as such, it is typical for 10 to 20% additional reinforcement to be required. However, there are applications where the reinforcement needs between steel reinforcing bars and GFRP reinforcing bars will be equivalent. ACI published a series of design examples in MNL-7(23), *GFRP-Reinforced Concrete Design Handbook*,⁸ which is intended to mirror the examples in MNL-17(21), *ACI Reinforced Concrete Design Handbook*.⁹

Design examples in both MNL-17 and MNL-7 are based on fictitious buildings. MNL-17 is based on designing a

seven-story, steel-reinforced concrete building according to ACI CODE-318-19.¹⁰ In MNL-7(23), the example problems are based on the design of various elements in a four-story, GFRP-reinforced concrete building. However, the basic floor plan and structural system for the building presented for GFRP-reinforced

concrete is the same as the building in MNL-17. The intent is to allow for comparison between elements that are designed using GFRP reinforcing bars to elements designed using steel reinforcing bars in MNL-17.

Additionally, ACI PRC-440.1-15, "Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer (FRP) Bars,"¹¹ uses design examples from the American Cement Association (ACA) publication *Notes on ACI 318-08 Building Code Requirements for Structural Concrete*.¹² Both of these design resources were developed with the intention for designers to be able to draw design comparisons between steel-reinforced concrete and GFRP-reinforced concrete. The reader is encouraged to review these examples for a comparison.



Q5. Is it true that with larger allowable crack widths, GFRP-reinforced concrete designs result in unsightly cracking?

A5. For comparison purposes, the crack control provisions for steel reinforcement in ACI CODE-318 correspond to a maximum crack width that is approximately 0.018 in., regardless of exposure condition. Acceptable crack widths in GFRP-reinforced concrete members are larger than those in steel-reinforced concrete members. In situations where crack widths are limited for aesthetic reasons, limiting crack widths in the range of 0.016 to 0.028 in. is generally acceptable. The maximum bar spacing limits given in ACI CODE-440.11 are based on limiting crack width to 0.028 in. Regardless of reinforcement type, in cases when the licensed design professional believes a more restrictive maximum allowable crack width is appropriate, the numerical coefficients in the reinforcement spacing equations may be adjusted. The primary factors affecting crack widths were found over many decades of research to be concrete cover, reinforcement spacing, and reinforcement bond characteristics; this is true for both steel and GFRP reinforcement. While allowable crack widths are nominally larger as explained by the philosophy of ACI CODE-440.11—0.028 in. compared to 0.018 in.—both are still quite small.

Crack width is inherently subject to wide scatter even in careful laboratory work and is influenced by shrinkage and other time-dependent effects. Improved crack control is obtained when the reinforcement is well distributed over the zone of maximum concrete tension. Several bars at moderate spacing are much more effective in controlling cracking than one or two larger bars of equivalent area. Crack control based on distribution of reinforcement and sound construction practices (including proper mixture proportions and curing methods) are important considerations regardless of the reinforcement type.

Though designed using the AASHTO design guide¹³ and not ACI CODE-440.11, bridges comprise some of the first GFRP-reinforced concrete structures in the United States, whereas, in buildings, magnetic resonance imaging (MRI) rooms took advantage of magnetic transparency. All U.S. bridges are required by federal regulation to be inspected at least every 2 years. This includes condition ratings (including examination of cracking) for the bridge deck and other structural elements, as well as appraisal ratings documented and reported to the Federal Highway Administration (FHWA). The FHWA's National Bridge Inventory (NBI) houses the database of this information at <https://catalog.data.gov/dataset/national-bridge-inventory-abd5a>. We know from the NBI required bridge inspection data and anecdotally that bridges designed and constructed using GFRP reinforcing bars in the late 1990s and early 2000s report satisfactory ratings. These bridges have over 20 years of service with many more to come.



FRP bar examples (photo courtesy of the University of Miami)

Q6. I heard that you can now make structural concrete with seawater. Is that counterintuitive?

A6. The use of seawater as mixing water for structural concrete is only counterintuitive if you assume that concrete must be reinforced with steel reinforcing bars, which is no longer the case. Much of the world's concrete is plain concrete or nonstructural concrete, and if we further consider the use of GFRP reinforcing bars, the paradigm shifts.

International Code Council (ICC) AC574-24, "Acceptance Criteria for Seawater Concrete for Use in Plain or FRP-Reinforced Concrete Members,"¹⁴ was published in June 2025. This allows seawater under the 2024 International Building Code¹⁵ and International Residential Code¹⁶ (as well as earlier versions) through the alternative materials provisions. The acceptance criteria (AC) document outlines the chemical composition of the seawater, as well as how to identify the source. Furthermore, the AC provides requirements for the

concrete's fresh and hardened properties.

This is an important development due to sustainability efforts around fresh water and sand as global resources. According to the U.S. Bureau of Reclamation, only 3% of the Earth's water is fresh water. A significant amount of that is currently isolated in glaciers and deep aquifers, leaving only 0.5% of the water on Earth as available fresh water.¹⁷ According to a 2022 report¹⁸ by the United Nations Environment Programme, global sand use has roughly tripled in the last 20 years and continues to rise at an unsustainable rate—approximately 6% annually. Population and economic growth, a global trend toward urbanization, and climate change are contributing factors.

ACI Committee 243, Seawater Concrete, is in the process of publishing "Report on Seawater-Mixed Concrete," a document that summarizes the current practice globally for the use of seawater and sea-sourced aggregates in concrete. The report aims to detail current knowledge as well as knowledge gaps while highlighting several demonstration projects and field applications. The report is currently under review by ACI's Technical Advisory Committee (TAC) and publication is anticipated in 2026.

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The Standard for GFRP-Reinforced Concrete Design



Design with Confidence Using GFRP Bars

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