

## REFERENCE

### Standards, Specification, Codes and Reports for FRP Composites for Construction & Infrastructure

(Compiled by the American Composites Manufacturers Association)

#### American Composites Manufacturers Association (ACMA)

- **ANSI**
  - **ANSI/ACMA/UCSC UP01-18** – Standard Specification for FRP Composites Utility Poles
  - **ANSI/ACMA/PIC – Standard Practice – 2011**, Code of Standard Practice for FRP Pultruded Structural Shapes
  - **ANSI/ACMA/FGMC-Grating Manual FG01-17** – 2<sup>nd</sup> Edition, FRP Composites Grating Manual for Pultruded and Molded Grating and Stair Treads
- **Recommended Industry Guides**
  - Guidelines and Recommended Practices for Fiber Reinforced Polymer Architectural Products
  - Industry Recommendations for Installation and Maintenance of FRP Grating

#### American Concrete Institute (ACI)

- **General Reports and Design Guidelines**
  - **440.1R-15**: Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer Bars
  - **440.2R-17**: Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures
  - **440.3R-12**: Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures
  - **440.4R-04**: Prestressing Concrete Structures with FRP Tendons
  - **440.7R-10**: Guide for Design & Construction of Externally Bonded FRP Systems for Strengthening Unreinforced Masonry Structures
  - **440.9R-15**: Guide to Accelerated Conditioning Protocols for Durability Assessment of Internal and External Fiber-Reinforce
  - **440R-07**: Report on Fiber-Reinforced Polymer (FRP) Reinforcement for Concrete Structures
- **Standards**
  - **440.5-08**: Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars
  - **440.5M-08**: Specification for Construction with Fiber-Reinforced Polymer (FRP) Reinforcing Bars (Metric)
  - **440.6-08(17)**: Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement (Reapproved 2017)
  - **440.6M-08**: Specification for Carbon & Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement (Metric)
  - **440.8-13**: Specification for Carbon and Glass Fiber-Reinforced Polymer Materials Made by Wet Layup for External Strengthening
  - **440.8M-13**: Specification for Carbon and Glass Fiber-Reinforced Polymer Materials Made by Wet Layup for External Strengthening (Metric)
- **Codes**
  - **ACI 562-19** - Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Structures and Commentary

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#### American Society of Mechanical Engineers (ASME)

- **RTP-1** - Reinforced Thermoset Plastic Corrosion-Resistant Equipment
  - Certification of a fabricator's quality control system in accordance with the ASME
- **ASME NM.2-2018** - Glass-Fiber-Reinforced Thermosetting-Resin Piping Systems

#### American Society of Civil Engineers (ASCE)

- **Design Guidelines**
  - **MOP 66** - Structural Plastics Selection Manual
  - **MOP 102** - Design Guide for FRP Composite Connections
  - **MOP 104** – 2<sup>nd</sup> Edition - Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures
  - **MOP 111** - Reliability-Based Design of Utility Pole Structures
  - **PreStandard** - Load and Resistance Factor Design (LRFD) of Pultruded Fiber Reinforced Polymer (FRP) Composite Structures

#### ASTM

- **Rebar Standards - ASTM D30.10 (Composites for Civil Structures)**
  - **D7205-06(2016)** [Bar Tension] – Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
  - **D7337-12(2019)** [Bar Creep Rupture] – Standard Test Method for Tensile Creep Rupture of Fiber Reinforced Polymer Matrix Composite Bars
  - **D7617-11(2017)** [Bar Transverse Shear] – Standard Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars
  - **D7705-12(2019)** [Bar Alkaline Tension] – Standard Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction
  - **D7913-14(2020)** [Bar Concentric Pullout] – Standard Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing
  - **D7914-21** [Bar Strength at Bends] – Standard Test Method for Strength of Fiber Reinforced Polymer (FRP) Bent Bars in Bend Locations
  - **D7957-17** - Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement
- **Strengthening Standards - ASTM D30.10 (Composites for Civil Structures)**
  - **D7522-21** [Lam/Concrete Bond] – Standard Test Method for Pull-Off Strength for FRP Laminate Systems Bonded to Concrete or Masonry Substrates
  - **D7565-10(2017)** [Laminate Tension] – Standard Test Method for Determining Tensile Properties of Fiber Reinforced Polymer Matrix Composites Used for Strengthening of Civil Structures
  - **D7616-11(2017)** [Laminate Lap Shear] – Standard Test Method for Determining Apparent Overlap Splice Shear Strength Properties of Wet Lay-Up Fiber-Reinforced Polymer Matrix Composites Used for Strengthening Civil Structures
  - **D7958-17** [Lam/Concrete Bond – Shear] – Standard Test Method for Evaluation of Performance for FRP Composite Bonded to Concrete Substrate using Beam Test

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### Standards, Specification, Codes and Reports for FRP Composites for Construction & Infrastructure

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- **D8337/D8337M-21** Standard Test Method for Evaluation of Bond Properties of FRP Composite Applied to Concrete Substrate using Single-Lap Shear Test
- **Other Standards - ASTM D30.10 (Composites for Civil Structures)**
  - **D7290-06(2017)** [Characteristic Values] – Standard Practice for Evaluating Material Property Characteristic Values for Polymeric Composites for Civil Engineering Structural Applications
- **Reinforced Thermosetting Plastics – ASTM D20.18 (Pultrusion)**
  - **D953-19** - Standard Test Method for Pin-Bearing Strength of Plastics
  - **D2291/D2291M-16** - Standard Practice for Fabrication of Ring Test Specimens for Glass-Resin Composites
  - **D2343-17** - Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics
  - **D2562-94(2015)** - Standard Practice for Classifying Visual Defects in Parts Molded from Reinforced Thermosetting Plastics
  - **D2563-08(2015)** - Standard Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts
  - **D2584-18** - Standard Test Method for Ignition Loss of Cured Reinforced Resins
  - **D2734-16** - Standard Test Methods for Void Content of Reinforced Plastics
  - **D3647-16** - Standard Practice for Classifying Reinforced Plastic Pultruded Shapes According to Composition
  - **D3846-08(2015)** - Standard Test Method for In-Plane Shear Strength of Reinforced Plastics
  - **D3914-02(2016)** - Standard Test Method for In-Plane Shear Strength of Pultruded Glass-Reinforced Plastic Rod
  - **D3916-08(2016)** - Standard Test Method for Tensile Properties of Pultruded Glass-Fiber-Reinforced Plastic Rod
  - **D3917-15a** - Standard Specification for Dimensional Tolerance of Thermosetting Glass-Reinforced Plastic Pultruded Shapes
  - **D4385-19** - Standard Practice for Classifying Visual Defects in Thermosetting Reinforced Plastic Pultruded Products
  - **D4475-02(2016)** - Standard Test Method for Apparent Horizontal Shear Strength of Pultruded Reinforced Plastic Rods By the Short-Beam Method
  - **D4476/D4476M-14** - Standard Test Method for Flexural Properties of Fiber Reinforced Pultruded Plastic Rods
  - **D5028-17** - Standard Test Method for Curing Properties of Pultrusion Resins by Thermal Analysis
  - **D5117-17** - Standard Test Method for Dye Penetration of Solid Fiberglass Reinforced Pultruded Stock
  - **D7029-17** - Standard Test Method for Determination of Reactivity of Unsaturated Polyesters and Vinyl Esters at 180.0°F (82.2°C)
  - **D7745-19** - Standard Practice for Testing Pultruded Composites
  - **D7792/D7792M-15** - Standard Practice for Freeze/Thaw Conditioning of Pultruded Fiber Reinforced Polymer (FRP) Composites Used in Structural Designs

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- **D7992/D7992M-15** - Standard Practice for Elevated Temperature and Moisture Conditioning of Pultruded Fiber Reinforced Polymer (FRP) Composites Used in Structural Designs
- **D8019-15** - Standard Test Methods for Determining the Full Section Flexural Modulus and Bending Strength of Fiber Reinforced Polymer Crossarms Assembled with Center Mount Brackets
- **D8069-17a** - Standard Test Method for Determining Flexural Modulus of Full Section Pultruded Fiber Reinforced Polymer (FRP) Composite Members with Doubly Symmetric Cross Sections under Bending

### American Association of State Highway & Transportation Officials (AASHTO)

- **Design Guidelines**
  - Guide Specifications for Design of FRP Pedestrian Bridges, 1<sup>st</sup> Edition, (2008)
  - AASHTO LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes, 1<sup>st</sup> Edition (2012)
  - Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements, 1<sup>st</sup> Edition (2012)
  - AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete, 2<sup>nd</sup> Edition (2018)
  - Guide Specifications for the Design of Concrete Bridge Beams Prestressed with Carbon Fiber-Reinforced Polymer (CFRP) Systems, 1<sup>st</sup> Edition (2018)

### International Code Council (ICC)

- **International Building Code**
  - Section 2613 – Fiber Reinforced Polymer
- **ICC-ES, Acceptance Criteria**
  - **AC102** - Development of Proprietary Design Formulae for Plastic-reinforced Glued-laminated Beams
  - **AC125** - Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-reinforced Polymer (FRP) Composite Systems
  - **AC177** - Translucent Fiberglass Reinforced Plastic (FRP) Faced Panel Wall, Roof and Skylight Systems
  - **AC178** - Inspection and Verification of Concrete and Reinforced and Unreinforced Masonry Strengthening Using Fiber-reinforced Polymer (FRP) Composite or Steel-reinforced Polymer (SRP) Composite Systems
  - **AC265** - Fiber-reinforced Polymer (FRP) Composite Columns Used as Axial Loadbearing and Nonload-bearing Architectural and Decorative Columns
  - **AC280** - Fiber-reinforced-polymer Glued-laminated Timber Using Mechanics-based Models
  - **AC447** - Fiber Reinforced Plastic (FRP) Modular Wall Systems
  - **AC454** - Fiber-reinforced Polymer (FRP) Bars for Internal Reinforcement of Concrete Members

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### Standards, Specification, Codes and Reports for FRP Composites for Construction & Infrastructure

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- **AC521** - Fiber-reinforced Polymer (FRP) Bars and Meshes for Internal Reinforcement of Non-structural Concrete Members

### Institute of Electrical and Electronics Engineers (IEEE)

- **National Electric Safety Code® (NESC®) 2017** - Working on change proposals for 2022 code cycle

### The Masonry Society (TMS)

- **TMS 402/602** - Building Code Requirements and Specification for Masonry Structures
  - New provision – Public Comment - Addition of Appendix D to TMS 402, Glass Fiber Reinforced Polymer (GFRP) Reinforced Masonry

### International Concrete Repair Institute (ICRI)

- **ICRI 330-2-16** – Guide Specification for Externally Bonded FRP Fabric Systems for Strengthening Concrete Structures

### Underwriters Laboratory (UL)

- **UL 568** - Standard for Nonmetallic Cable Tray Systems

### Canadian Standards Association (CSA)

- **Standards/Specifications**
  - **CAN/CSA C22.2 No 126.2** - Nonmetallic Cable Tray Systems
  - **CSA C116:18** - Fibre-reinforced polymer composite crossarms
  - **CSA S806:12 (R2017)** - Design and construction of building structures with fibre-reinforced polymers
  - **CSA S807:19** - Specification for fibre-reinforced polymers
  - **CSA S808:14 (R2019)** - Specification for fibre-reinforced polymer (FRP) materials for externally reinforcing structures
- **Codes**
  - **CSA S6:19** - Canadian Highway Bridge Design Code
    - Section 16 (Fibre Reinforced Structures)

### Florida Department of Transportation

- **Materials Manual**
  - <https://www.fdot.gov/materials/administration/resources/library/publications/materialsmanual/default.shtm>
    - CHAPTER 12: Fiber Reinforced Polymer Composites
- **Design Manual**
  - <https://www.fdot.gov/design/innovation/>
    - Fiber Reinforced Polymer (FRP) Reinforcing Bars and Strands

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#### Transportation Research Board (TRB)

- **NCHRP Report 503** - Application of Fiber Reinforced Polymer Composites to the Highway Infrastructure
- **NCHRP Synthesis 512** - Use of Fiber-Reinforced Polymers in Highway Infrastructure
- **NCHRP Report 514** - Bonded Repair and Retrofit of Concrete Structures Using FRP Composites - Recommended Construction Specifications and Process Control Manual
- **NCHRP Report 564** - Field Inspection of In-Service FRP Bridge Decks
- **NCHRP Report 609** - Recommended Construction Specifications and Process Control Manual for Repair and Retrofit of Concrete Structures Using Bonded FRP Composites
- **NCHRP Report 655** - Recommended Guide Specification for the Design of Externally Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements
- **NCHRP Report 678** - Design of FRP Systems for Strengthening Concrete Girders in Shear
- **NCHRP Research Report 864** - Seismic Evaluation of Bridge Columns with Energy Dissipating Mechanisms, Volume 1: Research Overview and Volume 2: Guidelines
- **NCHRP Research Report 907** – Design of Concrete Bridge Beams Prestressed with CFRP Systems
- **NCHRP Project 20-68A, Scan 13-03** – Advances in Fiber-Reinforced Polymer (FRP Composites in Transportation Infrastructure
- **NCHRP Consensus Study Report (2019)** – Performance of Bridges that Received Funding Under the Innovative Bridge Research and Construction Program

#### Whole Building Design Guide

WBDG is a gateway to up-to-date information on integrated 'whole building' design techniques and technologies. The goal of 'Whole Building' Design is to create a successful high-performance building by applying an integrated design and team approach to the project during the planning and programming phases.

- **US Army Corps of Engineers – United Facilities Guide Specifications (UFGS)**
  - **UFGS 35 20 15** - FRP Composites for Low-Head Water Control Structures
  - **UFGS 35 59 13.14 20** – Polymeric Fender Piles
  - **UFGS 06 73 01** - Fiberglass Reinforced Plastic (FRP) Grating
  - **UFGS 06 71 33** - Fiberglass Reinforced Plastic (FRP) Ladders
  - **UFGS 06 82 14** - Fiberglass Reinforced Plastic (FRP) Pipe and Tube Railings
  - **UFGS 04 01 20.75** - Masonry Strengthening Using Surface Applied FRP Composites
  - **UFGS 04 01 20.73** - Masonry Strengthening Using FRP Bars
  - **UFGS 04 01 20** - Rehabilitation of Reinforced and Unreinforced Masonry Walls Using FRP Composite Structural Repointing
  - **UFGS 04 01 21** - Rehabilitation of Reinforced and Unreinforced Masonry Walls Using Surface Applied FRP Composites

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#### Fenestration and Glazing Industry Alliance (FGIA)

- **Specifications**
  - **101/I.S. 2/A440-17** - North American Fenestration Standard/Specification for windows, doors, and skylights
  - **305-18** - Voluntary Specification for Fiber Reinforced Thermoset Profiles
  - **623-21** - Voluntary Specification, Performance Requirements and Test Procedures for Organic Coatings on Fiber Reinforced Thermoset Profiles
  - **624-20** - Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Fiber Reinforced Thermoset Profiles
  - **625-20** - Voluntary Specification, Performance Requirements and Test Procedures for Superior Performance Organic Coatings on Fiber Reinforced Thermoset Profiles
- **Guides**
  - **112-13** - Procedural Guide for the AAMA Fenestration Exterior Fiber Reinforced Thermoset Profile Certification Program

#### Suppliers of Advanced Composite Materials Association (SMACNA)

- **ANSI/SMACNA 011-2017** Thermoset FRP Duct Construction Manual
- **ANSI/SMACNA 005-2013** Round Industrial Duct Construction Standards

#### American Water Works Association

- **AWWA D121-2012** - Bolted Aboveground Thermosetting Fiberglass-Reinforced Plastic Panel-Type Tanks For Water Storage

#### ISO

- **ISO/TC 71/SC 6** – Non-traditional reinforcing materials for concrete structures ISO 10406-1:2015 - Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 1: FRP bars and grids
  - **ISO 10406-2:2015** - Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 2: FRP sheets
  - **ISO 10406-3:2019** - Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods — Part 3: CFRP strips
  - **ISO 14484:2020** - Performance guidelines for design of concrete structures using fibre-reinforced polymer (FRP) materials
  - **ISO 18319:2015** - Fibre-reinforced polymer (FRP) reinforcement for concrete structures — Specifications of FRP sheets
  - **ISO 19044:2016** - Test methods for fibre-reinforced cementitious composites — Load-displacement curve using notched specimen
  - **ISO 21022:2018** - Test method for fibre-reinforced cementitious composites — Load-deflection curve using circular plates
  - **ISO 21914:2019** - Test methods for fibre-reinforced cementitious composites — Bending moment — Curvature curve by four-point bending test
- **ISO/TC 61/SC 13** - Composites and reinforcement fibres
  - <https://www.iso.org/committee/49462/x/catalogue/>

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#### Updates in Progress:

##### 1. ACMA

- Code of Standard Practice Update (PIC) – This document has been updated and currently in balloting for the second edition. It is expected to be published in 2021.
- Standard Specification for FRP Crossarms (UCSC) – After publishing the utility pole standard, the Council is now focused on developing a new FRP crossarm standard. Although FRP composite crossarms have been in service for over 30 years, no standard exists just for FRP.
- Grating Manual Update (Vehicular loads – FGMC) – After publishing the grating standard, the Council is now focused on developing a new section devoted to vehicular loading and grating applications. It is expected that this process will take 1-2 years as there might be some testing involved.

##### 2. ACI

- Rebar Code – ACI Committee 440 is currently finishing the development of a new ACI dependent code focused on GFRP rebar. The dependent code is modeled after the ACI 318 concrete building code with the same chapter structure and content but revised to reflect GFRP rebar design and protocol. It is expected the draft code will be finished and presented to ACI Technical Activities Committee in Fall 2021 as next step in the process to make this a code document. The ACMA FRP Rebar Manufacturers Council fully supports the activity.
- Structural Stay-in-Place Formwork – ACI Committee 440J is currently drafting of a new design guideline titled “Guide for Design of Circular Concrete-Filled Fiber Reinforced Polymer Tubes”.

##### 3. American Society of Civil Engineers (ASCE)

- LRFD – PreStandard - Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer (FRP) Composite Structures. This document has been finalized by the ASCE Fiber Composites and Polymers Standards Committee and is being prepared for a Public Comment expected to be initiated in June 2021.