FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

DAY 2 Friday, August 9th – Advancement of FRP-RC

Session 4: Standards & Specifications Perspective on the use of FRP Rebar

CSA S806, CSA S807, CSA S6:19 & S6:25 updates

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University of Sherbrooke, Sherbrooke, QC, CANADA

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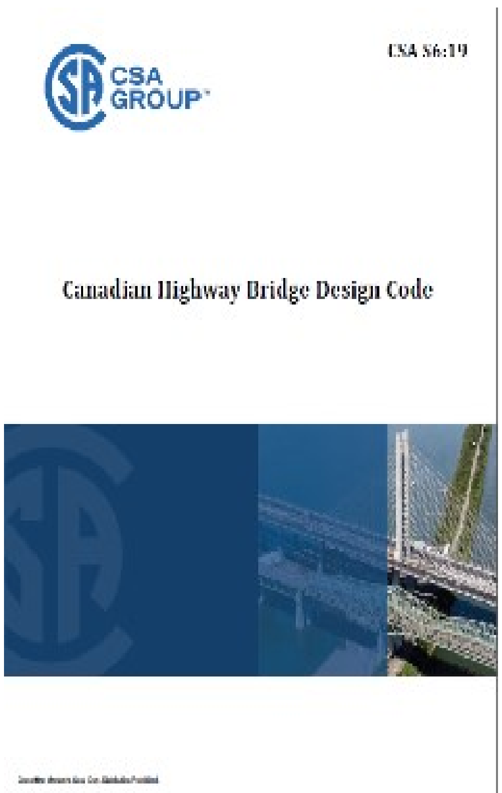
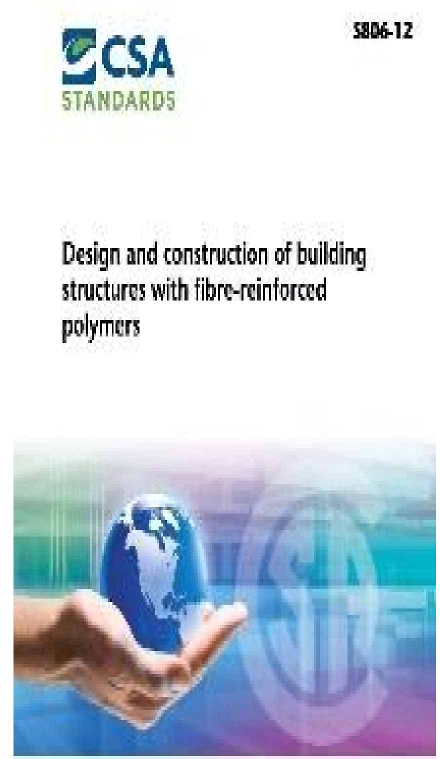
PULTRALL V-ROD FIBERGLASS Innovations ALTAIR MST BAR MAXIMUM STRENGTH GFRP SFTec AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION ACMA FRP Rebar Manufacturers Council

UNIVERSITÉ DE SHERBROOKE NSERC CRSNG UNIVERSITY OF MIAMI Center for Integration of Composites into Infrastructure FDOT

CSA FRP Rebar Design Codes & Certifications



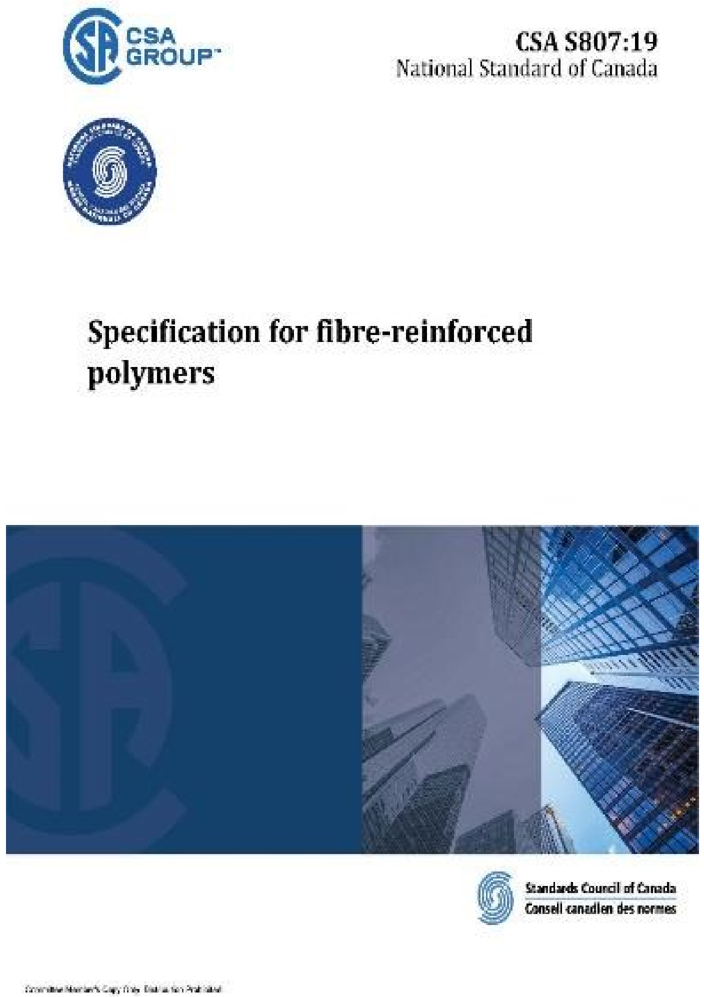


HOW TO CERTIFY/QUALIFY/SPECIFY FRP BARS

CSA S807

The most comprehensive specs for FRP rebars in the world

- First edition in 2010
- Re-approved in 2015
- Second Edition in 2019
- Re-approved in 2024


CSA GROUP
CSA S807:19
National Standard of Canada

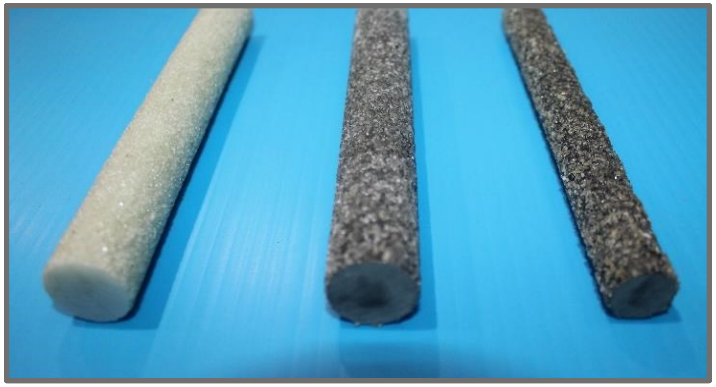
Specification for fibre-reinforced polymers

Standards Council of Canada
Conseil canadien des normes

CSA Material Specifications (CSA S807)

Describes permitted constituent materials, limits on constituent volumes, and minimum performance requirements.

Provides provisions governing testing and evaluation for product qualification and QC/QA.

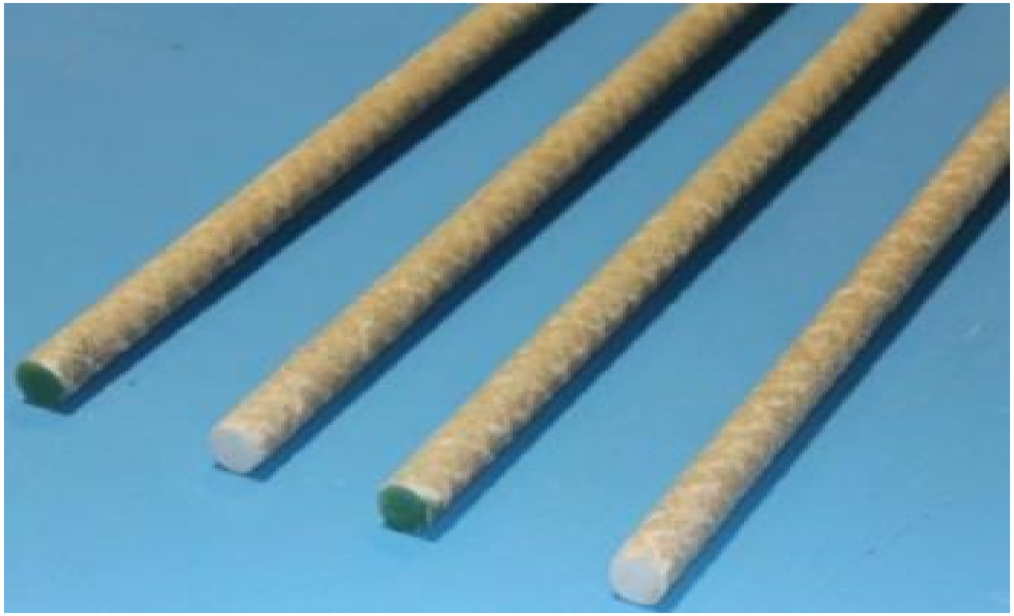


GFRP BFRP CFRP

CSA Material Specifications (CSA S807)

The mechanical and physical properties of FRP rebars are critical in determining the performance, durability and cost.

Three grades (**40 GPa, 50 GPa, and 60 GPa**) are identified in the CSA S807 for GFRP bars which allows optimization in design based on performance and/or cost.



CSA Material Specifications (CSA S807)

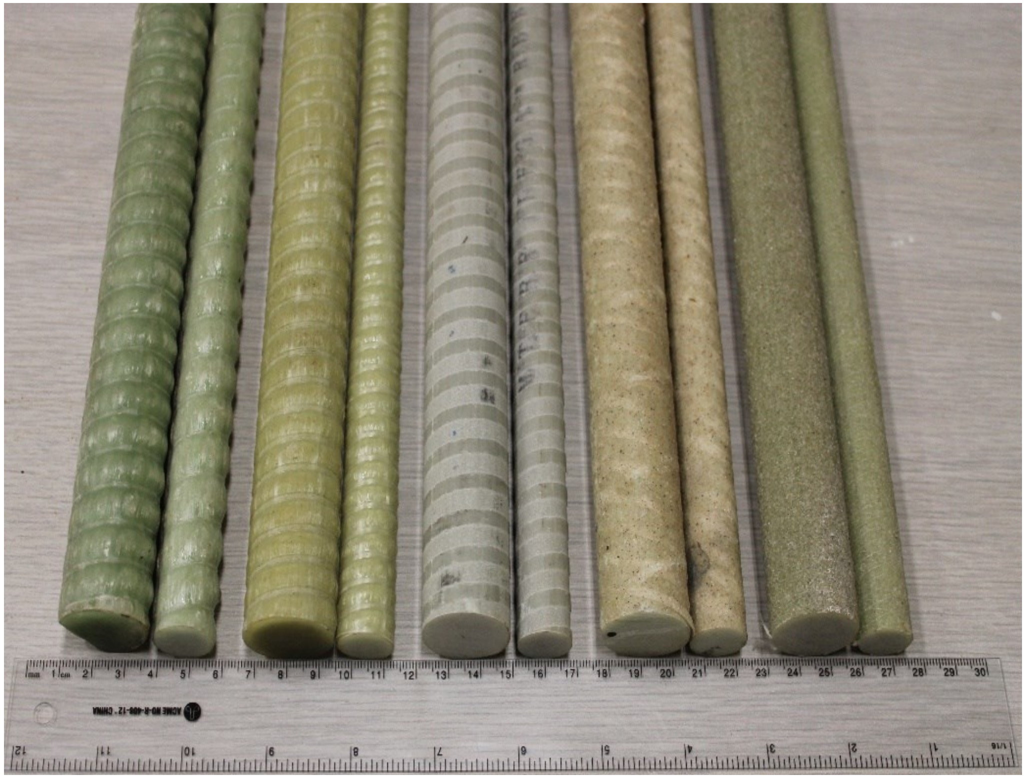
TESTS PER BAR SIZE (Physical , Durability, and Mechanical Properties for 3 lots)

- Tensile Strength: 24 specimens
- Bond Strength: 24 specimens
- Transverse Shear Strength: 24 specimens
- Strength of bent bars: 24 specimens
- Tensile Strength at cold temperature: 24 specimens
- Fibre Content: 9 specimens
- Transverse Coefficient of Thermal Expansion: 9 specimens
- Void Content: 9 specimens
- Water Absorption: 15 specimens
- Cure Ratio: 15 specimens
- Glass Transition Temp.: 15 specimens
- Alkaline Resistance without/load: 24 specimens
- Alkaline Resistance with/load: 24 specimens
- Creep Rupture load level: 24 specimens

Several GFRP bar manufacturers or suppliers qualified their products and obtained approvals from end-users and government authorities (such as MTO, MTQ, etc.):

Mean Tensile Modulus: 60 GPa (High Modulus)
Minimum Guaranteed Tensile Strength: 1000 MPa

1. **MST-BAR INC.**
2. **PULTRALL INC.**
3. **PULTRON INC.**
4. **SFTec INC.**
5. **TUF-BAR**
6. **ROECHLING**
7. **Etc.**



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CSA S6 Canadian Highway Bridge Design Code

CSA S6 (CHBDC)

- First Edition in **2000** (GFRP as secondary reinforcement)
- Second Edition in **2006** (GFRP as main reinforcement)
- Third Edition in **2010** (FRP-RC beams & slabs, Shear equation, crack-width, Kb, and barrier walls)
- Re-approved in **2014**
- Fourth Edition in **2019**
- **Fifth Edition in 2025 (Completed) – CSA S6-25**

The Code includes 17 Sections (FRP in Section 16)

CSA GROUP

CSA S6:19

Canadian Highway Bridge Design Code

CSA S6:19 (2019)

- **Changes Implemented in the Current Edition:**
  - **Endorses the use of FRP bars in compression members**

$$P_0 = \varphi_c \alpha_1 f'_c A_g + \varphi_{FRP} 0.002 E_{FRP} A_{FRP}$$

  - **Increasing the GFRP material resistance factor**

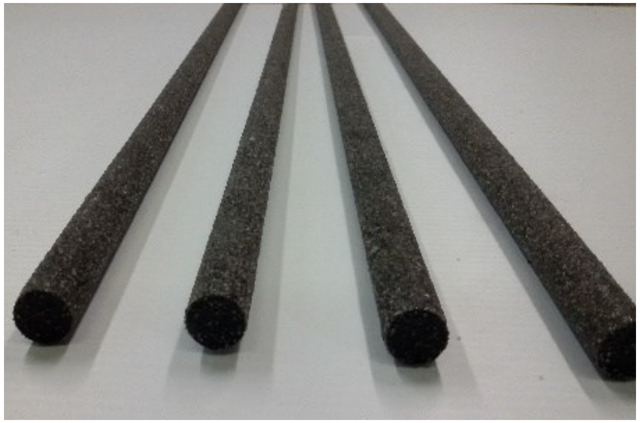
$$\phi_f = 0.65 \text{ (0.55 in previous edition)}$$

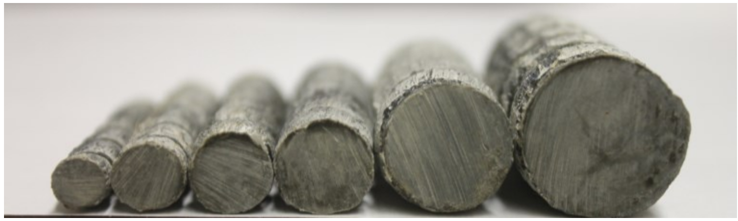
  - **Additional clauses for detailing bundled FRP bars, bent bars, and headed bars**
  - **Requirements for the Strut-and-Tie Model**

CSA S6:25 (2025)

- **Introducing Basalt FRP bars (BFRP)**

Following the introduction of the material in the CSA S807 Specifications. The main conclusion of previous studies is that the behavior of BFRP-reinforced elements is similar to GFRP-reinforced ones, therefore, the proposed change includes adding the BFRP bars as an acceptable fiber type with the same limitations, recommendations, and specifications as GFRP bars.

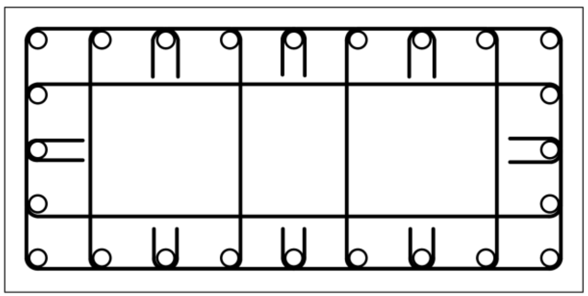


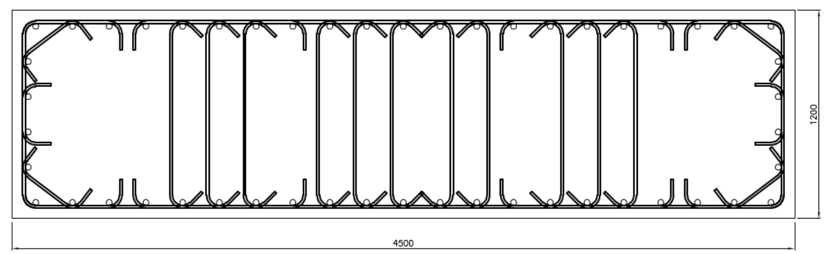


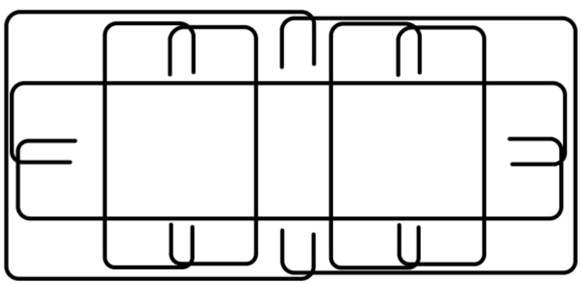
CSA S6:25 (2025)

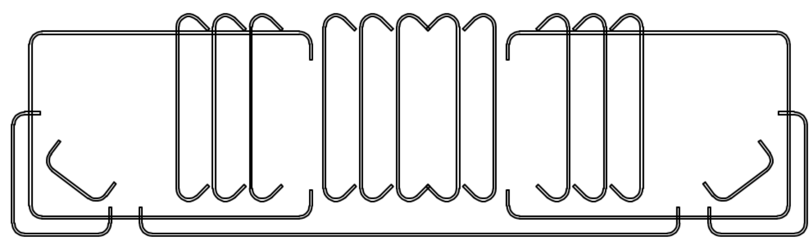
- **FRP transverse reinforcement in columns for seismic**

  This is based on several experimental studies at the University of Toronto, University of Sherbrooke, and the University of Manitoba.







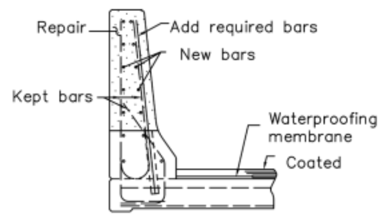


CSA S6:25 (2025)

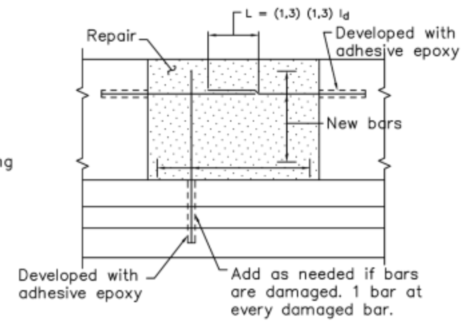
- Added Clauses on the slenderness ratio and effect,
- Added Clauses on the splice length for members under compression,
- Modified the creep rupture limit for GFRP bars,
- Added clauses for punching (two-way) shear strength,
- Modified existing clauses for the shear interface,
- Etc.

CSA S6:25 (2025)

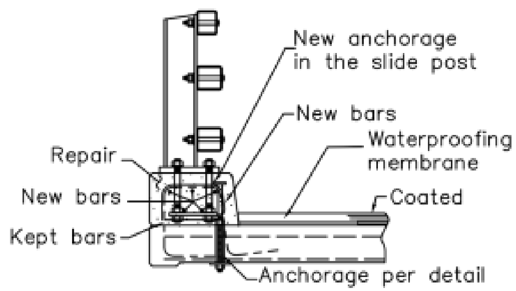
- Repair of damaged bridge barrier walls, curbs, and slabs reinforced with FRP bars



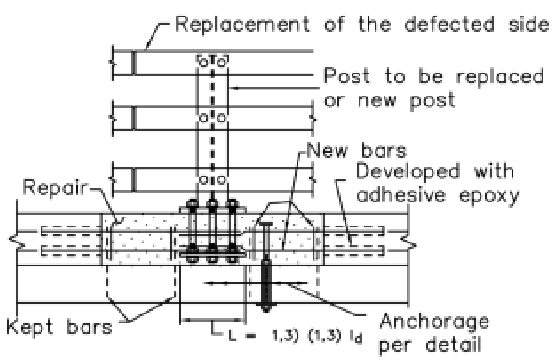
Typical Detail (Slab on beams)



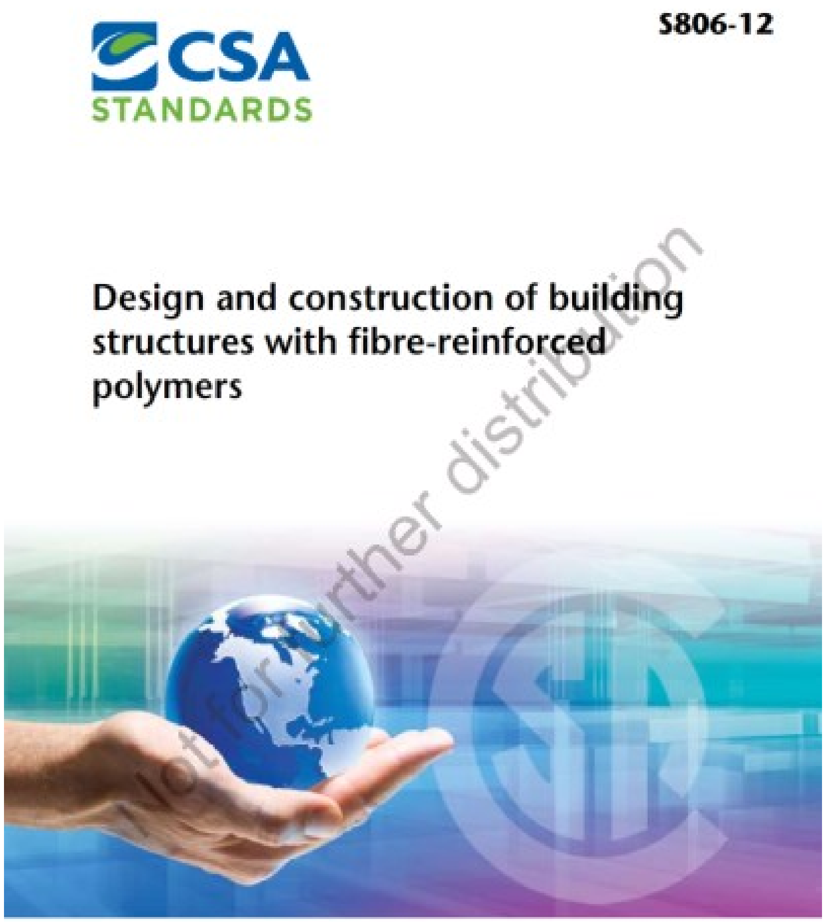
Elevation



Typical Detail (Slab on beams)



CAN/CSA S806: Design and Construction of Building Components with Fibre-Reinforced Polymers



- 1st Edition in **2002**
- 2nd Edition in **2012**
- Re-approved in **2017 & 2022**
- Third Edition in 2025 (Start in June 2024)

CSA S806-25 (2025)

Change Proposed in the Next Edition (FRP Rebar) :

- Address GFRP bars in compression (not ignoring the contribution of GFRP rebars in compression),
- Update the minimum reinforcement ratio,
- Add provisions for the slender elements subjected to axial load and moment,
- Add clauses for masonry walls reinforced with GFRP bars,
- Add clauses for shear walls, and column reinforcement details under seismic loads,
- Update equations for deflection calculations (Bishoff equation, similar to ACI CODE 440.11-22),
- Update equations for one-way and punching shear,

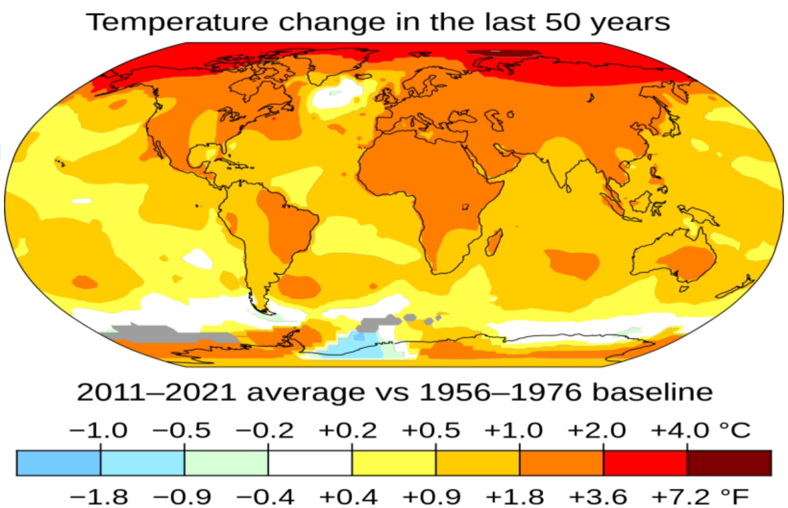
CSA S806-25 (2025)

Change Proposed in the Next Edition (FRP Rebar):

- Update the equations for development/splice length,
- Update the existing stress limits for creep rupture,
- Update the equations and limits for the crack width,
- Recalibration of phi factors,
- Update clauses for fire protection,
- Add special provisions for seismic design,
- Add clauses for the shear interface,
- Add clauses for the headed bars,
- Update the clauses for the development length of bundled bars larger than 25 mm,
- Add provisions for hybrid reinforcement (steel and FRP).

Climate adaptation of structures

The climate adaptation of structures involves th ability of existing or new structures to fulfill the requirements of safety and serviceability



Climate change:

1) Extreme temperatures due to heat waves;
2) High-temperature fluctuations; and
3) Changes in humidity conditions.

Additional stresses due to creep, shrinkage, or soil settlement

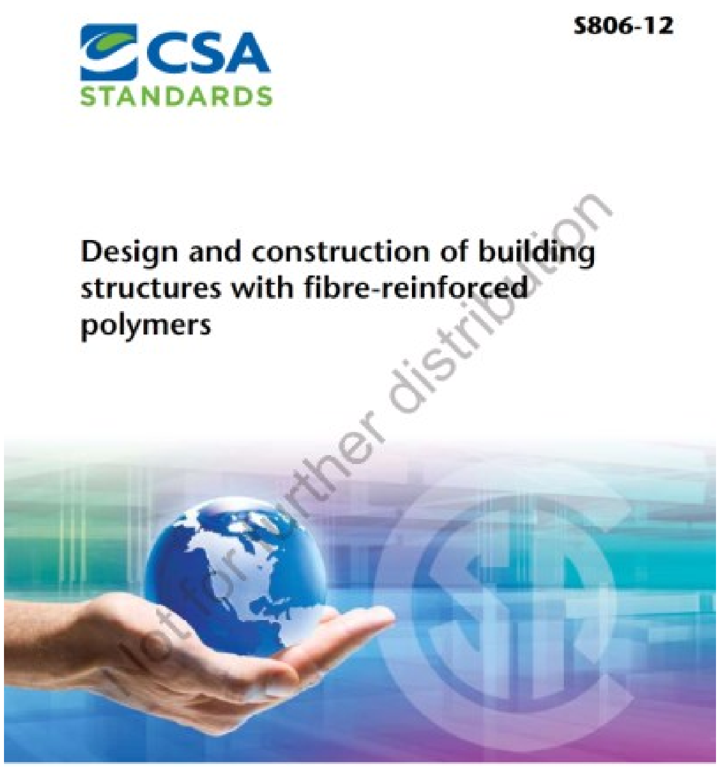
Climate adaptation of structures

Recent studies conducted in Canada on **FRP-reinforced concrete elements** show that the extremes of temperature and temperature humidity fluctuations **could affect the performance of FRP in the short and long terms**.

Revisions of some requirements related to the selection of the material, the effective bond length of the FRP reinforcement, and other detailed aspects are needed to be implemented in CSA **material specification**, and **design standards and codes**.

CSA S806-25 (2025)

Climate adaptation of structures



CSA S806 Design Standard

- New Edition (2025) currently under development

Addressing this important issue for both **internal and external FRP reinforcement**

New Edition CSA S413-21 (2021) Parking Structures


CSA GROUP
CSA S413:21
National Standard of Canada

Parking structures

SCC CCN

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Inclusion of GFRP Reinforcing as an alternative reinforcing to traditional black steel rebars in the New Edition of CSA S413-21 (October 2021)

New Edition of CSA S900.2-21 (2021) Structural Design of Wastewater Treatment Plants

CSA S900.2:21
National Standard of Canada

Structural design of wastewater treatment plants

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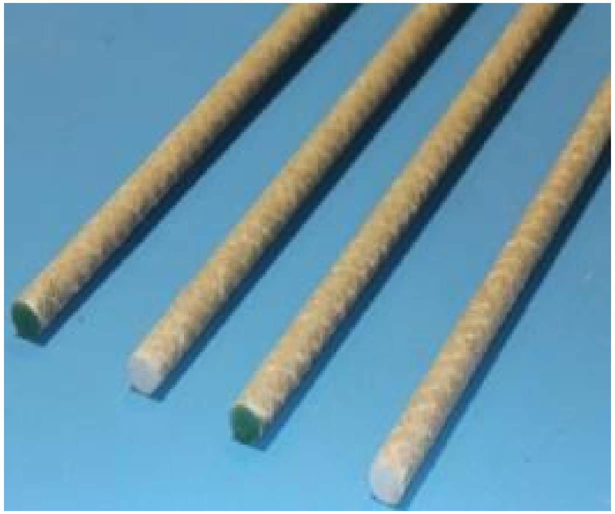
Inclusion of GFRP Reinforcing as an alternative reinforcing to traditional black steel rebars in the New Edition of CSA S900.2 (December 2021)



Thank you

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FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

ACI CODE 440.11-22

Vicki L. Brown

Widener University

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PULTRALL V-ROD FIBERGLASS Innovations

ALTAIR

MST BAR MAXIMUM STRENGTH GFRP

SFTec

ACMA AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION FRP Rebar Manufacturers Council

UNIVERSITÉ DE SHERBROOKE

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Center for Integration of Composites into Infrastructure

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ACI CODE 440.11-22

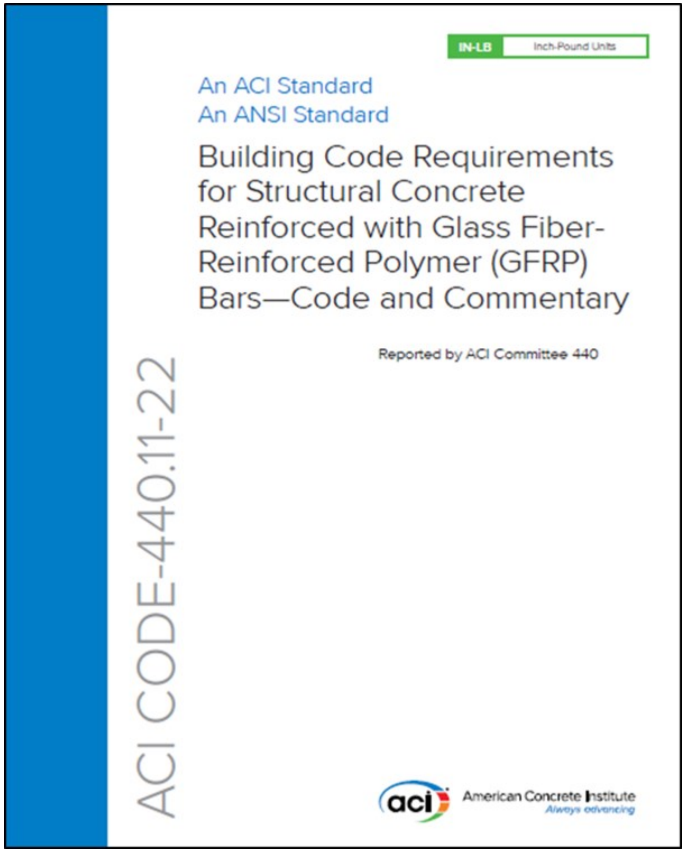
Presentation Objective: Introduce ACI Code 440.11 for GFRP RC, discuss key design requirements, and explain limitations that apply to using the Code.

Presentation Outline:

- **Introduction**
- Transitioning from Guide to Code
- Key Design Requirements
- Future Code Revisions and Educational Materials

ACI CODE 440.11-22 Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars

- Published September 2022
- Dependent on ACI 318-19
    - Mandated to use 318-19 requirements where possible
    - Same layout and chapters as 318-19
    - Consistent numbering with 318-19
- Adopted by ICC for inclusion in 2024 version of the **International Building Code**



ASTM D7957-22 – Standard Specification for Solid Round GFRP Bars for Concrete Reinforcement

- Glass fiber, vinyl ester resin bars only
- Manufactured by pultrusion
- Specified material properties
- Specified durability properties

Designation: D7957/D7957M – 22

Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation D7957/D7957M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers glass fiber reinforced polymer (GFRP) bars, provided in cut lengths and bent shapes and having an external surface enhancement for concrete reinforcement. Bars covered by this specification shall meet the requirements for geometric, material, mechanical, and physical properties described herein.

1.2 Bars produced according to this standard are qualified using the test methods and must meet the requirements given by Table 1. Quality control and certification of production lots of bars are completed using the test methods and must meet the requirements given in Table 2.

1.3 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables) shall not be considered as requirements of the specification.

1.4 The following FRP materials are not covered by this specification:

1.4.1 Bars made of more than one load-bearing fiber type (that is, hybrid FRP).

1.4.2 Bars having no external surface enhancement (that is, plain or smooth bars, or dowels).

1.4.3 Bars with geometries other than solid, round cross sections.

1.4.4 Pre-manufactured grids and gratings made with FRP materials.

1.5 This specification is applicable for either SI (as Specification D7957M) or inch-pound units (as Specification D7957).

1.6 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials
D570 Test Method for Water Absorption of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D3171 Test Methods for Constituent Content of Composite Materials
D3878 Terminology for Composite Materials
D7205/D7205M Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
D7617/D7617M Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars
D7705/D7705M Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction
D7913/D7913M Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing

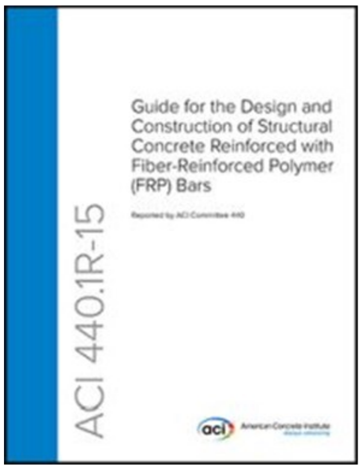
[1] This specification is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.10 on Composites for Civil Structures.

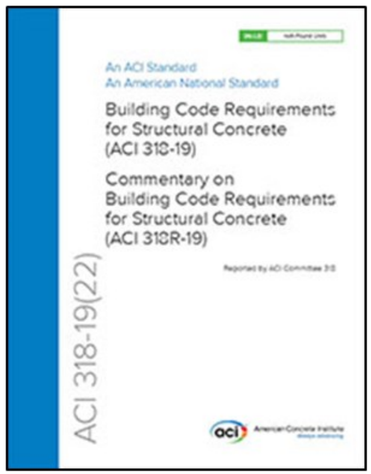
Current edition approved Feb. 1, 2022. Published March 2022. Originally approved in 2017. Last previous edition approved in 2017 as D7957/D7957M – 17. DOI: 10.1520/D7957_D7957M-22.

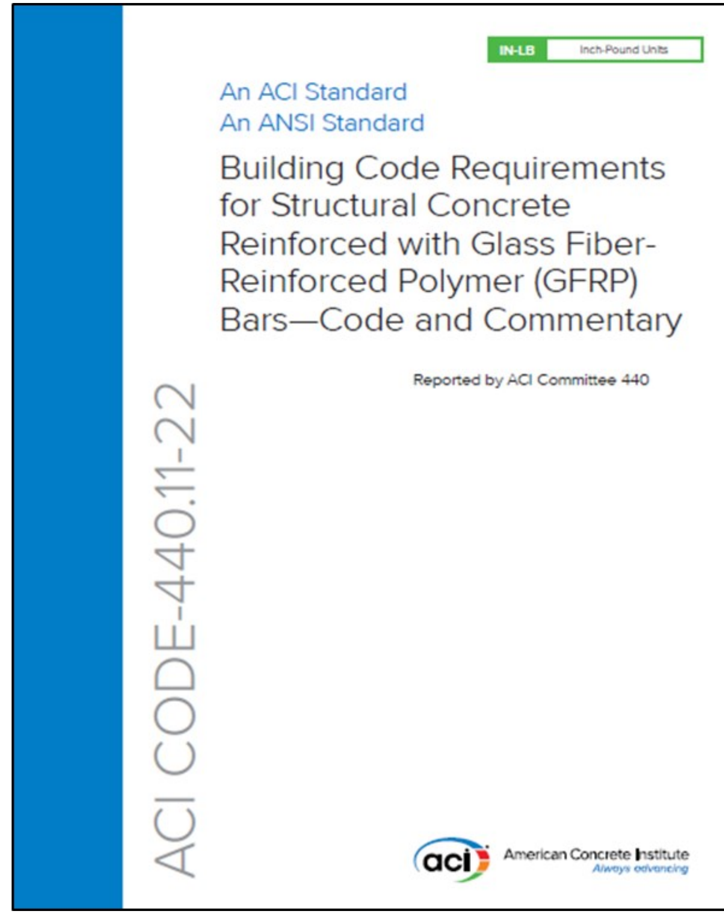
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

NSERC CRSNG MIAMI FDOT

- Introduction
- **Transitioning from Guide to Code**
- Key Design Requirements
- Future Code Revisions and Educational Materials







Required development of design methods for GFRP-RC members under torsion and GFRP-RC columns.

Chapter 1 – General

Chapter 2 - Notation and Terminology

Chapter 3 - Referenced Standards

Chapter 4 – Structural System Requirements

Chapter 5 – Loads

Chapter 6 - Structural Analysis

Chapter 7 – One-Way Slabs

Chapter 8 – Two-Way Slabs

Chapter 9 – Beams

Chapter 10 – Columns

Chapter 11 – Walls

~~Chapter 12 – Diaphragms~~

Chapter 13 – Foundations

~~Chapter 14 – Plain Concrete~~

Chapter 15 – Beam-Column/Slab-Column Joints

Chapter 16 – Connections between Members

~~Chapter 17 – Anchoring to Concrete~~

~~Chapter 18 – Earthquake-Resistant Structures~~

Chapter 19 – Concrete: Design and Durability Requirements

Chapter 20 – GFRP Reinforcement Properties, Durability, and Embedments

Chapter 21 – Strength Reduction Factors

Chapter 22 – Sectional Strength

~~Chapter 23 – Strut &Tie Models~~

Chapter 24 – Serviceability Requirements

Chapter 25 – Reinforcement Details

Chapter 26 – Construction Documents/Inspection

Chapter 27 – Strength Evaluation of Existing Structures

Code DOES cover:

- Beams
- One-way and two-way slabs
- Columns
- Walls
- Foundations
- Joints/Connections between members
- Strength evaluation of existing structures
- Torsion

Code does not currently cover:

- Lightweight concrete
- Prestressed concrete
- Deep beams
- Shotcrete
- SDC D-F totally excluded
- SDC B-C excluded if part of the lateral load resisting system

- Introduction
- Transitioning from Guide to Code
- **Key Design Requirements**
- Future Code Revisions and Educational Materials

Design Tensile Properties

Design tensile strength and rupture strain for straight bars

$$f_{fu} = C_E f_{fu}^* \qquad \varepsilon_{fu} = \frac{\varepsilon_{fu}^*}{E_f}$$

f_{fu}^* *and* ε_{fu}^* *are guaranteed properties based on average minus* 3 σ

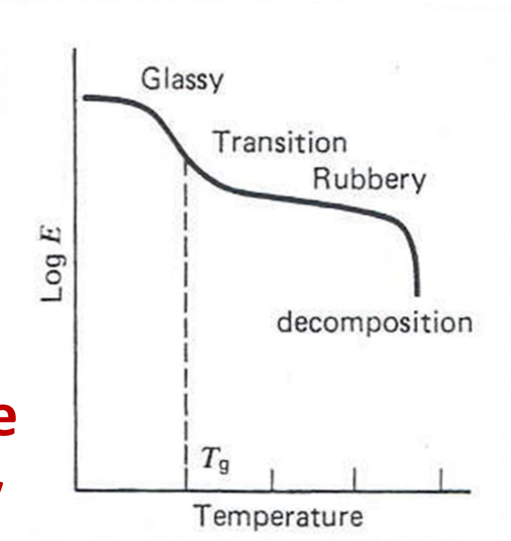
Design tensile strength for transverse reinforcement

$$f_{ft} = C_E f_{fb}^* \leq 0.005 E_f \quad \text{where } f_{fb}^* = \text{guaranteed bent bar strength}$$

C_E is an environmental reduction factor = 0.85

Effects of Fire and High Temperatures

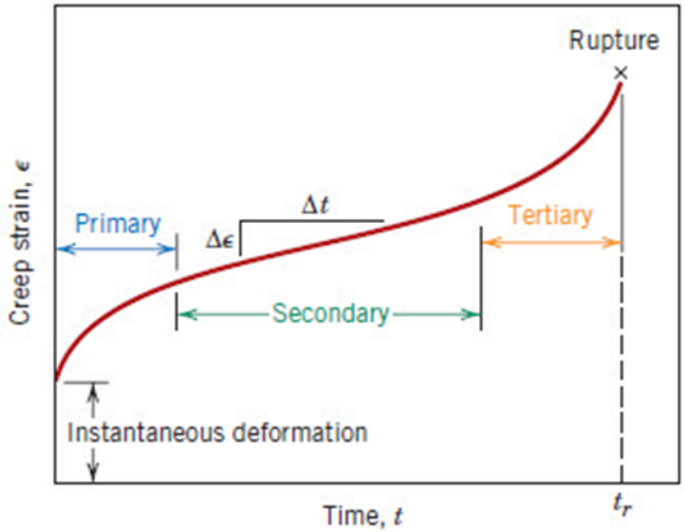
- Bond diminishes when temperatures approach Glass Transition Temperature
- T_g value of 120°C typical; ASTM D 7957 requires a minimum T_g of 100°C.
- **Code limited to structures not requiring fire resistance rating except where fire resistance is shown to be adequate and is approved by the building official.**



- Proper detailing and use of insulation can provide fire resistance in excess of 2 hours
- Service temperatures not permitted to exceed T_g - 15°C

Creep-rupture Behavior

- GFRP reinforcing bars subjected to a constant load over time can suddenly fail
- Phenomenon is known as creep rupture (or static fatigue)
- Keep stress due to **unfactored** sustained loads less than 0.3 f_{fu}



Control of Deflections: Limits identical to ACI 318

Immediate deflections calculated using effective moment of inertia:

$$I_e = \frac{I_{cr}}{1 - \gamma\left(\frac{0.8\,M_{cr}}{M_a}\right)^2\left(1 - \frac{I_{cr}}{I_g}\right)} \leq I_{g;}\quad \gamma = 1.72 - 0.72\frac{0.8\,M_{cr}}{M_a}$$

$$\Delta_{(long-term)} = 0.6\,\xi(\Delta_i)_{sus}$$

$(\Delta_i)_{sus}$ = short term deflection due to sustained load

ξ = time-dependent factor equal to 1.0 at 3 months and 2.0 at 5 years or more

Bar Spacing for Control of Crack Widths

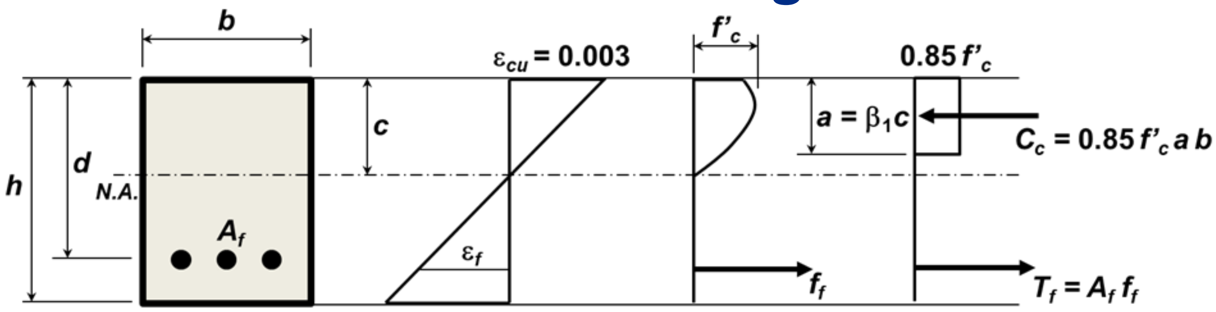
$$s \leq \frac{0.81\,E_f}{f_{fs}k_b} - 2.5c_c \leq 0.66\frac{E_f}{f_{fs}k_b}$$

E_f = elastic modulus of the GFRP reinforcement
f_{fs} = reinforcement stress under service loads
k_b = 1.2 (bond factor)
c_c = clear cover

Crack widths less than 0.41 to 0.71 mm are generally acceptable

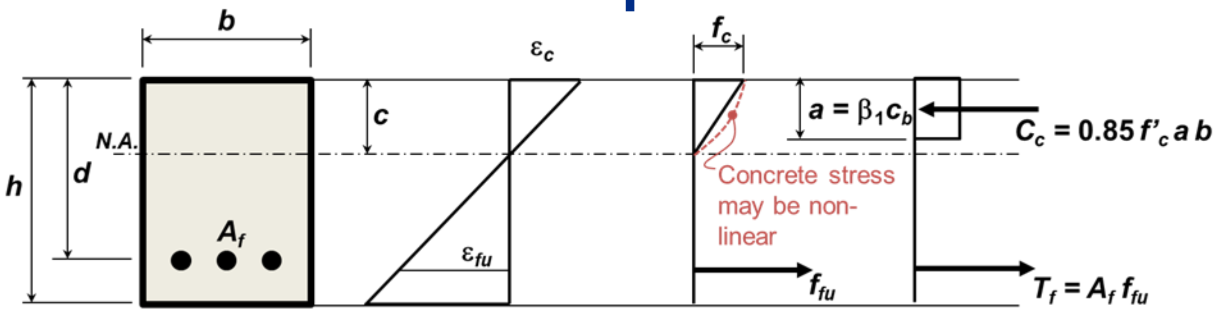
Flexural Strength

Concrete Crushing



Find neutral axis and GFRP stress f_f by equilibrium and strain compatibility

GFRP Rupture



True ***c*** has to be less than $\boldsymbol{c_b}$. Conservative to take moment arm as $\boldsymbol{d - \beta_1 c_b / 2}$ <u>or</u> use equilibrium and strain compatibility.

*Strength reduction factor **ϕ** dependent on failure mode*

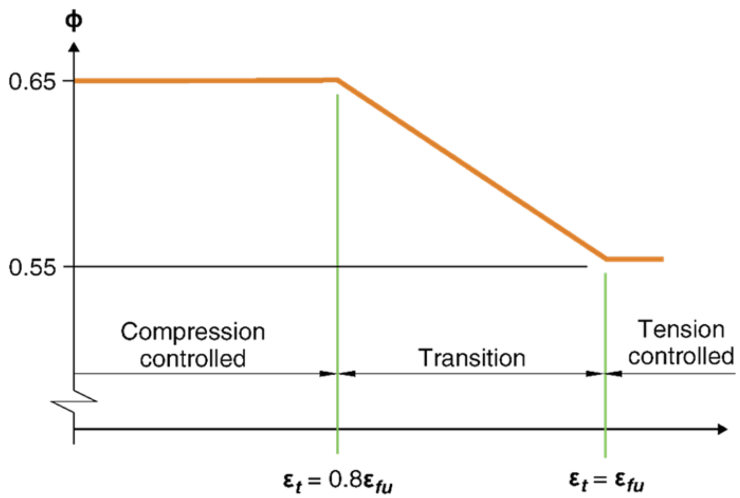
Strength Reduction Factors

Shear and Torsion → ϕ = 0.75

Bearing → ϕ = 0.65

Moment, Axial Force, Combined Moment/Axial Force

Net tensile strain at failure, ε_{ft}	Flexural Strength reduction factor, Φ
$\varepsilon_{ft} = \varepsilon_{fu}$	0.55 (tension-controlled)
$\varepsilon_{fu} > \varepsilon_{ft} > 0.8\varepsilon_{fu}$	$1.05 - 0.5\varepsilon_{ft} / \varepsilon_{fu}$ (transition)
$\varepsilon_{ft} \leq 0.8\varepsilon_{fu}$	0.65 (compression-controlled)



Shear Design Equations

$$V_n = V_c + V_f$$

Shear strength provided by concrete reinforced with GFRP is lower than shear strength provided by concrete reinforced with steel reinforcement

- Increased crack width → Less aggregate interlocking
- Small compressive zone depth → Less concrete resistance in the compressive zone

$$V_c = 5\lambda_s \sqrt{f_c'}\, b_w c$$

$c = k_{cr} d$ → Compression area of the **elastic** cracked transformed section

$$V_f = \frac{A_{fv} f_{ft} d}{s}$$

A_{fv} = amount of GFRP shear reinforcement within spacing, s

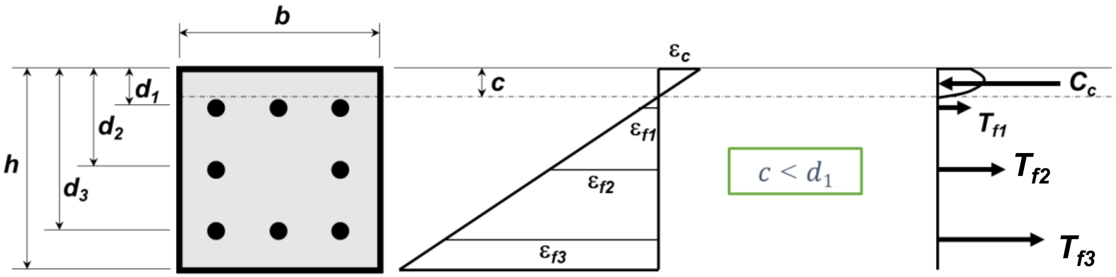
f_{ft} = min(f_{fb}, 0.005E_f) → strain in stirrups limited to 0.005 to provide adequate aggregate interlock

Moment Redistribution

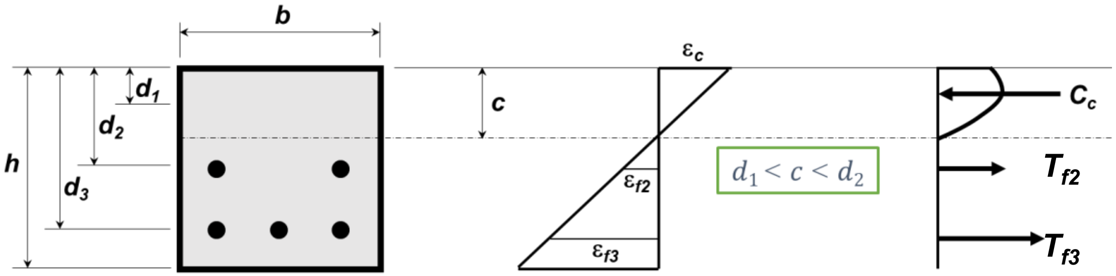
- Moment redistribution is smaller in GFRP-RC flexural members than for members with steel reinforcement, but does occur due to concrete cracking
- Direct Design Method (DDM) and Equivalent Frame Methods (EFM) are permitted, based on observed moment redistribution in GFRP RC
- Moment redistribution is **not** allowed beyond that required for DDM/EFM
- Inelastic analysis is also **out of scope**

Column Design Philosophy

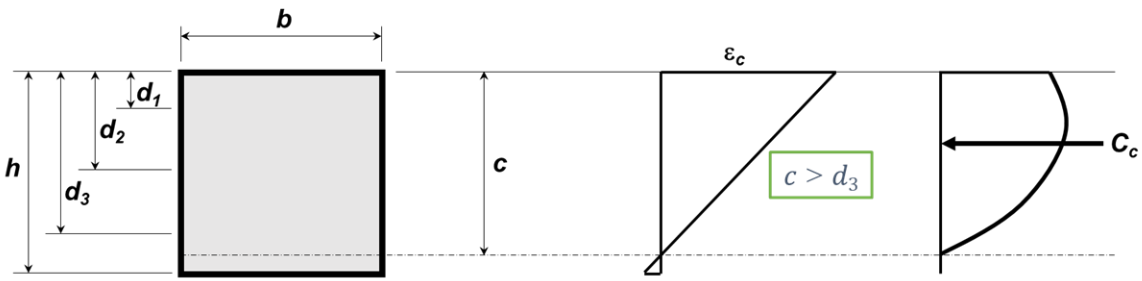
At lower axial loads, all bars are in tension



As axial loads increase, bars in compression "disappear" (treated as concrete)



At higher axial loads, all bars "disappear" in compression



For $P_u > 0.1f'_cA_g$, GFRP design tensile strain in GFRP is limited to 0.01

- Introduction
- Transitioning from Guide to Code
- Key Design Requirements
- **Future Code Revisions and Educational Materials**

ACI Committee 440C – FRP RC Building Code

Committee Mission: Develop and maintain code requirements for the design of structural concrete internally reinforced with fiber-reinforced polymer composite bars.

Sunset Date: December 2027

Committee Chair: Vicki Brown

Vice Chair: Carol Shield

Secretary: Will Gold

Committee Membership: Hakim Bouadi, John Busel, Jennifer Dimig, Ehab El-Salakawy, Hamzeh Hajiloo, Maria Lopez de Murphy, Antonio Nanni, Steven Nolan, Carlos Ospina, Shawn Platt, Randall Poston, Hayder Rasheed, Douglas Tomlinson

ACI Committee 440C – FRP RC Building Code

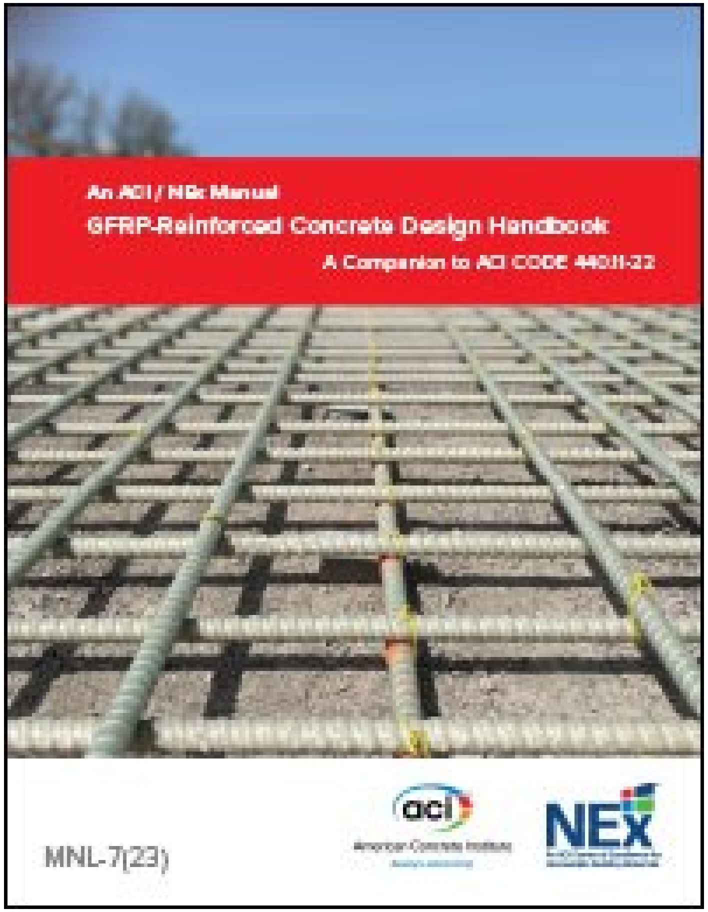
Timeline includes approximately 2 years in which to develop new technical content and translate into Code language

Priorities for this Code cycle:

- Update to ACI 318-25
- Shear friction/diaphragms
- Development length equation
- Bundled bars
- Fire resistance ratings
- Seismic design categories B & C
- Chapter 15 on cast-in-place joints
- Lightweight concrete
- Shotcrete
- Removing designer "road blocks"

ACI DESIGN HANDBOOK

- Engineering design examples for beams, one-way slabs, two-way slabs, and slender columns reinforced with GFRP bars.
- Guidance on use of GFRP rebar, its material/ durability characteristics, typical applications, and fire resistance considerations.
- Key differences between designing GFRP RC versus traditional steel RC.
- Explanation of ACI CODE 440.11 as pertains to flexure, shear, torsion, and axial strength, serviceability, stability, and structural analysis.
- Closely related to examples presented in ACI's Reinforced Concrete Design Handbook (ACI MNL-17) to allow for comparison to steel RC members.



ACI On-Demand Courses

Free to ACI Members, $39 each for non-members

- ACI CODE-440.11-22: Overview of GFRP Reinforced Concrete
- ACI CODE-440.11-22: Serviceability and Flexural Design of GFRP Reinforced Concrete
- ACI CODE-440.11-22: Shear and Torsion Design of GFRP Reinforced Concrete
- ACI CODE-440.11-22: Requirements for GFRP Reinforced Concrete Columns, Fire, and Structural Analysis
- Practical Utilization of the New ACI CODE 440.11 on GFRP Reinforced Concrete: Manuals for Engineers and Contractors

Thank You for Attending!

Questions?

FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

Updating AASHTO Guide Specifications for GFRP Reinforced Concrete Structures – 2018

Steven Nolan for **Tanarat Potisuk**

AASHTO Committee on Bridges and Structures – Concrete Committee (formerly T-10)

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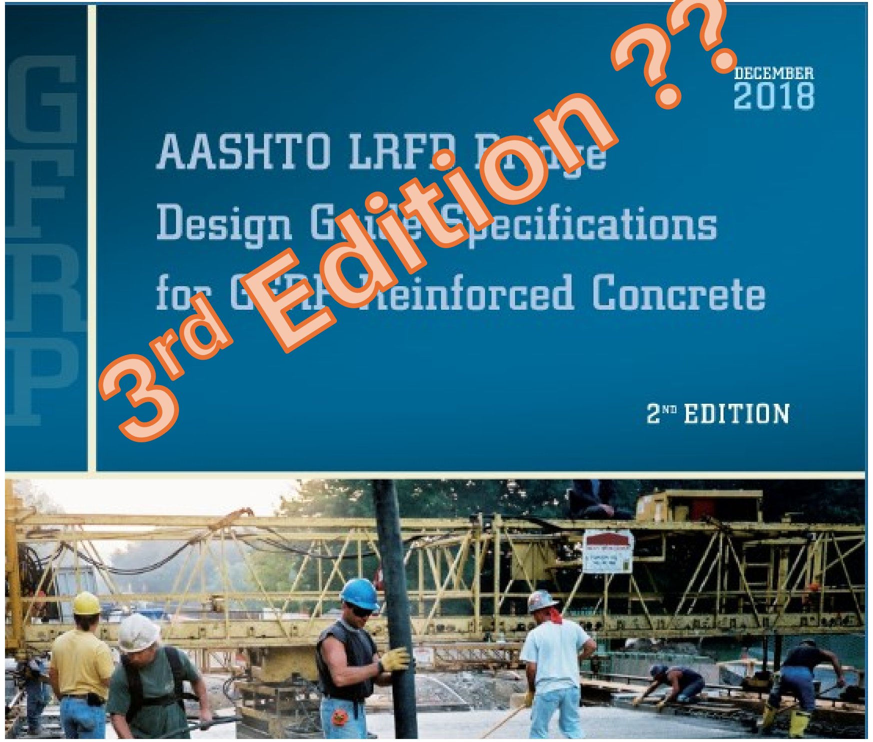
ALTAIR
MST BAR MAXIMUM STRENGTH GFRP
SFTec
ACMA American Composites Manufacturers Association FRP Rebar Manufacturers Council
Université de Sherbrooke
NSERC CRSNG
University of Miami
Center for Integration of Composites into Infrastructure
FDOT

AASHTO

AASHTO COBS Concrete Committee:

https://transportation.org/bridges/membership/?committee_code=CBS_BPRS

Planned update for 2025/26



Currently 3 Work Agenda Items being prepare for balloting in Summer of 2025:

- **GFRP Axial Resistance** – Change from Net Area to Gross Area of concrete *(Will be discussed at PCI Committee Days (Nashville, Sept 24th).*
- GFRP add references to **ASTM D8505-23** option for straight bars.
- GFRP **Max. Transverse Reinforcement** – to propose change/correction to *Eq. 2.7.2.5-1. (To be distributed by August 30th)*

AASHTO Technical Committee for Concrete
(8:00 - 11:30 AM & 1:30 – 5:00 PM

2.7.2.5—Maximum Transverse Reinforcement

The nominal shear resistance provided by the transverse reinforcement, V_f, as specified in Article 2.7.3.5 shall satisfy:

$$V_f \le 0.25\sqrt{f'_c}\, b_v d_v \qquad (2.7.2.5\text{-}1)$$

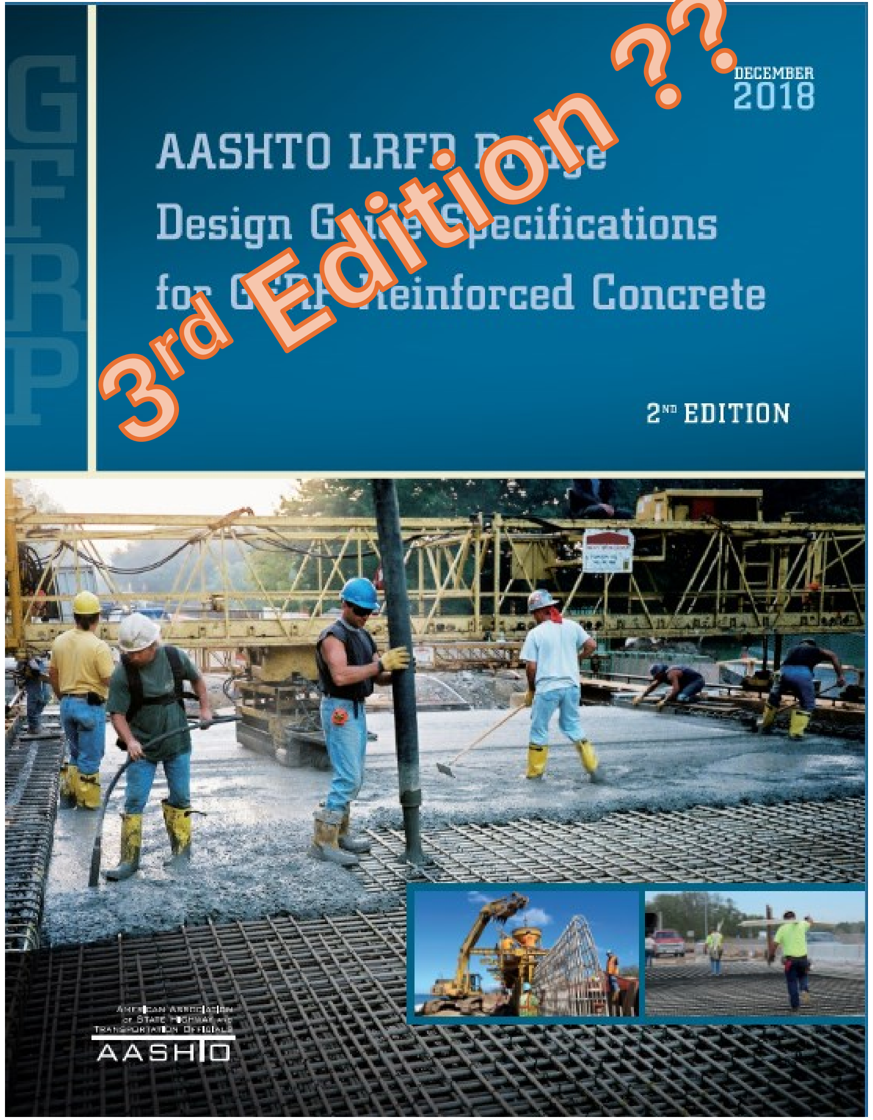
where:

This should be $\le 0.25 f'c\, b_v d_v - V_c$

Planned update for 2025/26

Other potential updates for discussion:

- Interface shear resistance refinement *(pending **NCHRP 12-121** recommendations).*
- Minimum reinforcement requirements.
- Review ***ACI CODE-440.11-22*** for potential harmonization.
- Potential addition of Basalt FRP Rebar.
- Incorporating GFRP design provisions from the Guide Specs into ***BDS*** Section 5. ***NCHRP 20-123*** research roadmap is an option for the starting effort.



Planned update for 2025/26

Other potential updates:

- Axial Resistance coefficient consistency with ***BDS***.

2.6.4.2—Factored Axial Resistance

The factored axial resistance of concrete compressive components, symmetrical about both principal axes, shall be taken as:

This is the similar to k_e as proposed in the paper

$$P_r = \phi P_n \tag{2.6.4.2-1}$$

This is the same as k_c in the AASHTO Bridge Code

in which:

- For members with spiral or hoop reinforcement:

$$P_n = 0.85\left[0.85 f'_c\left(A_g - A_f\right)\right] \tag{2.6.4.2-2}$$

- For members with tie reinforcement:

$$P_n = 0.80\left[0.85 f'_c\left(A_g - A_f\right)\right] \tag{2.6.4.2-3}$$

C2.6.4.2

The values of 0.85 and 0.80 in $\boxed{\text{Eqs. 2.6.4.2-2}}$ and $\boxed{\text{2.6.4.2-3}}$ place upper limits on the usable resistance of compression members to allow for unintended eccentricity.

In the absence of concurrent bending due to external loads or eccentric application of prestress, the ultimate strain on a compression member is constant across the entire cross section.

These provisions have been verified based on testing of full-scale reinforced concrete columns subject to uniaxial compressive forces (De Luca et al., 2010).

NSERC CRSNG MIAMI FDOT

Planned update for 2025/26

Other potential updates:

- FRP Rebar Couplers - proposed testing criteria

Proposed Acceptance Criteria

General - Failure located in couplers is not acceptable.

Acceptance Criteria -

1) **Tension Test** – The tensile force achieved by the coupler system shall be at least 80 percent of the minimum guaranteed ultimate tensile force of the bars to be spliced according to ASTM D7957. The coupler system shall develop the required tensile force without visible cracking on the surface.
2) **Slip Test** – The maximum allowed slip is 0.02 inch.
3) **Cyclic Tension Test** – No failure of the coupler system shall occur during the Stages 1 and 2 cyclic tests. The failure load in Stage 3 is for information only.
4) **Creep Test** – The residual tensile force of the coupler system shall be greater than 75 percent of the minimum guaranteed ultimate tensile force to be spliced according to ASTM D7957.

Future Work

Monotonic compression, cyclic compression, and fatigue tests are not required for this initial phase of the coupler development. These tests will be investigated further for different bar sizes and application in the future.

General - A minimum of 5 couplers are required for all tests. The coupl
of the adjoining GFRP bars and shall be tested as a system. Perform ter
D7205.

Required tests -

1) **Tension Test** – Perform tension tests to failure. Record the failure l
2) **Slip Test** – Perform slip tests by applying tension to 0.40 f_{fu} and unl
slip.
3) **Cyclic Tension Test** – Perform cyclic tests by loading the specimen t

Stage	Upper Tension	Lower Tension
1	0.40 f_{fu}	0.05 f_{fu}
2	0.80 f_{fu}	0.05 f_{fu}
3	Load in tension to failure, record the fa	

f_{fu} = guaranteed tensile strength calculated by dividing the m
tensile force shown in ASTM D7957 by the measured cross-sectional ar

4) **Creep Test** – Perform sustained tension tests by applying tension to
hours under laboratory conditions according to ASTM D7337. Test
determine the residual tensile force.

Proposed Acceptance Criteria

General - Failure located in couplers is not acceptable.

Acceptance Criteria -

1) **Tension Test** – The tensile force achieved by the coupler system sh
minimum guaranteed ultimate tensile force of the bars to be splice
coupler system shall develop the required tensile force without visi
2) **Slip Test** – The maximum allowed slip is 0.02 inch.
3) **Cyclic Tension Test** – No failure of the coupler system shall occur d
tests. The failure load in Stage 3 is for information only.
4) **Creep Test** – The residual tensile force of the coupler system shall l
minimum guaranteed ultimate tensile force to be spliced according to ASTM D7957.

PROPOSED BY: T-6 Fiber Reinforced Polymer Composites
VERSION: 2.0
DATE ORIGINALLY PREPARED: 07/21/2022
DATE REVISED: 07/20/2023

Background

Staged construction has been used for bridge construction projects to avoid full road closure. The construction method minimizes impact to traveling public. GFRP rebar is corrosion resistant and is a good alternative to stainless steel rebar. GFRP reinforcing bars meeting the requirements of ASTM D7957 and ASTM D8505 are commercially available, however availability of couplers to extend the bars for staged construction is lacking. Material and testing specifications for GFRP bar couplers are currently not available.

Scope of Current Work

Several GFRP bar manufacturers have developed GFRP bar couplers, however testing and acceptance criteria are not available. T-6 has worked with the industry to develop criteria based on applicable publications for metal couplers and the AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete 2nd Edition which only references ASTM D7957. For this initial phase, T-6 would like to focus on GFRP bar couplers for reinforced concrete bridge deck, which include #4, #5, and #6 bars. Once the GFRP bar couplers are successfully developed, couplers for larger size bars and for different applications will be further investigated. The testing criteria and acceptance are subject to change when coupler size and application are different from this initial phase of the coupler development.

Goals and Requirements

1) Factory-installed couplers onto GFRP bars are preferred.
2) For couplers installed at a construction site, installation of the couplers should be simple and reasonably quick.
3) The coupler system shall be corrosion resistant and last at least the target service life of the bridge deck.
4) The coupler system should allow the subsequent stage to be constructed within 6 inches from the previous stage.
5) Dimensions of couplers should not be longer than 24 inches and not be larger than 3 times the GFRP bar diameter.
6) When epoxy adhesive is used as part of the coupler system, the adhesive must have Evaluation

QUESTIONS ?

FOURTH INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 8-9, 2024 - Toronto, Ontario

Material Standards in FRP Concrete Reinforcement

Francisco De Caso, Ph.D., LEED A.P.

University of Miami

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Université de Sherbrooke NSERC CRSNG University of Miami Center for Integration of Composites into Infrastructure FDOT

Table of Contents

American Concrete Institute
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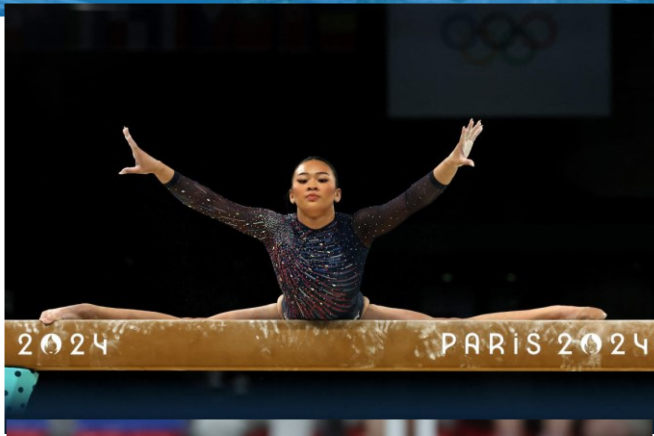
ASTM INTERNATIONAL

INTERNATIONAL CODE COUNCIL
ICC EVALUATION SERVICE

Preamble

- **Consistent Testing and Validation**
  - Establishes uniform procedures across the industry
  - Ensures reliable and reproducible results
  - Fair playing field
- **Material Performance and Safety**
  - Sets minimum performance criteria essential for durability and reliability
  - Enhances safety for both construction and long-term use
- **Code Compliance**
  - Integral for adherence to codes (IBC)
  - Facilitates approval and market entry for new products
  - Market stability



ICC-ES

- **ICC Develops the International Building Code (IBC)**
  - Current version: IBC 2021 → FRP not referenced
  - Next publication: 2024 → ACI 440.11 will be referenced
- **ICC-ES Develops Acceptance Criteria For IBC compliance**
  - Technical evaluations of building products, materials and systems for code compliance.
  - Material properties (for design and durability)
  - Quality Control
  - Traceability

ES ICC EVALUATION SERVICE®

ICC-ES Evaluation Report

ESR-[redacted]

Issued [redacted]

Subject to renewal May 2025

This report also contains:
- **LABC Supplement**
- **CBC Supplement**
- **FBC Supplement**

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DIVISION: 03 00 00—CONCRETE Section: 03 20 00—Concrete Reinforcing Section: 03 25 00—Composite Reinforcing	REPORT HOLDER: [redacted]	EVALUATION SUBJECT: FIBER-REINFORCED POLYMER WIRE MESH W1.4

1.0 EVALUATION SCOPE

Compliance with the following codes:
- 2021, 2018 and 2015 *International Building Code*® (IBC)
- 2021, 2018 and 2015 *International Residential Code*® (IRC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)†

†The ADIBC is based on the 2009 IBC. 2009 IBC code sections referenced in this report are the same sections in the ADIBC.

For evaluation of compliance with codes adopted by *Los Angeles Department of Building and Safety (LADBS)*, see ESR-4933 LABC and LARC Supplement.

Properties evaluated:
- Crack Control
- Physical

2.0 USES

The [redacted] Glass Fiber-Reinforced Polymer (GFRP) Wire Mesh W1.4 is used as an alternative to the shrinkage and temperature reinforcement specified in Section 24.4 of ACI 318-19 (2021 IBC) and ACI 318-14 (2018 and 2015 IBC) for plain concrete footings and for plain concrete slabs (as defined by ACI 360) supported directly on the ground.

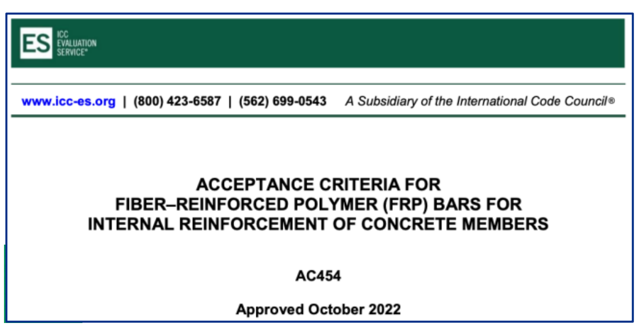
The [redacted] GFRP Wire Mesh W1.4 is also used as an alternative to horizontal temperature and shrinkage reinforcement in structural plain concrete walls covered in Section 1901.2 of the 2021 and 2018 IBC, Section

ICC-ES: FRP rebar relevant AC

- **AC454 (Structural applications)**
  - Approved in Oct. 2022
  - For Glass and Basalt FRP bars
  - Meshes not included
  - Includes alkaline exposure testing for durability
  - References ASTM D7975
  - References ACI 440.11-22

- **AC521 (Non-structural applications)**
  - Approved in Oct. 2020
  - Only for non-structural applications
  - For Glass and Basalt FRP bars and 'meshes'
  - No alkalinity exposure
  - specific test protocols for FRP meshes
  - No ASTM reference

- **AC552 (Couplers)**
  - Approved in Oct. 2023
  - FRP couplers only
  - Tensile Cyclic testing
  - References ASTM D7975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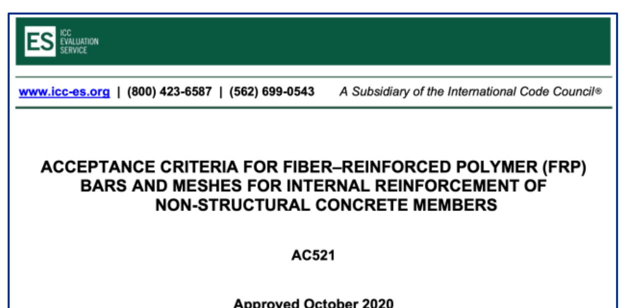
ACCEPTANCE CRITERIA FOR
FIBER–REINFORCED POLYMER (FRP) BARS FOR
INTERNAL REINFORCEMENT OF CONCRETE MEMBERS

AC454

Approved October 2022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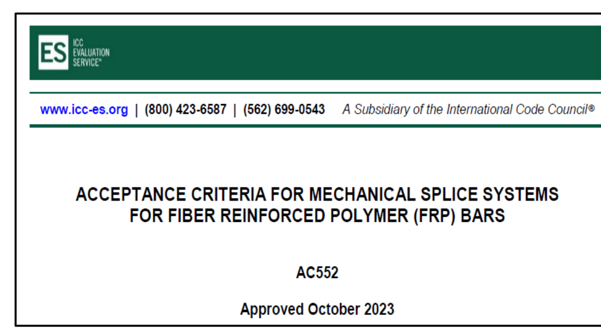
ACCEPTANCE CRITERIA FOR FIBER–REINFORCED POLYMER (FRP)
BARS AND MESHES FOR INTERNAL REINFORCEMENT OF
NON-STRUCTURAL CONCRETE MEMBERS

AC521

Approved October 2020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ACCEPTANCE CRITERIA FOR MECHANICAL SPLICE SYSTEMS
FOR FIBER REINFORCED POLYMER (FRP) BARS

AC552

Approved October 2023

ICC-ES

AC 454

ACCEPTANCE CRITERIA FOR FIBER–REINFORCED POLYMER (FRP) BARS FOR INTERNAL REINFORCEMENT OF CONCRETE MEMBERS (AC454)

TABLE 1—SUMMARY OF TESTS FOR FRP BARS*

PROPERTY	TEST OR CALCULATION METHOD
Fiber mass content	ASTM D2584
Mean glass transition temperature	ASTM E1640 (DMA) ASTM E1356 (DSC)
Mean total enthalpy of polymerization (resin)	ASTM E2160
Mean degree of cure	ASTM D2160
Mean measured cross-sectional area	ASTM D7205/D7205M ASTM D792
Guaranteed ultimate tensile force	ASTM D7205/D7205M
Tensile modulus of elasticity	
Guaranteed transverse shear strength (⊥ to the Bar)	ASTM D7617
Mean horizontal shear strength (of straight bar)**	ASTM D4475
Guaranteed bond strength	ASTM D7913
Mean moisture absorption (24 hours)	ASTM D570
Mean moisture absorption to saturation	
Mean alkaline resistance	ASTM D7705 (A or B)
Guaranteed ultimate tensile force of bent portion of bar	ASTM D7914
Tensile force of straight portion of bent bar; or mean horizontal shear strength (// to the bar) of straight portion of bent bar; and fiber mass content of bend portion	ASTM D7205 or ASTM D4475 and ASTM D2584

* Specimen selection and number of specimens shall comply with ASTM D7957.
** Test applicable to straight portion of bent bars, refer to Section 4.4.4.

AC 521

TABLE 1 — SUMMARY OF REQUIRED TESTS FOR FRP BARS AND MESHES

PROPERTY TO REPORT	TEST OR CALCULATION METHOD	NUMBER OF TEST SPECIMENS
Physical		
Fiber Content	ASTM D2584	For each bar/mesh size: total 24 (8 from 3 separate lots)
Mean Glass Transition Temperature	ASTM E1640 (DMA) ASTM E1356 (DSC)	Total 15: 5 from smallest, median and largest bar/mesh size each
Mean Total Enthalpy of Polymerization (Resin)	ASTM E2160	For the neat resin system: total 3
Mean Degree of Cure	ASTM E2160	For each bar/mesh size: total 9 (3 from 3 separate lots)
Mean Measured Cross-Sectional Area	ASTM D7205 ASTM D792	For each bar/mesh size: total 24 (8 from 3 separate lots)
Permissible Variation in Diameter (Mesh only)	Section 4.1.6	For each mesh size: total 24 (8 from 3 separate lots)
Mean Moisture Absorption to Saturation	ASTM D570 or ASTM D5229	For each bar/mesh size: total 24 (8 from 3 separate lots)
Mechanical		
Guaranteed Ultimate Tensile Force	ASTM D7205	For each bar/mesh size: total 24 (8 from 3 separate lots)
Mean Tensile Modulus of Elasticity	ASTM D7205	
Guaranteed Transverse Shear Strength (⊥ to the Bar)	ASTM D7617	
Mean Horizontal (Inter-laminar) Shear Strength	ASTM D4475	
Mean Ultimate Tensile Strain	Tensile Strength to Modulus of Elasticity Ratio	
Guaranteed Bond Strength (Bar only)	ASTM D7913	Total 15 (5 from smallest, median and largest bar size each)
Mean Shear Strength of Mesh Intersection (Mesh only)	ASTM A1064	For each mesh size: total 24 (8 from 3 separate lots)
Shrinkage Cracking	ASTM C1579	For each bar/mesh size: total 9 (3 from 3 separate lots)

ICC-ES

AC 552

TABLE 1—DESCRIPTION OF CYCLIC TENSION TESTS

STAGE	UPPER TENSION	LOWER TENSION	CYCLES
1	0.40 f_{fu}*	0.05 f_{fu}*	20
2	0.85 f_{fu}*	0.05 f_{fu}*	5
3	Load in tension to failure		

Note:
f_{fu}* is guaranteed tensile strength according to ASTM D7957.

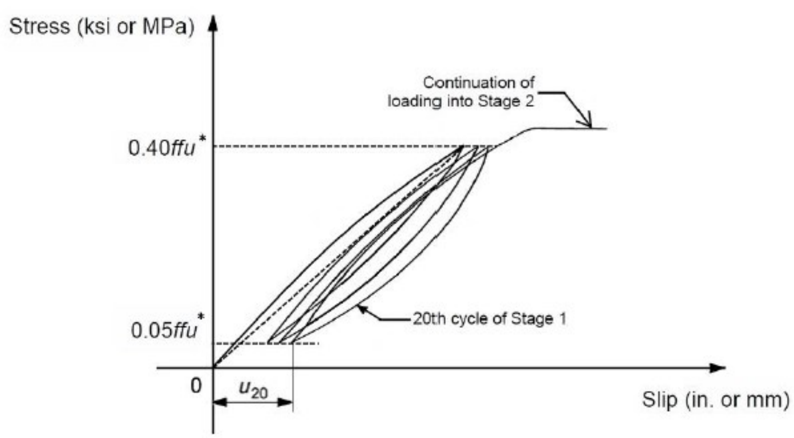


FIGURE 1 MEASUREMENT OF RESIDUAL SLIP DURING LAST CYCLE OF STAGE 1

ICC-ES – What is next?

- Inclusion of ASTM D8505
- Inclusion of ACI 440.1R-??
- Large diameter bars?
- Mesh classification
- Masonry:

Add TMS 402/602 references,
FRP Horizontal ladder

- Value added solutions:

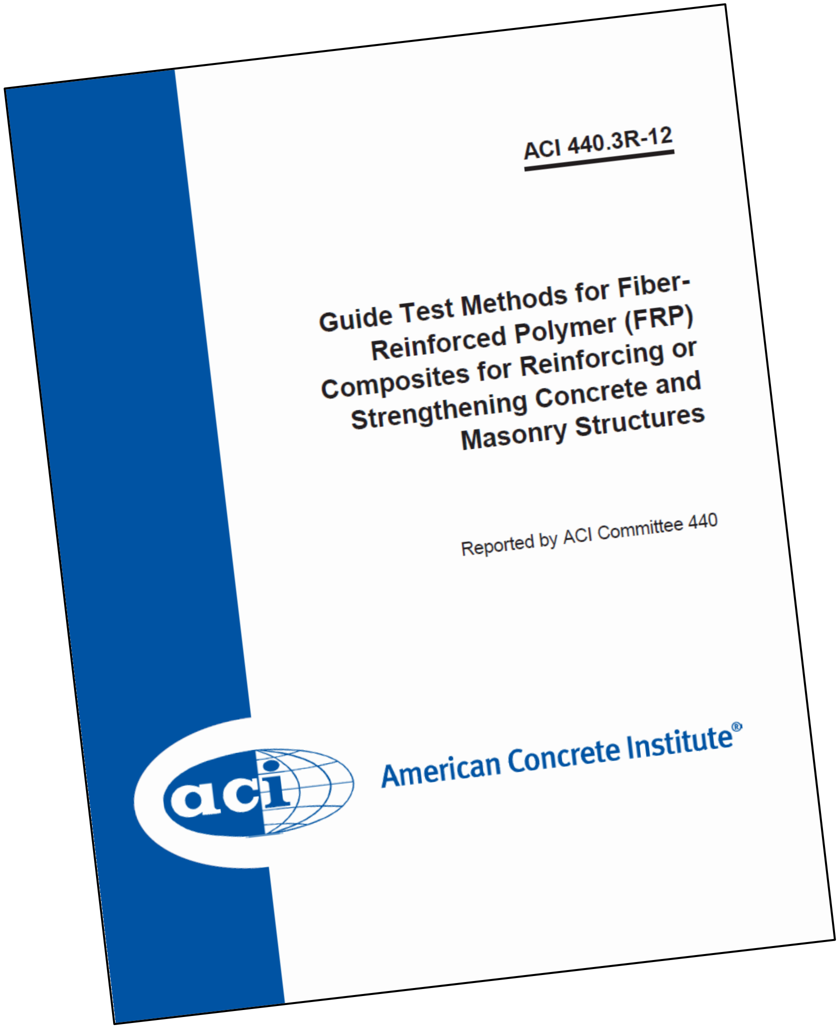
3D printed RC elements,
precast elements,

- Hybrid construction (Steel-FRP)

ACI (excluding CODE)

- **ACI 440K Sub-committee 'FRP-Material Characteristics'**
  - Defines characterization methods and testing protocols for FRP bars to be used within 440
  - 440.3R-12: Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures
  - Pipeline for ASTM D30.10
- **ACI 440H Sub-committee 'FRP-Reinforced Concrete'**
  - Expanding knowledge and state of art and practice
  - Design of RC related aspects
  - 440.1R-15 Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer (FRP) Bars
  - Inclusion of Basalt FRP
  - Pipeline for 440.11 CODE

ACI



ACI 440.3R-12

Guide Test Methods for Fiber-Reinforced Polymer (FRP) Composites for Reinforcing or Strengthening Concrete and Masonry Structures

Reported by ACI Committee 440

American Concrete Institute®

CONTENTS

NSERC CRSNG MIAMI FDOT

ACI


An ACI Standard

Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement

Reported by ACI Committee 440

Reapproved 2017

ACI 440.6-08(17)

American Concrete Institute
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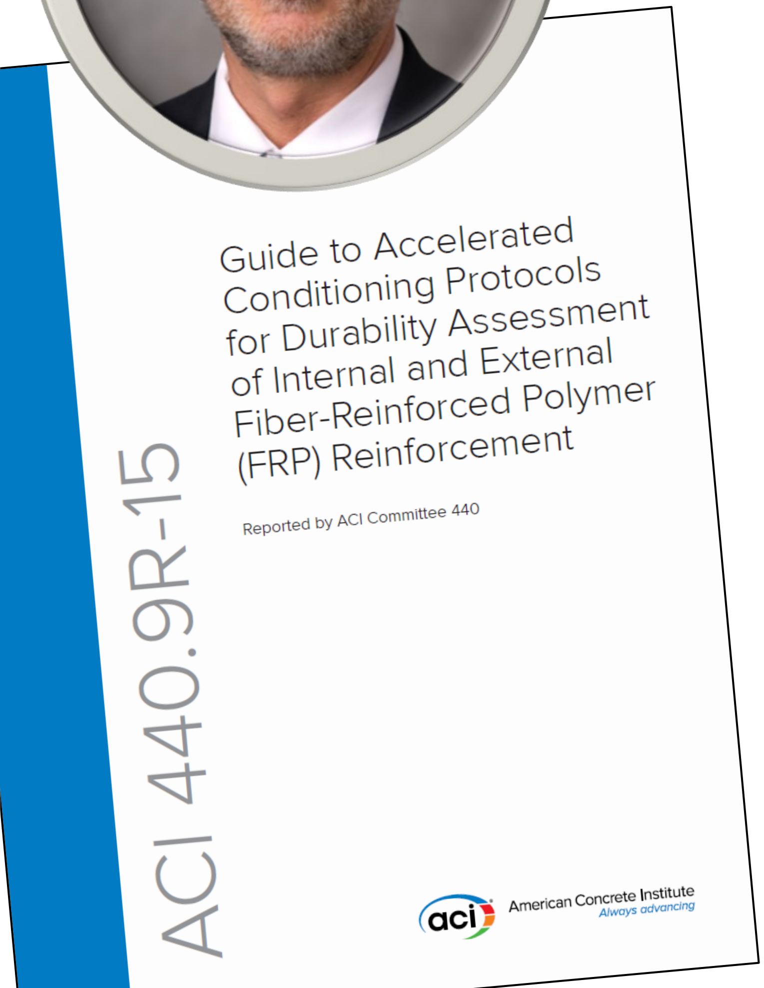
This Material Specification covers provisions governing testing, evaluation, and acceptance of carbon and glass fiber-reinforced polymer (FRP) bars used as reinforcement for concrete.

Keywords: carbon fiber; concrete; concrete construction; FRP reinforced concrete; fiber-reinforced polymer reinforcement; glass fiber; specification.

CONTENTS

ACI 440.6-08 was adopted April 30, 2008, and published June 2008.

- Obsolete as a document for Glass
- Replaced with ASTM D7957 fro GFRP



ACI 440.9R-15

Guide to Accelerated Conditioning Protocols for Durability Assessment of Internal and External Fiber-Reinforced Polymer (FRP) Reinforcement

Reported by ACI Committee 440

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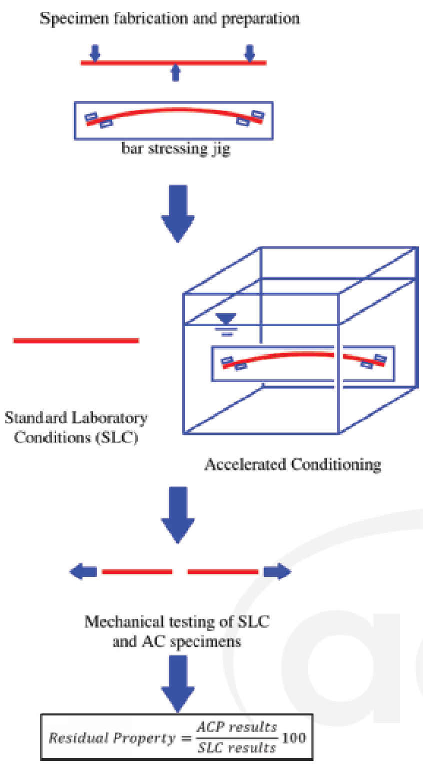
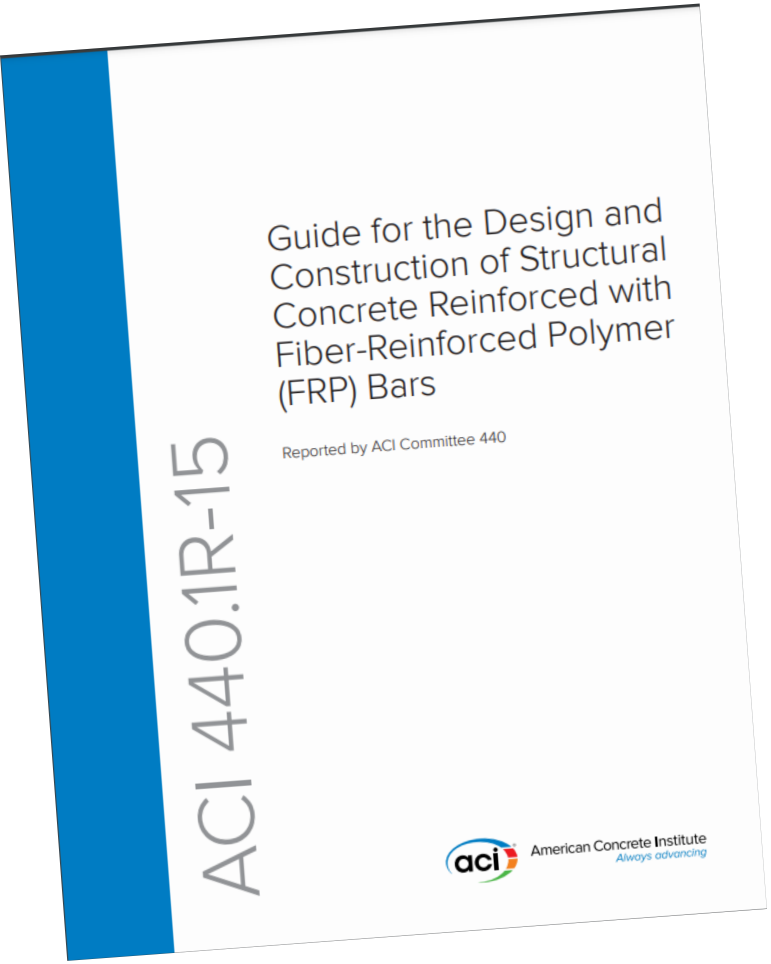


CONTENTS

- Potential to expand
- Mechanics of deterioration

ACI



- Inclusion of Basalt FRP
- Inclusion of ASTM D8505
- Expansion on design methods for shear
- Contribution of confinement
- Referenced used actively in Asia
- Relevant to non-building applications

ASTM

- **Subcommittee D30.10 Composites for Civil Structures**
  - Develops standard test methods, practices, guides, terminology, specifications for composites used in civil.
  - Works in tandem ACI subcommittee '440-K: FRP-Material Characteristics' to align standards and improve testing methods
  - Main FRP concrete reinforcement specifications:

Designation: D7957/D7957M – 22

Standard Specification for
Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation D7957/D7957M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

Designation: D8505 – 23

Standard Specification for
Basalt and Glass Fiber Reinforced Polymer (FRP) Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation D8505; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

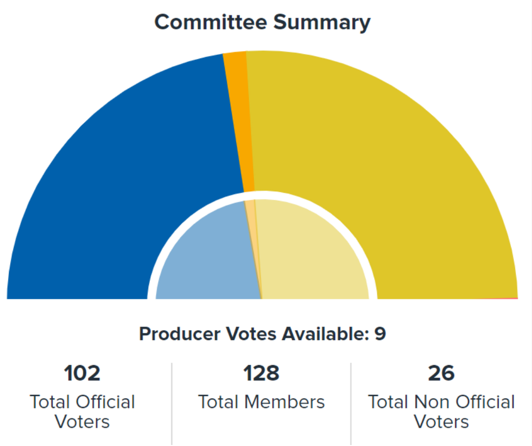
Designation: D8444/D8444M – 24

Standard Specification for
Fiber Reinforced Polymer Dowel Bars for Load Transfer Between Concrete Slabs[1]

This standard is issued under the fixed designation D8444/D8444M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ASTM

- **D30.10 Summary of activities**
  - x 15 ACTIVE Standards under D30.10
  - x 2 NEW Standards published in the last 12 months
  - x 6 NEW Standards UNDER DEVELOPMENT for ballot
  - x 3 existing Standards due to revision in the next 12 months, and many ballots revising existing standards.
  - ...several Standards in the pipeline for development



ASTM

- **ASTM D7957**
  - First ASTM for FRP Bars (2022)
  - Referenced in ACI 440.11-22
  - Covers only GFRP bars up to #10
  - Minimum modulus: 44.8 GPa
  - Alkaline durability ASTM D7705/D7705M, Procedure A
- **ASTM D8505**
  - Latest ASTM for high-modulus FRP bars (2023)
  - In the process of being adopted in ACI PRC-440.1R
  - Includes BFRP in addition to GFRP
  - Maximum bar size: #10
  - Minimum modulus: 60 Gpa
  - Alkaline durability: ASTM D7705/D7705M, Procedure A + Procedure B
  - MA: includes 24h MA
  - Includes apparent horizontal shear testing

ASTM D7957

TABLE 1 Property Limits and Test Methods for Qualification[A]

Property	Limit	Test Method
Mean Glass Transition Temperature	Midpoint temperature ≥100 °C [212 °F]	ASTM E1356
Mean Degree of Cure	≥95 %	ASTM E2160
Mean Measured Cross-Sectional Area	Table 3	ASTM D7205/D7205M, subsection 11.2.5.1
Guaranteed[B] Ultimate Tensile Force	Table 3	ASTM D7205/D7205M
Mean Tensile Modulus of Elasticity	≥44,800 MPa [6 500 000 psi]	ASTM D7205/D7205M
Mean Ultimate Tensile Strain	≥1.1 %	ASTM D7205/D7205M
Guaranteed[B] Transverse Shear Strength	≥131 MPa [19 000 psi]	ASTM D7617/D7617M
Guaranteed[B] Bond Strength	≥7.6 MPa [1100 psi]	ASTM D7913/D7913M
Mean Moisture Absorption to Saturation	≤1.0 % to saturation at 50 °C [122 °F]	ASTM D570, subsection 7.4
Mean Alkaline Resistance	≥80 % of initial mean ultimate tensile force following 90 days at 60 °C [140 °F]	ASTM D7705/D7705M, Procedure A
Guaranteed[B] Ultimate Tensile Force of Bent Portion of Bar	≥60 % of the values in Table 3	ASTM D7914/D7914M

[A]For the determination of the mean and guaranteed properties, at least 24 samples shall be obtained in groups of eight or more from three or more different production lots. The mean and guaranteed properties shall satisfy the limits.
[B]Guaranteed property is defined in 3.2.4.

ASTM D8505

TABLE 1 Property Limits and Test Methods for Qualification[A]

Property	Limit	Test Method
Mean Glass Transition Temperature	≥ 100 °C [212 °F] (DSC) ≥ 110 °C [230 °F] (DMA)	E1356 D7028
Mean Degree of Cure	≥ 95 %	E2160
Mean Measured Cross-Sectional Area	Table 3	D7205/D7205M, subsection 11.2.4.1
Guaranteed[B] Ultimate Tensile Force	Table 3	
Guaranteed Ultimate Tensile Strength	Report value	
Mean Tensile Modulus of Elasticity	≥ 60 000 MPa [8 700 000 psi]	D7205/D7205M
Mean Tensile Modulus of Elasticity (using measured Cross-Sectional Area)	Report value	
Mean Ultimate Tensile Strain	≥ 1.1 %	
Mean Transverse Shear Strength	≥ 152 MPa [22 000 psi]	D7617/D7617M
Mean Apparent Horizontal Shear Strength	≥ 37.9 MPa [5 500 psi]	D4475
Mean Bond Strength	Table 3	D7913/D7913M
Mean Moisture Absorption	≤ 0.25 % in 24 hrs. at 50 °C [122 °F], and ≤ 1.0 % to saturation at 50 °C [122 °F]	D570, subsection 7.4
Mean Alkaline Resistance	≥ 80 % of initial mean ultimate tensile force following 90 days at 60 °C [140 °F] ≥ 75 % of initial mean ultimate tensile force following 90 days at 60 °C [140 °F]	D7705/D7705M, Procedure A D7705/D7705M, Procedure B set an initial tensile strain equal to 3000 microstrain

[A] For the determination of the mean and guaranteed properties, at least 24 specimens (that is, test repetitions) shall be obtained in groups of eight or more from three or more different production lots. The mean and guaranteed properties shall satisfy the limits.
[B] Guaranteed property is defined in 3.2.2.

ASTM D8444

TABLE 1 Property Limits and Test Methods for Qualification[A]

Property	Limit	Test Method
Mean Glass Transition Temperature	≥100 °C [212 °F] (DSC) or ≥110 °C [230 °F] (DMA)	Test Method E1356 (DSC) or Test Method D7028 (DMA)
Mean Degree of Cure	≥95 %	Test Method E2160
Mean Measured Cross-Sectional Area	Table 3	Test Method D7205/D7205M, subsection 11.2.4.1
Mean Transverse Shear Strength	≥160 MPa [23 200 psi]	Test Method D7617/D7617M
Mean Apparent Horizontal Shear Strength	≥50 MPa [7250 psi]	Test Method D4475
Moisture Absorption in 24 h	≤0.25 % in 24 h at 50 °C [122 °F]	Test Method D570, subsection 7.4
Moisture Absorption to Saturation	≤1.0 % to saturation at 50 °C [122 °F]	
Alkaline Resistance	>80 % of the initial mean Apparent Horizontal Shear	Subjected to Test Method D7705/D7705M Procedure A for 90 days followed by Test Method D4475
Mean Bond Strength	Table 3	Annex A1

[A] For the determination of each of the property limits, at least 24 samples shall be obtained in groups of eight or more from three or more different production lots. The mean properties shall satisfy the limits.

TABLE 2 Property Limits and Test Methods for Quality Control and Acceptance[A]

Property	Limit	Test Method
Fiber Mass Content	≥70 %	Test Method D2584 or Test Method D3171
Glass Transition Temperature	≥100 °C [212 °F] (DSC) or ≥110 °C [230 °F] (DMA)	Test Method E1356 (DSC) or Test Method D7028 (DMA)
Degree of Cure	≥95 %	Test Method E2160
Measured Cross-Sectional Area	Table 3	Test Method D7205/D7205M, subsection 11.2.4.1
Transverse Shear Strength	≥160 MPa [23 200 psi]	Test Method D7617/D7617M
Apparent Horizontal Shear Strength	≥50 MPa [7250 psi]	Test Method D4475
Moisture Absorption in 24 h	≤0.25 % in 24 h at 50 °C [122 °F]	Test Method D570, subsection 7.4

[A] For the determination of each of the property limits, five random samples shall be obtained from each production lot. The mean value shall satisfy the property limits.

Gaps and Opportunities

- **What is next…?**
  - Low hanging fruit (active work):

- WK87882 Standard Specification for Carbon Fiber Reinforced Polymer (FRP) Bars and Strands for Concrete Reinforcement (Technical Contact: Francisco De Caso)
- WK88484 Standard Specification for Standard Specification for Basalt and Glass Fiber Reinforced Polymer (FRP) Mesh for Concrete Reinforcement (Technical Contact: Francisco De Caso)
- WK88485 Standard Terminology for Standard Terminology for Composite materials applied to Civil Engineering Structures (Technical Contact: Francisco De Caso)

  - Adding precision statements to test standards
  - Bendable bars
  - Expand resin specifications (work partly supported by NEx Project # P0056-RD24.02 Material Specifications to Implement Polyolefin Resins for use in FRP Rebar Applications

NEx™ An ACI Center of Excellence for Nonmetallic Building Materials

NSERC CRSNG MIAMI FDOT

Conclusions

- Material characterization/testing standards exist for FRP: mainly developed by ASTM
- Acceptance criteria for FRP: ASTM D7957 & D8505 and ICC-ES AC 454 & 521
- Design code for FRP: ACI 440.11-22
- The current IBC (2021) does not reference 440.11 but the next version (2024) will
- Constant progress by ASTM, ACI and ICC-ES to improve and update codes/standards

The FRP Institute

Founded in 2022, we are an unbiased source of technical information based on consensus standards, focused on practical implementation, design advice and training, third party qualification and oversight, plant certification and independent quality assurance testing.

Our Mission

- Sharing of information on new technology
- Work toward standardization of material acceptance practices
- Advocacy of technologies that will facilitate more efficient data sharing and data transfer

WHO WE ARE

FRP INSTITUTE

WHO WE ARE

FRP Institute Leadership Team

CEO

Richard Krolewski

Founder, Regulatory Resources

Chairman, Advisory Board

Cabell Garbee, P.E.

Manufactured Products Engineer
Materials and Tests Unit
North Carolina Department of Transportation

Lead Auditor

Rudi Seracino, Ph.D., F.ACI, F.IIFC

Professor of Structural Engineering
North Carolina State University

Chairman, Technical and QC

Joseph Stilwell, P.E.

FRP/Composites Subject Matter Expert
U.S. Army Corps of Engineers Inland Navigation Design Center

Codes and Standards

Matt Chynoweth, P.E.

Vice President/National Bridge Discipline Leader
RS&H

FRP INSTITUTE

WHAT WE DO

PLANTS AUDITED 2024

EDUCATIONAL SESSIONS

Date TBD: Texas Department of Transportation
Date TBD: **Maryland Department** of Transportation **State Highway** Administration
Oct. 29: California Department of Transportation
Sept. 16: Hawaii Department of Transportation (2nd training)
July 18: Ohio Department of Transportation
June 10: Virginia Department of Transportation
April 19: Hawaii Department of Transportation
April 4: Pennsylvania Department of Transportation
Nov. 30: North Carolina Department of Transportation
Nov. 8: New Jersey Department of Transportation
Oct. 20: Michigan Department of Transportation
Feb. 15: California Department of Transportation

WHAT WE DO

QPL/MPL

Work with DOT's to streamline approvals regarding QPL/MPL

MATERIAL VERIFICATION

The auditing program established by the FRP Institute is expected to accelerate DOT acceptance of FRP materials

EDUCATION/OUTREACH

Develop and conduct technical education courses for DOT personnel, engineering firms and manufacturers and build awareness and support for FRP usage in civil infrastructure

M337 SPECIFICATION

The FRP Institute has been tasked by AASHTO Specialized Structures to lead the effort in establishing a consensus standard in the industry through an update of the M337 specification

FRP INSTITUTE

WHAT WE DO

AASHTO REPRESENTATION

The FRP Institute continues to foster a close relationship with AASHTO

Richard Krolewski, FRP Institute CEO, serves as an Industry Representative on the Composite Concrete Reinforcements (CCR) Technical Committee for manufacturing audits of Fiber Reinforced Polymer products.

He represents all manufacturers of products that are covered in the CCR Technical Committee GFRP Work Plan.

FRP INSTITUTE

NORTH CAROLINA
Department of Transportation

AASHTO Product Evaluation and Audit Solutions

Composite Concrete Reinforcements (CCR) Overview

W. Cabell Garbee, II, PE

NCDOT Manufactured Products Engineer

CCR Technical Committee Chair

August 2024

AASHTO
Product Evaluation & Audit Solutions

- *Formerly:*
  National Transportation Product Evaluation Program (NTPEP)

  AASHTO Product Evaluation & Audit Solutions Program combines the professional and physical resources of the AASHTO member departments in order to **evaluate materials, products, and devices of common interest for use in highway and bridge construction.** The primary goal of the program is to **provide cost-effective evaluations** for the State DOTs by **eliminating duplication of testing and auditing** by States and duplication of effort by manufacturers that provide products for evaluation.

  24 Technical Committees
  42 States Participated at the 2023 Annual Meeting

  https://transportation.org/product-evaluation-and-audit-solutions/

CCR Committee

June 2024 Annual Meeting

Membership

- Matt Bluman, AASHTO Liaison
- Cabell Garbee, North Carolina DOT Chair
- Steve Nolan, Florida DOT Vice Chair
- Representatives from 18 State Departments of Transportation (DOT)
- Four Manufacturers
- Testing Facility and Auditors
  - Contracted to AASHTO
- Industry Association
  - FRP Institute
- Note
  - State DOT each have a voting member, all other members are non-voting

Composite Concrete Reinforcements (CCR)

Timeline

- 2021/2022 Task Force and Committee
  - Judge Interest, Develop Workplan
- 2023/2024 Committee
  - Work Plan Approved
    - Participating Materials
      - Glass Fiber Bars
      - Basalt Fiber Bars (upcoming 2024)
      - Carbon Fiber Strands (upcoming)
    - Facility Required Components
      - Quality Management System
      - Facility Audit
      - Sampling and Testing

Quality Management System

Minimum Components

- Quality Manual
- Standard Specifications
- Training and Competency Evaluation Records
- Equipment Calibration Records
- Certificates of Analysis
- Raw Material Test Results
- Product Physical Test Results

Annual Facility Audits

Components

- Yard Inspection
- Manufacturing Process Evaluation
- Review of AASHTO/ASTM Test Methods
- Demonstration/Observation of Quality Control Tests
- Traceability of Final Product
- Collection of Split Samples for Third Party Testing

Four Audits performed in 2023

Sampling and Testing

Minimum QMS Requirements

Measurement/Test	Frequency: Minimum	Test Methods
Fiber Mass Content	Once per Lot	ASTM D2584
Glass Transition Temperature	Once per Lot	ASTM E1356
Ultimate Tensile Force	Once per Lot	ASTM D7205
Tensile Modulus of Elasticity	Once per Lot	ASTM D7205
Ultimate Tensile Strain	Once per Lot	ASTM D7205
Moisture Absorption (24hr)	Once per Lot	ASTM D570
Transverse Shear Strength	Once per Lot	ASTM D7617
Cross sectional Area	Once per Lot	ASTM D7205
Degree of Cure	Once per Lot	ASTM E2160
Alkaline Resistance*	Annually (one lot, #5 or #6 bar)	ASTM D7705 Pro.A
Bond Strength	Annually	ASTM D7913
Horizontal Shear	Once per Lot	ASTM D4475

Sampling and Testing

Audit Split Samples

Product Test Property	Test Methods
Ultimate Tensile Force	ASTM D7205
Tensile Modulus of Elasticity	ASTM D7205
Ultimate Tensile Strain	ASTM D7205
Transverse Shear Strength	ASTM D7913
Cross sectional Area	ASTM D7205
Horizontal Shear Strength	ASTM D4475

Manufacture Retainage for Audit

25 Different Lot Samples, Five 80” bars each lot

Audit Sample Obtained from Retainage

3 Different Lot Samples, Five 80” bars each lot

AASHTO Website

Datamine (restricted access)
- Audit Reports
- Sample Test Reports

Industry Document Repository (restricted access)
- Technical Information
  - Physical/Design Properties
- Environmental Product Declaration
- Buy America/BABA Documentation

Program Information
- https://transportation.org/product-evaluation-and-audit-solutions/

Questions?

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