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GFRP Misconceptions—Part 1

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 reinforcing, 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 can't 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 reinforced 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. *GFRP reinforcing bars are not approved for use, so it will be harder for me to "experiment"; is that true?*

A1. Development of consensus-based codes and standards for GFRP bars has been underway for several decades. ASTM International material specifications ASTM D7957/D7957M[1] and ASTM D8505/D8505M[2] are published and reference ASTM test methods for physical, mechanical, and durability characteristics. The bar diameter sizes available for GFRP reinforcing bars use the same nomenclature (that is, No. 3 [9.5 mm], No. 4 [12.7 mm], and larger) as steel reinforcing bars to denote the diameter to the 1/8 in. (3 mm) designation.

In addition, International Code Council (ICC) Evaluation Reports exist for commercially available GFRP reinforcing bars. GFRP reinforcing bar meets or exceeds ICC-ES AC454 acceptance criteria,[3] including bond strength, tensile strength, and modulus of elasticity, among others. These and the fact that ACI CODE-440.11-22[4] was adopted into the 2024 International Building Code (IBC)[5] mean that engineers can confidently design with GFRP-reinforced concrete within Code limitations. All codes place limits on the use of materials, even higher-strength concretes and higher-strength or specialty reinforcing steels (more on that in the upcoming Part 2 of this Q&A article).

From a bridge and highway perspective, American Association of State Highway and Transportation Officials (AASHTO) design codes exist for use of GFRP reinforcement in pedestrian and vehicular bridges and have been used across the country since the late 2000s. The AASHTO *Load and Resistance Factor Design (LRFD) Bridge Design Guide Specifications for GFRP-Reinforced Concrete*, second edition, was published in 2018[6] and *LRFD Guide Specifications for the Design of FRP Pedestrian Bridges*, second edition,[7] was released this year. The AASHTO Product Evaluation and Audit Services (formerly National Transportation Product Evaluation Program or NTPEP) has quality control audits and test sampling criteria for both steel and GFRP reinforcing bar manufacturers. Several state departments of transportation also have design guides and material specifications for reference.

In Canada, material specification CSA S807[8] governs bar manufacturing, while CSA S6:25[9] and CSA S806[10] are the design codes and standards for the design of highway bridges and buildings, respectively. Specifications also exist in other countries around the world but are not delineated herein.

Q2. *What are the physical, mechanical, and durability tests that GFRP reinforcing bars must meet?*

A2. ASTM D7957/D7957M contains references to standard test methods and minimum requirements for several properties. Table 1 provides a detailed list of test methods and required results. This material specification speaks to efforts by the composites industry to ensure quality and continuous improvement over previous generations of GFRP reinforcing bars, namely in the

Table 1: Test methods and requirements for GFRP bars

Property	Test method	Limits
Fiber content	ASTM D2584[11]	≥ 70%
Degree of cure	ASTM D2160[12]	≥ 95%
Glass transition temperature	ASTM E1356[13]	≥ 100°C ≥ 212°F
Water absorption	ASTM D570[14]	≤ 0.25% in 24 hours at 50°C (122°F)
Resistance to alkaline environment	ASTM D7705/D7705M[15]	≥ 80% of initial mean ultimate tensile force following 90 days at 60°C (140°F)
Ultimate tensile strength	ASTM D7205/D7205M[16]	Varies, reported as a force by bar diameter
Tensile modulus of elasticity	ASTM D7205/D7205M	≥ 44,800 MPa ≥ 6,500,000 psi
Ultimate tensile strain	ASTM D7205/D7205M	≥ 1.10%
Transverse shear strength	ASTM D7617/D7617M[17]	≥ 131 MPa ≥ 19,000 psi
Bond strength	ASTM D7913/D7913M[18]	≥ 7.6 MPa ≥ 1100 psi

material's performance both at the time of production and after environmental exposure to demonstrate durability.

Q3. *GFRP doesn't have any residential codes/standards though, right?*

A3. The Masonry Society (TMS) published TMS 402/602: Building Code Requirements and Specification for Masonry Structures,[19] which outlines provisions for GFRP reinforcing for masonry elements in Appendix D. Additionally, ACI documents can be used for residential concrete design. GFRP reinforcing bars can be used in residential concrete, including footings and foundation walls, as prescribed in ACI CODE-332-20[20] using ACI CODE-440.11-22 design methodology. ACI CODE-332 will next be published in 2026 and will include GFRP bars as an accepted reinforcing material.

Suggested prescriptive tables are contained in MNL-6(23): Recommended Practice Guidelines for FRP Bars in Pre-Engineered Projects.[21] These guidelines use the ASTM D7957/D7957M minimum material properties for design to detail prescriptive design tables for residential work consistent with ACI CODE-440.11-22 for slabs-on-ground and foundations. Check with your GFRP manufacturer for prescriptive design tables to eliminate engineering review and calculations for conditions within allowable parameters.

Q4. *What design philosophy for flexure, for example, is recommended by ACI CODE-440.11-22?*

A4. ACI CODE-440.11-22 allows for the reinforced concrete section to be over-reinforced, with a failure mode of concrete crushing, or under-reinforced, with a failure mode of reinforcement rupture. ACI design procedures for both failure modes use appropriate factors of safety to ensure life-safety and structural reliability as with other recognized engineering codes. Either method uses classic Whitney stress block analysis and assumptions. Due to the lower elastic modulus (roughly one-quarter that of steel) and linear-elastic behavior to failure, serviceability often controls the designs, which we will explore more throughout this article series.

Q5. *How does bond testing differ for GFRP and steel reinforcing bars?*

A5. Bond testing for GFRP bars is conducted according to the pullout test method defined in ASTM D7913/D7913M.[18] The results obtained by performing this test are reported by manufacturers to ensure quality and compliance with material specifications. Even though the pullout test method is not necessarily representative of the actual behavior of a bar

Tied reinforcing bar grid *(photo courtesy of Mateenbar Composite Reinforcements)*

Placing concrete with GFRP reinforcing bars *(photo courtesy of Mateenbar Composite Reinforcements)*

Low Battery Seawall Project in Charleston, SC, USA *(photo courtesy of Mateenbar Composite Reinforcements)*

embedded in a concrete beam, it is nonetheless a rapid and effective way to describe the efficiency of the surface profile that is not yet standardized.

Q6. *GFRP does not corrode, but what are the degradation mechanisms at work over time?*

A6. Because GFRP is non-ferrous, it will never corrode and cause the expansion of rust by-products and subsequent spalling of concrete that we are familiar with. The composite nature of the material leads to the fibers serving as the tensile strength of the bar and the resin serving as the binding agent impregnating and encapsulating the fibers. The ASTM International test methods outlined previously (water absorption, alkaline resistivity, and degree of cure) were developed to establish threshold limits to ensure long-term performance. Physical property testing of bars has been conducted on several in-place bridges and shows very nominal degradation over time. This continues to be an area of research for the composites industry. In any event, ACI CODE-440.11-22, similarly to other codes, introduces a reduction coefficient, C_E, that accounts for environmental effects to ensure a service life of 100+ years.

Q7. *What considerations may be different during construction and concrete placement?*

A7. Construction tolerances are generally specified according to ACI SPEC-117-10(15),[22] making them the same as for steel reinforcing bars. The lighter weight makes GFRP reinforcing bars easier to handle and can reduce demands on work crews and equipment. They are easier to cut, requiring only a small hand saw, and placing and tying follows with the same bar supports and ties as steel. Depending on placement drawings, the GFRP bars may need to be tied or supported slightly more often based on their lighter weight (that is, the bars can exhibit a tendency to float in freshly placed concrete) and flexibility (that is, longer bars will tend to deflect more under their own weight, making supports more critical for clear cover). These details are covered by ACI SPEC-440.5-22: Construction with Glass Fiber-Reinforced Polymer Reinforcing Bars—Specification.[23]

Q8. *Can GFRP bars be bent?*

A8. Because the thermoset resin (that is, vinyl ester as required by the ASTM International specification) used in the bars polymerizes irreversibly during the manufacturing process, GFRP bars cannot be bent in the field. Any bent shapes need to be formed in the bar in the manufacturing facility (that is, like steel, prior to delivery at the jobsite in most markets). However, because of this process, the bends are exact, which we see as an advantage. The bars are formed around the necessary pins and cured in place, meaning tolerances, shape, and dimensions are exact and consistently uniform. The manufacturing facility serves as mill and fabricator, providing both bent and straight bars for the project. GFRP reinforcing bars are available in the same bend shapes as designers and contractors would be used to using. In some cases, for longer-legged bends, the bar will need to be supplied in two pieces and then lapped in the field. Lap lengths are generally longer than steel bars, but like steel vary based on the design parameters of concrete strength, bar diameter, and so on. Calculations should be made for your specific design.

Q9. *How are recent tariffs affecting the supply chain for GFRP reinforcing bars?*

A9. The price of the component materials of GFRP reinforcement is relatively stable, unlike the price of steel that can vary considerably over time based on scrap prices and demand, seasonal variability, and other market forces. Advances in manufacturing technology have also resulted in efficiencies that have and will continue to lower the unit price for GFRP reinforcing bars. Domestic sources of resin and fibers are available, along with domestic sources of manufacturing.

The Infrastructure Investment and Jobs Act (IIJA) (**www.congress.gov/bill/117th-congress/house-bill/3684**) expanded domestic content rules for federally funded infrastructure to include composites. Composites can either be classified as "manufactured products" or "construction materials," with agencies having some discretion as to their acceptance criteria and each category having its own classification. Domestic manufacturers are available for projects that require Build America, Buy America (BABA) compliance. Check with your suppliers for their certification.

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