2020 FDOT-FRP Industry 4th RC/PC Workshop

August 4th, 2020

GoToMeeting

Workshop Outline


NW 23rd Ave / Ibis Waterway bridge replacement soldier pile retaining walls (City of Lighthouse Point, 2020)


Secant-pile bulkhead rebar cage installation (Flagler Beach, 2019)


Sunshine Skyway Rest Area seawall rehabilitation and extension (Tampa Bay, 2020)

Previous Participants/Collaborators

ACMA American Composites Manufacturers Association
Owens Corning
ATP construction composites
mafic
pultron composites
TUF-BAR
CMTE
MIAMI
Tokyo Rope Mfg. Co., Ltd.
UNF University of North Florida
UF University of Florida

Guiding Principles & Goals

- Stewardship
- Confidence
- Competence
- Consistency
- Codification


BFRP & GFRP-FRC link-slab construction (Port Charlotte, 2020)

2020 FDOT-FRP Rebar Industry 4th Workshop

(online)

Safe Deployment of FRP-RC/PC for Structural Reinforcement of

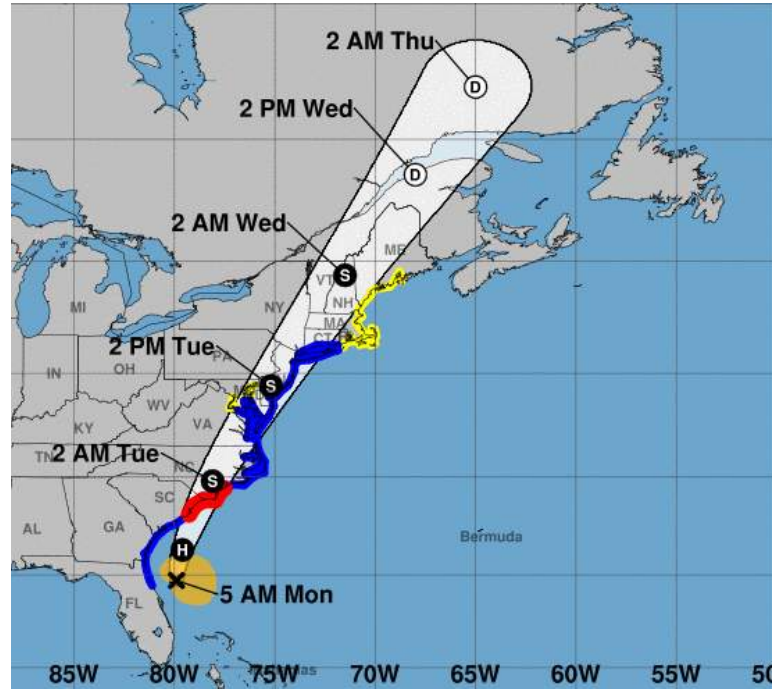
** *August 4, 2020 (9:30am-2:30pm EDT)* **


GFRP bars and spirals for secant-pile seawall (Flagler Beach, 2019)

Preface

- Following up on a successful ***FRP-RC Workshops*** initiated in Daytona Beach in 2016, then at the Florida Turnpike Enterprise HQ in 2017 & 2018, and in continual support of FDOT's ***Invitation to Innovation*** initiative for Fiber Reinforced Polymer (FRP) Reinforcing Bars and Strands, FDOT's State Structures Design Office is hosting the 4th ***FRP-Reinforced Concrete Workshop*** to be held again at the Florida Turnpike Headquarters in Orlando, Florida. The workshop is critical for advancing the practical implementation of design and material criteria to get the most benefit from these newer materials. The workshop aim is to collaborate with design practitioners, FRP Industry producers and academia for FDOT structural items of interest.
- The workshop will be held virtually due to the current COVID-19 pandamic using the GoToMeeting platform, with no registration fee.
- Industry attendees are encouraged to review the previous workshop webpages and the distributed ***Strategic Workplan*** that has been updated since the 2018 Workshop:
  - 2016 1st Workshop webpage link *(Daytona Beach – Design Expo)*
  - 2017 2nd Workshop webpage link *(Orlando-FTE)*
  - 2018 3rd Workshop webpage link *(Orlando-FTE)*

Florida Yesterday



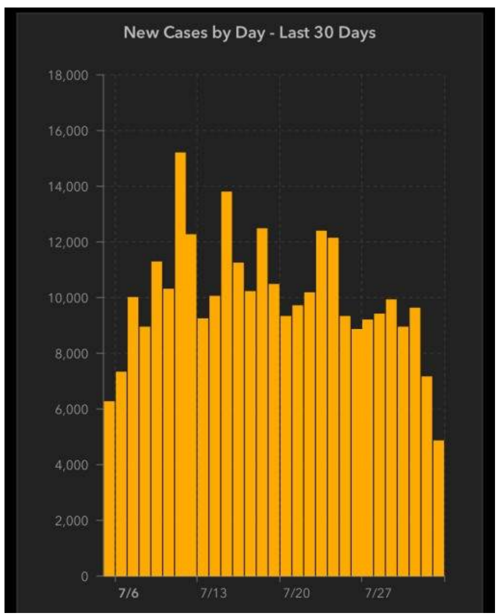
Current Situation in Florida

as of Mon 8/3/2020 10:34:45 AM EST

Positive Residents
486,384

Positive Non-Residents
5,500

Total Cases
491,884
4,866 New Cases in FL Residents



FLORIDA COVID-19 RESPONSE

Florida HEALTH

Mon 8/3/2020 10:34:45 AM EST

See latest data >

Take the community survey >

Select state-supported testing sites that will be impacted by Hurricane Isaias will be closed July 30 and reopen August 5.

Testing sites in Charlotte, Escambia, Hillsborough, Lake, Lee, Leon, Manatee, Okaloosa, Pasco, Pinellas, Polk and Sarasota will remain open

EVERY TRIP BUCKLE UP EVERY TIME


Protect
the vulnerable
Wash
your hands
Practice
social distancing
Wear
a mask
ONE GOAL ONE FLORIDA
GOVERNOR RON DESANTIS
TEXT "FLCOVID19" TO 888-777

GoToMeeting

4th FDOT/FRP Industry Reinforced/Prestressed Concrete Workshop (Part A)

Tue, Aug 4, 2020 9:30 AM - 12:00 PM (EDT)

https://global.gotomeeting.com/join/360067229

You can also dial in using your phone. United States: +1 (786) 535-3211

Access Code: 360-067-229

4th FDOT/FRP Industry Reinforced/Prestressed Concrete Workshop (Part B)

Tue, Aug 4, 2020 1:15 PM - 2:45 PM (EDT)

https://global.gotomeeting.com/join/412187349

You can also dial in using your phone. United States: +1 (872) 240-3412

Access Code: 412-187-349

Welcome and Introduction of topics

1. Objective of Workshop:
   - *Gain industry consensus on immediate changes to specs and standards for 2021*

2. Deliverables from Workshop:
   - *Update FDOT FRP-RC Strategic Workplan*

Agenda - Part A

9:30 - 9:45am: Welcome and Introduction of topics

a. Objective of Workshop
b. Deliverables from Workshop

9:45 – 10:55: Presentations – Current State of Activity

a. **Design** *(Vasconcelos)*
   - FDOT FRP-RC/PC Design implementation status & needs
b. **Durability and Endurance Testing** *(Knight & Fallaha)*
   - FDOT Materials Office update on durability focused research projects
   - Endurance Testing needs
c. **Other State DOT activity** *(Hartman)*
d. **Standards/Specifications**
   - ***ASTM D7957-17*** potential updates for mechanical property improvement *(Gremel)*
   - ***ACI Committee 440*** related activities *(Nanni)*
e. **Rebar Industry** *(Busel)*
   - ***ACMA FRP-RMC*** update ***Imagine Act*** progress
f. **Industry Accreditation Pathways** *(Krolewski)*
g. **International perspectives** *(Benmokrane, Manalo, & Ferrier)*

**** Coffee Break (5 mins) ****

11:00 - noon: Next Level of Activities based on Needs – *Moderated Discussion*

h. **Construction Issues** *(Nolan)*
   - *FDOT Construction related issue from recent projects & needs*
i. **Bar Properties *(Strategic Workplan Item #3)***
   - FDOT 2021 proposed increase in Elastic Modulus and Tensile design limits for ***FDOT Specification 932-3***
   - What to do about Bent Bars, at least for the intermediate future?
j. **Project level testing**
   - How much and how to pay for it?
k. **Barriers to seamless deployment**
   - Lifting hardware, couplers, splicing, replacement of damaged bars

Noon - 1:15pm: Lunch

Presentations
- Current State of Activity

a. **Design** *(Vasconcelos)*
b. **Durability and Endurance Testing** *(Knight & Fallaha)*
c. **Other State DOT activity** *(Hartman)*
d. **Standards/Specifications**
    1. ***ASTM D7957-17*** updates for mechanical property improvement *(Gremel)*
    2. ***ACI Committee 440*** related activities *(Nanni)*
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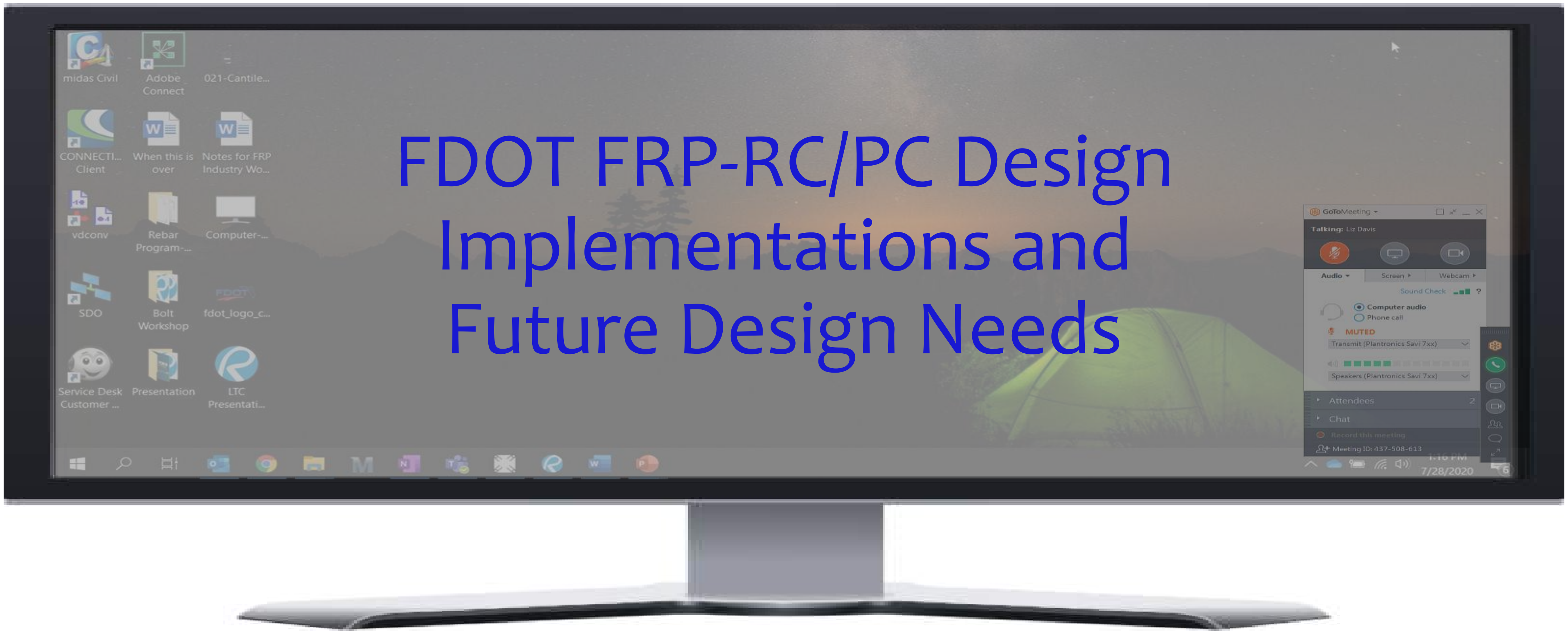
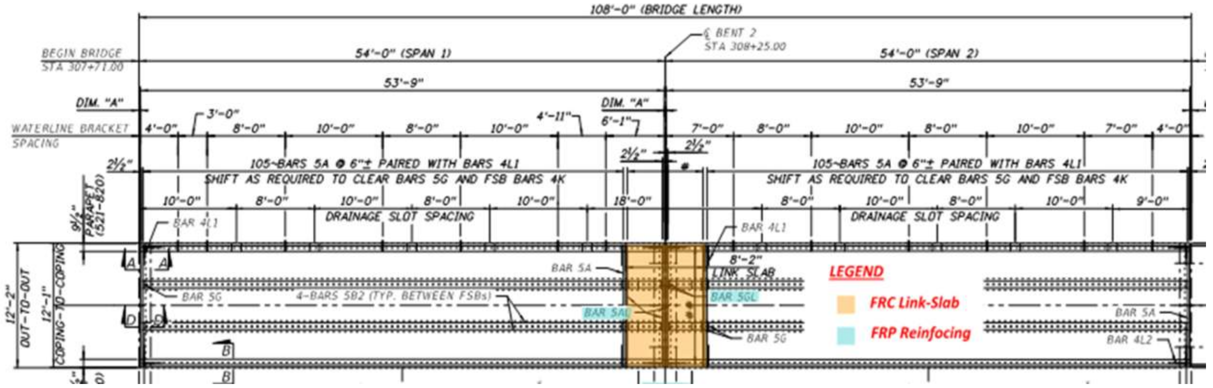
FDOT FRP-RC/PC Design Implementations and Future Design Needs

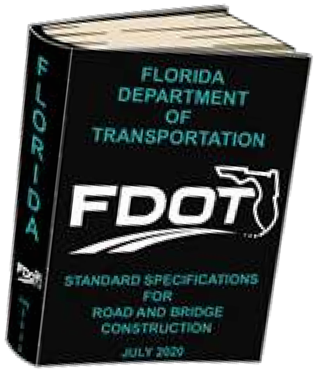


Bruno Vasconcelos - FDOT

Quick Outline:

- Projects (2018-present)
  - Use of many FRP products
- Specifications
  - Always a work in progress
- Design Needs
  - Some current challenges
- Construction Issues
  - Cost and learning curve

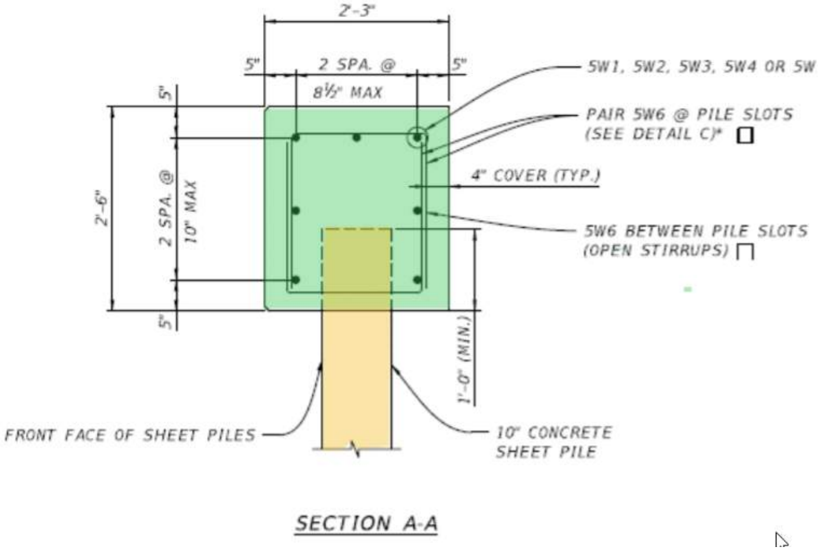




Projects

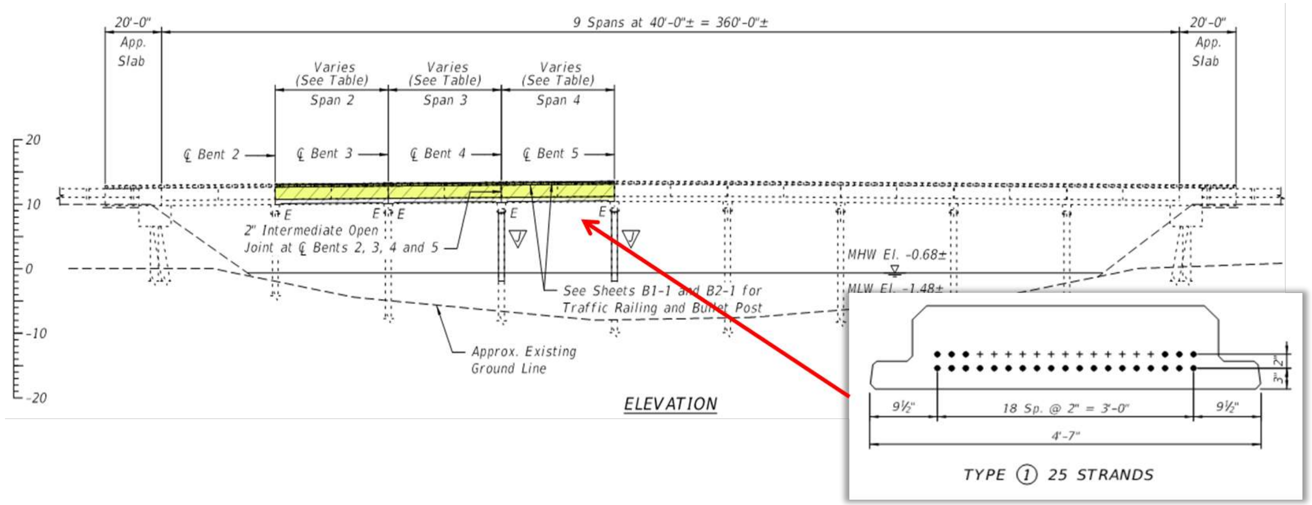
- Seawalls & Bulkheads
  - SR-A1A Flagler Beach Seawall
  - SR-30 over St. Joe Inlet
  - Sunshine Skyway Rest Area and Seawall Rehabilitation

- Pile Bent Cap
  - South Maydell Dr. over Palm River

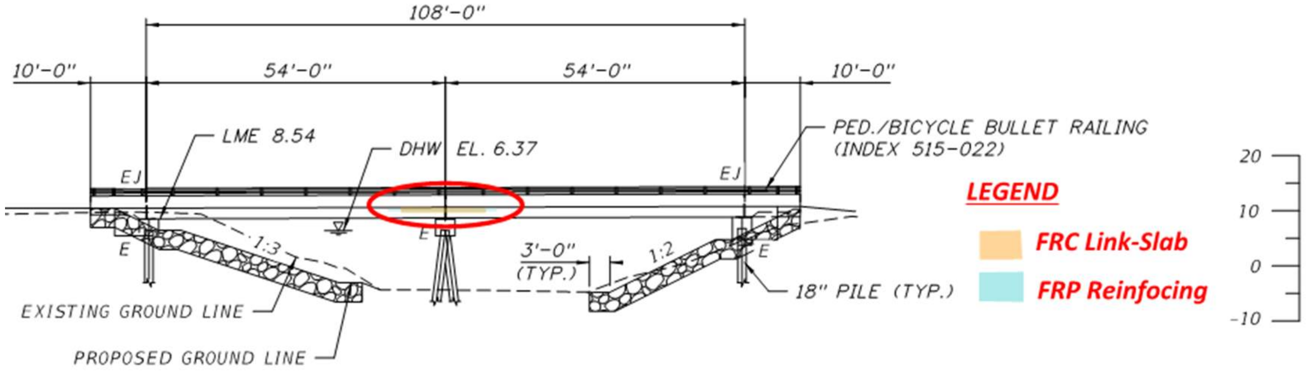


Projects

- FSB Bridges
  - US1 over Cow Key Channel →
  - 40th Ave NE over Placido Bayou

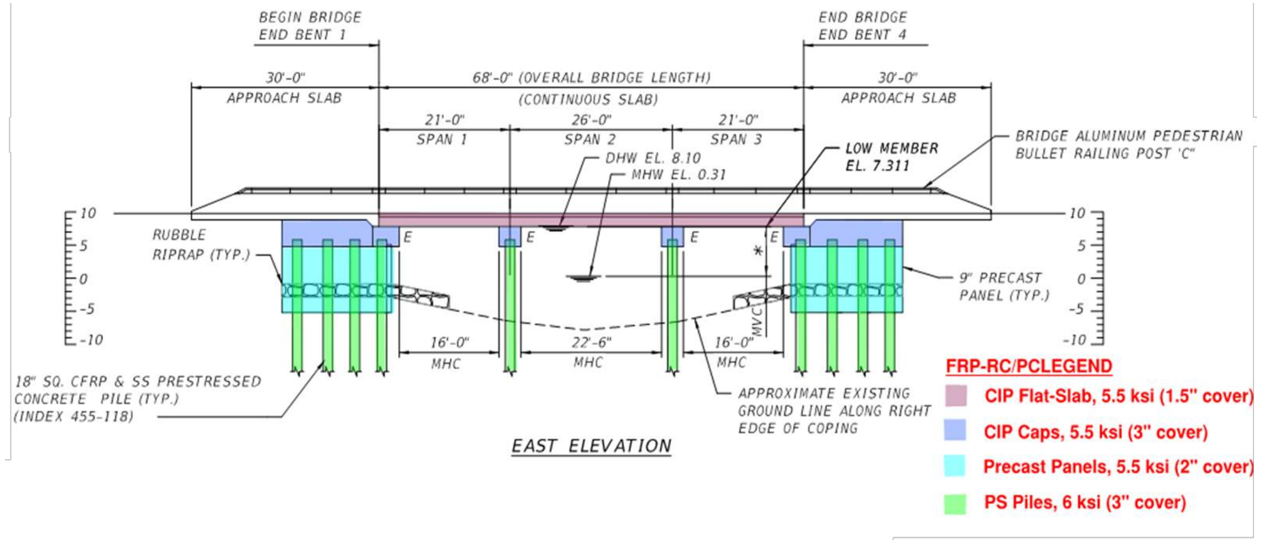


- Link Slab Bridges
  - SR-A1A over Myrtle Creek and Simpson Creek
  - SR-5 (US41) over Morning Star and Sunset Waterways

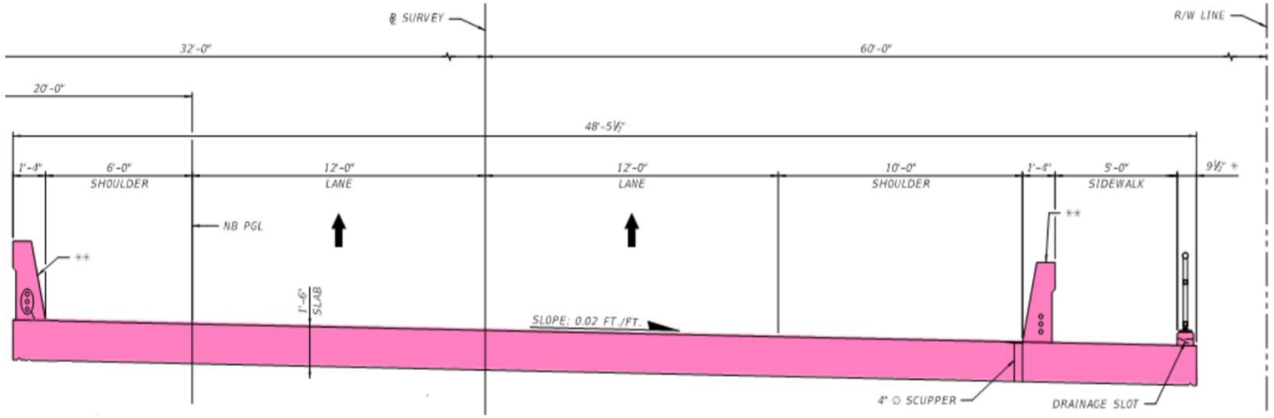


Projects

- Flat Slab Bridges
  - NE 23rd Ave. over Ibis Waterway

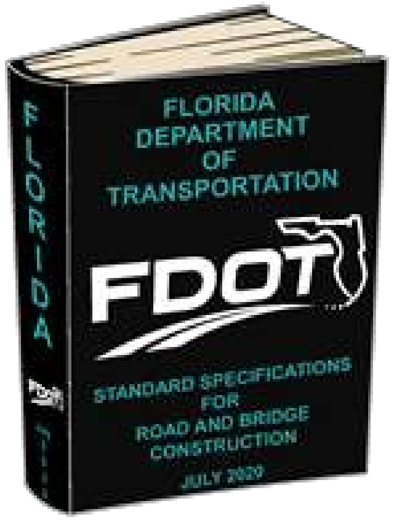


  - SR-45 (US 41) over North Creek



Specifications

- Bulkhead Caps – Eliminated project LOT testing in Section 932-3 of the Jan 2020 Spec Book
- Added **basalt fiber** as an equivalent to GFRP in Section 932-3 of the July 2020 Spec Book
- Increased **Min. Tensile Strength for 7-wire CFRP** in Section 933 of the July 2020 Spec Book



Design Needs

- Shear Design for slabs
  - Challenges stem from the 0.004 strain limit
  - Creates a need for tight stirrup spacing
  - Higher elastic modulus would help
- Coupling for Phase Construction
  - Not all construction can be completed in one go
  - Rebar couplers for decks and end bents

Construction Needs

- Unit Costs for GFRP are very high for small quantities
  - Presumably due to project testing requirements
- Many contractors do not understand lead times
- Modulus can improve GFRP competitiveness vs. other Corrosion Resistant Reinforcement
- Adhesive anchor issues, especially with bent bars

FDOT

Thank you!

Contact: Bruno Vasconcelos
Central Office Structures Design
bruno.vasconcelos@dot.state.fl.us

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Other State DOT Activity

Dave Hartman - Owens Corning

ODOT Activity

ODOT GFRP Specifications – January 2020 ODOT/GFRP Industry Meeting

- C&MS 509 Construction specifications based on ACI 440.5-08
- C&MS 705.28 Material specifications based on ASTM D7957 with the elastic modulus >8700 ksi (60 GPa), tensile strain >1.4%, guaranteed ultimate tensile force ASTM D7957 Table 3 +25%
- Supplement SS-1138 "GFRP Certification Program" for suppliers, as an alternative to Reinforcing Steel, GFRP reinforcement is also certified

ODOT Bridge Design Manual GFRP Design Tables – July-Sept 2020

- BDM will incorporate GFRP design specifications AASHTO approved
- Design focus on serviceability of GFRP-RC
- Traditional strip method with 1:1 substitution of steel rebar desired
- Interest in a GFRP database module for AASHTO-Ware used in bridge design and rating with certification to codes and standards

ODOT Activity

Bridge Flat Slab - bridge decks, approach slabs, and slab bridges

- Anthony Wayne Trail Bridge, I-475 Dorr St, and Hill St Overpass are examples of recent bridge projects in Ohio
- ODOT realized benefits of GFRP utility in flat slabs using VECP engineered solutions, design policy evolving to an owner decision in Scope of Services agreement.
- "made in America" GFRP alternative to epoxy steel

Anthony Wayne Trail Bridge

Learnings:

Need mechanical splice coupler for phased construction:

- ODOT approved list with specification to ASTM A1034 using guaranteed properties of C&MS 705.28
- Splice sample verification testing at the project level

Need GFRP detectability with Ground Penetrating Radar

Need GFRP field repair-ability guidance

I-475 Dorr St Overpass

ODOT Activity

Traffic Barriers

- ODOT previously specified GFRP dowel as a non-structural element at location of deflection joint saw-cuts. The new GFRP CM&S permitted use of GFRP rebar for longitudinal reinforcement in concrete barriers.
- In January 2020 ODOT released new drawing SBR-1 for traffic barrier standards requiring use of high modulus 60 GPa (8700 ksi) GFRP Rebar as the horizontal and stiffening reinforcement in 42" bridge railing or parapets meeting MASH TL-4 or TL-5.

- In July 2020 ODOT released SBR-2 drawing standards for use of GFRP horizontal and stiffening reinforcement in 57" tall median traffic barriers, single slope MASH TL-3 and double slope meeting MASH TL-5.
- In July 2020 ODOT released SBR-3 drawing standards for use of GFRP in 36" tall single slope bridge railing concrete barriers used off system.

VDOT Activity

Bridge Abutments

Approach:

- Design build projects for GFRP value engineering alternative to MMFX stainless steel concrete reinforcements
- GFRP demonstration projects with bridge slab and abutment
- Following FDOT and ODOT FRP RC/PC progress and learnings

Learnings: (VDOT, other State DOTs)

- Need GFRP complex bent bars capability to substitute stainless steel
- Interest in FRP pre-stressed concrete
- Strong support for improvements in GFRP codes & standards of design factors, material specifications, service life classification

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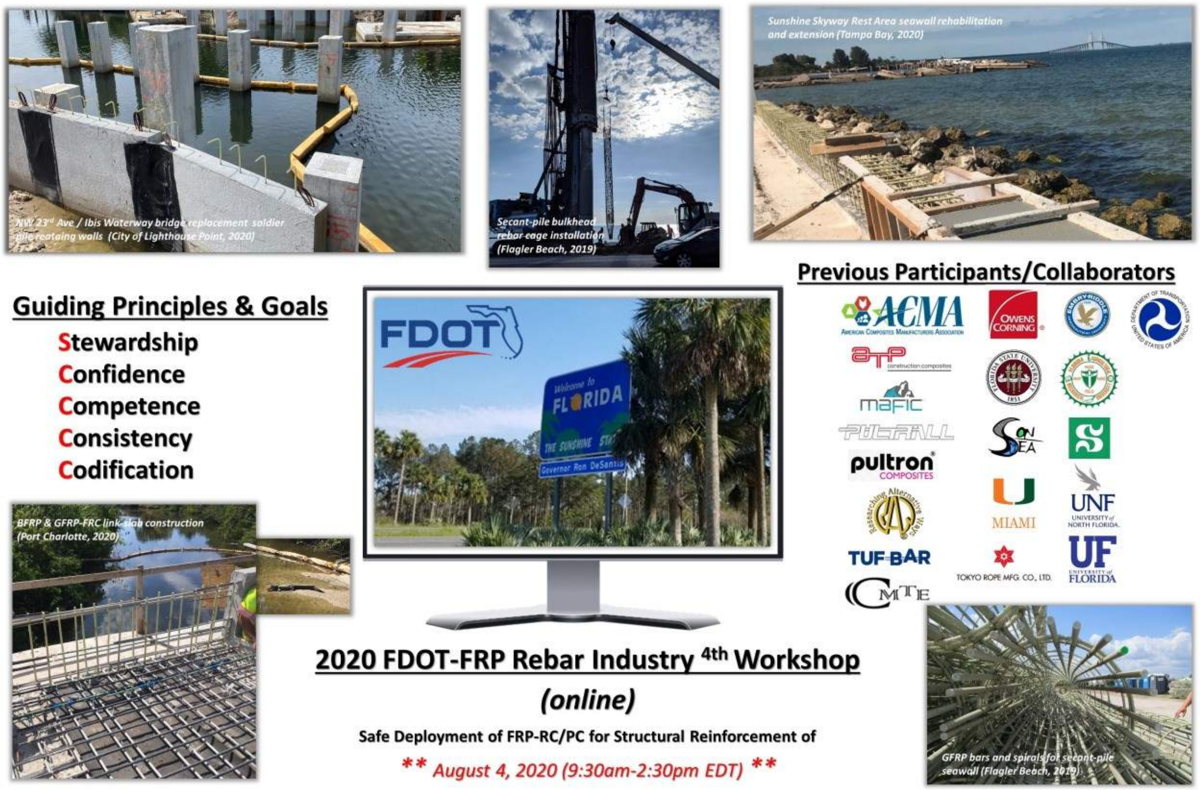
Other State DOT Activity



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Learnings: (VDOT, other State DOTs)

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- Interest in FRP pre-stressed concrete
- Strong support for improvements in GFRP codes & standards of design factors, material specifications, service life classification

ASTM Hi-Mod GFRP rebar standard(s)

Under purview of ASTM D30.10

D30.10 Co-Chairs asked industry to "work it out" prior to formal balloting

Industry discussions under the venue of FRP-Rebar Mfgrs Council

Then to D30.10 balloting for more broad audience

Allows industry to work out its differences on details, limits, tests to be performed etc

2 New Documents being drafted

- Hi-Mod Straight bars with modulus of 8.75 msi (60GPa)
- Hi-Mod Fabricated bends with modulus of 7.5msi (52GPa)

- Processes are different for most producers
- Physical & mechanical properties are different

- Highlights differences to the Designer

Hi-Mod Straight Bar draft

INTERNATIONAL Designation: DXXXX/DXXXXM –

Date:	<Enter Date>
To:	Subcommittee <AXX.XX> or Main Committee <AXX> members (both for concurrent ballots)
Tech Contact:	<Contact Name, email address/phone number>
Work Item #:	<Enter Work Item number>
Ballot Action:	Revision of <Enter Standard Designation/Title>
Rationale:	<Enter reasons for proposed ballot action. Include an update on previous ballot history, if applicable>

Standard Specification for
Solid Round, High Modulus Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement in Straight Lengths[1]

- Key Differences with ASTM D7957
  - Limits are higher for tensile modulus
  - Increased limits on tensile properties
  - Removes all references to bends (helps provide clarity)
  - Thermoset resins allowed as long as they meet durability requirements
  - Better resolution on bond strength & strain by bar diameter
- Similarities with ASTM D7957
  - Uses same “measured area” tolerances as existing ASTM D7957
  - Limits on Tensile strength & other parameters mirror CSA S807

Hi-Mod Fabricated Bent Bar draft

INTERNATIONAL Designation: DYYYY/DYYYYM –

Date:	<Enter Date>
To:	Subcommittee <AXX.XX> or Main Committee <AXX> members (both for concurrent ballots)
Tech Contact:	<Contact Name, email address/phone number>
Work Item #:	<Enter Work Item number>
Ballot Action:	Revision of <Enter Standard Designation/Title>
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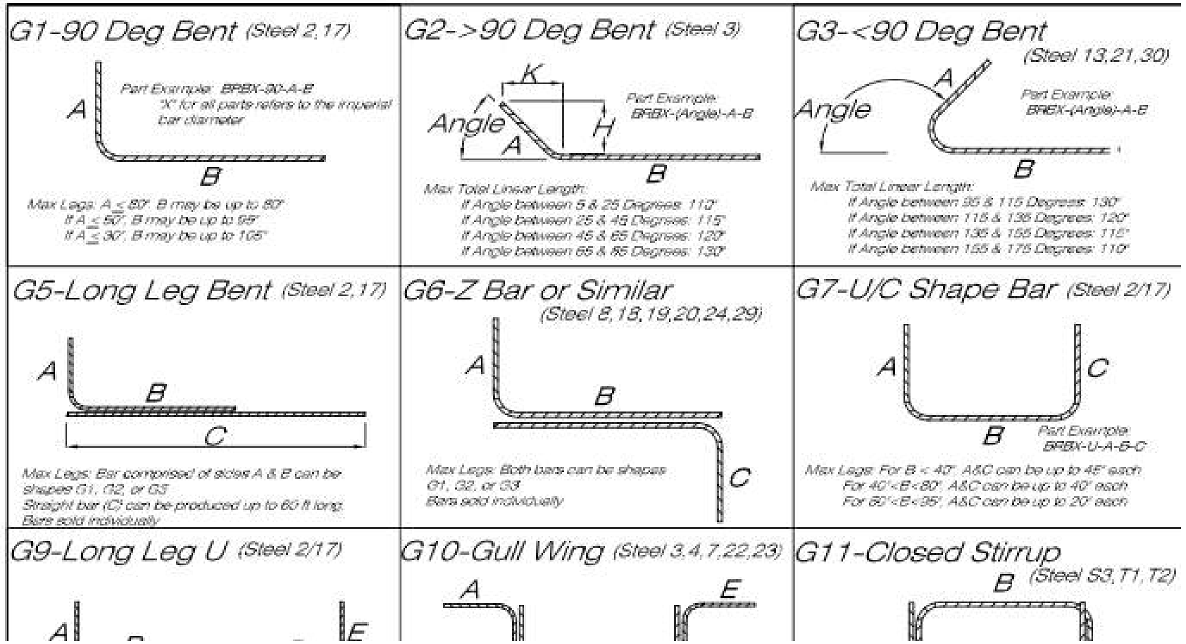
Standard Specification for
Solid RoundGlass Fiber Reinforced Polymer Bars for Concrete Reinforcement in Fabricated Bent Shapes[1]

- Key Differences with ASTM D7957
  - Limits on Tensile strength & other parameters mirror CSA S807 for Grade III bends
  - Should provide clarity on bent bar properties and QC/QA
    - Defines lot size based on resin batch, not by shape !
    - Strength of straight portion of a bent bar
    - Strength of the bent portion of a bent bar
  - Better resolution on bond strength & strain by bar diameter
- Similarities with ASTM D7957
  - Uses same “measured area” tolerances as existing ASTM D7957
  - Limits on Tensile strength & other parameters mirror CSA S807

Hi-Mod Fabricated Bent Bar draft

- Introduces “shape codes” and detailing guide similar to steel shape codes



Defining “limits” for bars

Straight

TABLE 3 Geometric and Mechanical Property Requirements

Bar Designation No.	Nominal Dimensions		Measured Cross-Sectional Area Limits mm² [in.²]		Minimum Guaranteed Ultimate Tensile Force kN [kip]	Minimum Guaranteed Ultimate Tensile Strength MPa [ksi]	Ultimate Tensile Strain %	Bond Strength MPa [ksi]
	Diameter mm [in.]	Cross-Sectional Area mm² [in.²]	Minimum	Maximum				
M6 [2]	6.3 [0.250]	32 [0.049]	30 [0.046]	55 [0.085]	?	?	?	12.4[1.8]
M10 [3]	9.5 [0.375]	71 [0.11]	67 [0.104]	104 [0.161]	71 [16]	1000 [145]	1.7%	12.4[1.8]
M13 [4]	12.7 [0.500]	129 [0.20]	119 [0.185]	169 [0.263]	129 [29]	1000 [145]	1.7%	10.3[1.5]
M16 [5]	15.9 [0.625]	199 [0.31]	186 [0.288]	251 [0.388]	200 [45]	1000 [145]	1.7%	10.3[1.5]
M19 [6]	19.1 [0.750]	284 [0.44]	268 [0.415]	347 [0.539]	255 [57]	900 [130]	1.5%	9.6[1.4]
M22 [7]	22.2 [0.875]	387 [0.60]	365 [0.565]	460 [0.713]	334 [75]	855 [125]	1.5%	9.6[1.4]
M25 [8]	25.4 [1.000]	510 [0.79]	476 [0.738]	589 [0.913]	433 [97]	850 [120]	1.4%	7.6[1.1]
M29 [9]	28.7 [1.128]	645 [1.00]	603 [0.934]	733 [1.137]	?	?	?	7.6[1.1]
M32 [10]	32.3 [1.270]	819 [1.27]	744 [1.154]	894 [1.385]	?	?	?	7.6[1.1]

Bends

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“I’m here about the details.”

Other pending documents

- ASTM GFRP Dowel bar standard – load transfer device
- Request for ”non-structural” rebar
  - What does that mean ?

- Need for refinement of QC & QA:
  - Reduce testing burden without compromising quality
  - Screen for “blended” resins similar to moisture content limit now
  - ”issues” / practical guidance for moisture absorption on sand coated bar, “FRP rebar test method needed”

How to get involved ?

- FRP-RMC to work out draft
- Formal ballot goes to ASTM D30.10

- Need to fill in all limits ! All bar diameters

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A NEW PROPOSED CODE STRUCTURE

Concrete International 06/01/2020

….Other technical committees that are currently writing codes need to be re-evaluated, including ACI Committees 350, Environmental Engineering Concrete Structures, and 440, Fiber-Reinforced Polymer Reinforcement. They both write codes along with specifications, guides, and reports. How these committees operate will be an ongoing discussion between TAC and the committees with a focus on efficiency in achieving ACI's goals…..

Jeffrey W. Coleman
ACI President

ACI Committee 440 Main Strategic Plan (Will Gold, Chair)

- **Code Development**
  - ✓ACI Committee 440 has long been focused on the ultimate goal of having FRP reinforcement for concrete (RC, PC, and repair) represented in model building codes (IBC, IEBC, etc.)
  - ✓The committee started officially developing an ACI Code document on FRP reinforced concrete for new construction in 2014. This document is nearing completion in 2020
  - ✓In 2020, ACI put in place a new structure for code documents that would support two primary code documents that ACI produces (ACI 318 for new construction and ACI 562 for repair). This involves small code writing committees that would focus on particular areas and would have the primary code document as their backbone

ACI Committee 440 Strategic Plan

- **Evolution to a New ACI Vision**
  - ✓ ACI Committee 440 will "spin off" two smaller code-writing committees. One focused on New Construction and one focused on Repair. These will follow the new ACI model
  - ✓ Work on the current code document on FRP reinforced concrete will transition to this new model. This transition is akin to the transition of material specifications under ACI Committee 440 to ASTM D30
  - ✓ As with ASTM D30, we will maintain a close relationship between 440 and code writing committees through our joint members
  - ✓ Critical to the transition will be timing and planning to maintain all of the work done to develop the FRP reinforced concrete code document to date as well as to accelerate the development of a new code document on FRP repair systems

ACI Committee 440 Strategic Plan

- **Future of ACI Committee 440**
  - ACI Committee 440 will still serve a vital role in developing cutting edge reports, guidelines, specifications, and industry support materials for FRP reinforcement, prestressing and repair systems consistent with our mission and goals.
    - ✓ The committee will maintain a membership with broad and deep knowledge of FRP reinforcement for concrete
    - ✓ Guidelines and reports will be developed to "feed" code documents that are envisioned only to adopt subjects that are "ready for prime time". 440 documents will be at the cutting edge of research and technology and help spawn continual innovation
    - ✓ The committee will continue to develop Construction Specifications and Material Specifications based on industry need
    - ✓ Educational and reference materials such as professional education webinars, student competitions, and example problems will continue to be developed by ACI Committee 440

CURRENT DOCUMENTS (Red/Green for RC&PC)

440:	Building Code Requirements for Structural Concrete Reinforced Internally with FRP Bars (underway)
440.1R:	Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars
440.2R:	Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures
440.3R:	Guide Test Methods for FRP Composites for Reinforcing or Strengthening Concrete Structures
440.4R:	Prestressing Concrete Structures with FRP Tendons
440.5:	Specification for Construction with FRP Reinforcing Bars
440.6:	Specification for Carbon and Glass FRP Bar Materials for Concrete Reinforcement
440.7R:	Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Masonry Structures

CURRENT DOCUMENTS (Red for RC&PC) Continued

440.8:	Specification for Carbon and Glass FRP Materials Made by Wet Layup for External Strengthening of Concrete and Masonry Structures
440.9R:	Guide to Accelerated Conditioning Protocols for Durability Assessment of Internal and External FRP Reinforcement
440.X :	Specification for Construction with Externally Bonded FRP Materials Using the Wet Layup Method
440.YT:	TechNote: Protection of FRP-Strengthened Members from Fire
440.ZR:	Design Guide for Concrete Filled FRP Tubes
440R:	Report on FRP Reinforcement for Concrete Structures

2020 FDOT-FRP Industry 4th RC/PC Workshop

Sub 440-0H Reinforced Concrete

Co-Chairs: Vicki Brown and Carol Shied

Code Requirements for Structural Concrete Reinforced with FRP Bars (
and Commentary

Reported by ACI Committee 440

Chapter 1 – General[1]
Chapter 2 - Notation and Terminology[4]
Chapter 3 - Referenced Standards[4]
Chapter 4 – Structural System Requirements[1]
Chapter 5 – Loads[1]
Chapter 6 - Structural Analysis[1]
Chapter 7 – One-Way Slabs[1]
Chapter 8 – Two-Way Slabs[2]
Chapter 9 – Beams[3]
Chapter 10 – Columns[2]
Chapter 11 – Walls[2]
~~Chapter 12 – Diaphragms~~ (Does Not Apply)
Chapter 13 – Foundations[1]
~~Chapter 14 – Plain Concrete~~ (Does Not Apply)
Chapter 15 – Beam-Column and Slab-Column Joints[1]
Chapter 16 – Connections between Members[2]
~~Chapter 17 – Anchoring to Concrete~~ (Does Not Apply)
~~Chapter 18 – Earthquake Resistant Structures~~ (Does Not Apply) (
19 – Concrete: Design and Durability Requirements[1]
Chapter 20 – GFRP Reinforcement Properties, Durability, and Embedments[1*]
Chapter 21 – Strength Reduction Factors[1*]
Chapter 22 – Sectional Strength[1]
~~Chapter 23 – Strut-and-Tie Models~~ (Does Not Apply)
Chapter 24 – Serviceability Requirements[1]
Chapter 25 – Reinforcement Details[1]
Chapter 26 – Construction Documents and Inspection[1]
~~Chapter 27 – Strength Evaluation of Existing Structures~~ (Does Not Apply)
References[4]
~~Appendix A – Steel Reinforcement~~ (Does Not Apply)
~~ACI 318.2-14 Building Code Requirements for Concrete Thin Shells~~ (Does Not Apply)

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[1] **Draft approved, 440 Main Ballot**
[1*] **Draft approved, 440 Main Ballot with exception of one outstanding negative**
[2] **Draft completed, under balloting at 440 Main level**
[3] **Draft completed, under balloting at 440H Sub-committee level**
[4] **Draft not yet completed**

2020 FDOT-FRP Industry 4th RC/PC Workshop

Sub 440-0I Prestressed Concrete

Chair: Jimmy Kim

ACI 440.4R-XX: Prestressing concrete structures with FRP tendons (new and upgraded doc to be approved)

Major changes are:

1. Recent literature is added, including field applications
2. New strength reduction factors are included
3. Jacking requirements are updated
4. Relaxation and friction losses are added
5. New deformability requirements are added
6. Minimum reinforcement requirements are updated
7. New deflection approaches are added
8. New long-term multipliers are added
9. Other items are in agreement with AASHTO Guide Specs

ACI Subcommittee 440-0K
FRP Material Characteristics
Co-Chairs: Chuck Bakis, Russ Gentry

440-0K Scope

1. Transition of existing 440.3R test methods to ASTM standards
2. Voting on new test standards taking place in ASTM committee D30 (Composite Materials) and subcommittee D30.10 (Civil Structures)

11 Active ASTM Standards

Topic	440.3R	ASTM D30
Bar Cross-Section	B1	D7205-06(2016)
Bar Tension	B2	
Bar Anchors	App. A.	
Bar Concentric Pullout	B3	D7913-14
Bar Transverse Shear	B4	D7617-11(R17)
Bar Strength at Bends	B5	D7914-14
Bar Alkaline Tension	B6	D7705-19
Bar Creep Rupture	B8	D7337-19
Lam/Concrete Bond - Normal	L1	D7522-15
Laminate Tension	L2	D7565-10(2017)
Laminate Calculations	App. B	
Laminate Lap Shear	L3	D7616-11(R17)
Lam/Concrete Bond - Shear	--	D7958-17
Characteristic Values	--	D7290-06(R17)

One Active ASTM Specification

Topic	ACI 440	ASTM D30
GFRP Bar Spec	440.6-08	D7957-17

Documents Close to Completion

- New standard specification for inspection of FRP installation for strengthening and retrofitting of civil structures
- New standard on GFRP dowel bars
  - ✓ Rebar council working out final detail

Longer Term Work in Progress or Planned

- B.9 Long-term relaxation of FRP bars
- B.10 Bar anchorage
- B.7 Bar tensile fatigue
- B.11 Test method for tensile properties of deflected FRP bars
- Guide for preparation of wet layup specimens
- New standard spec. for higher performing GFRP bars
- Guide for all D30.10 test methods

American Composites Manufacturers Association

FRP Rebar Manufacturers Council

John P. Busel, F.ACI, HoF.ACMA

VP, Composites Growth Initiative

FRP-RMC Member Companies
Member Companies (24)

Manufacturers (6)

- B&B FRP Manufacturing Inc.
- Marshall Composite Technologies, LLC
- Owens Corning Infrastructure Solutions, LLC
- Pultrall, Inc.
- Pultron Composites
- TUF-BAR Inc.

Suppliers / Distributors (11)

- AOC
- Aramco Services Company
- Arkema, Inc.
- Composites One, LLC
- INEOS Composites
- Interplastic Corporation
- Mafic Inc.
- OCSiAl LLC
- Olin Epoxy
- Owens Corning
- Teijin Carbon America, Inc.

Affiliates (7)

- Miller & Long Co., Inc.
- North Carolina State University - Civil Engineering
- Ryerson University
- University Of Massachusetts Lowell
- University Of Miami; Civil, Architectural, & Environmental Engineering
- University Of Sherbrooke
- West Virginia University

AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION

Council Vision & Mission

Vision

- To create a **forum for composites industry manufacturers** that ensures FRP rebars, tendons, and grids, are accepted by designers, engineers, and specifiers in construction and civil engineering applications

Mission

- Promote the use and growth of FRP reinforcement (rebar, tendons & grids) in concrete and masonry applications through **development of quality procedures, industry specifications, performance standards, and field application guidelines**

Council Leadership

- **Chair: Tom Ohnstad,** Marshall Composite Technologies
- **Vice Chair: Peter Renshaw,** Pultron, Inc.
- **Treasurer: Doug Gremel,** Owens Corning Infrastructure Solutions

American Composites Manufacturers Association

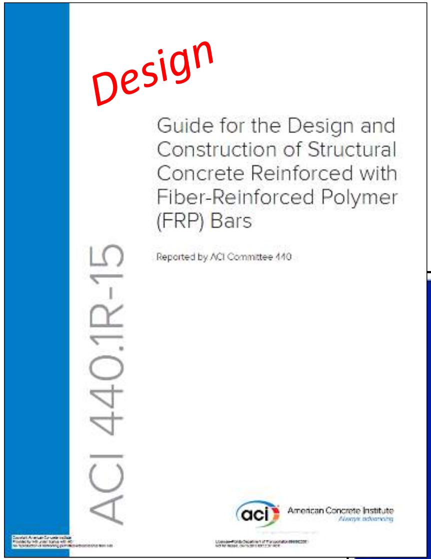
Strategic Goals

- **Standards Development -** The goal is to develop new or modify existing standards to assist engineers in design and specification of FRP rebar.
- **Education -** The goal is to provide basic education on the use and specification of FRP rebar that is targeted at designers, engineers in consulting firms or DOTs.
- **Marketing -** The goal is to promote the FRP rebar industry to a broad audience of users in the transportation infrastructure and building industry.
- **Outreach & Advocacy -** The goal is to work together as a cohesive industry to represent the needs that will remove barriers resulting in greater acceptance by educating and partnering with end-users, federal agencies, and legislators.

Design Rules and Tools – ACI, ASTM, AASHTO

2nd Edition

Design

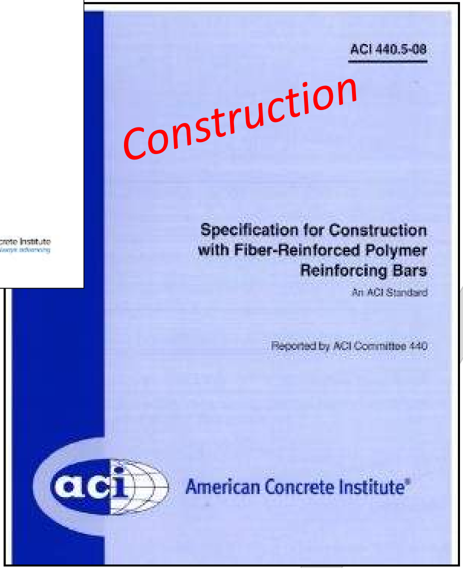

Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer (FRP) Bars

Reported by ACI Committee 440

ACI 440.1R-15

American Concrete Institute
Always advancing

Construction


ACI 440.5-08

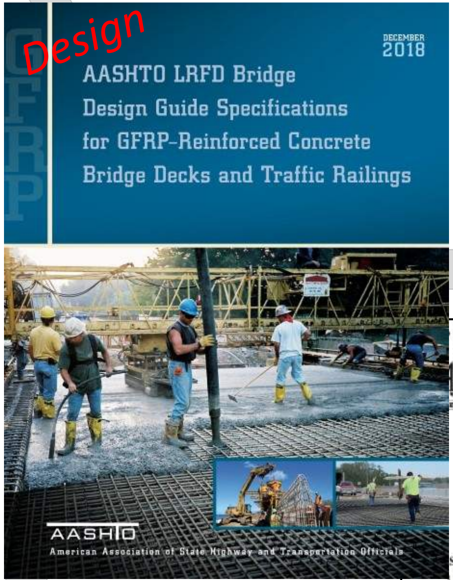
Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars

An ACI Standard

Reported by ACI Committee 440

American Concrete Institute®

Design

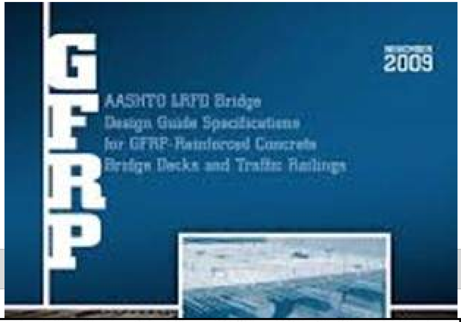

DECEMBER 2018

AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings

AASHTO

American Association of State Highway and Transportation Officials

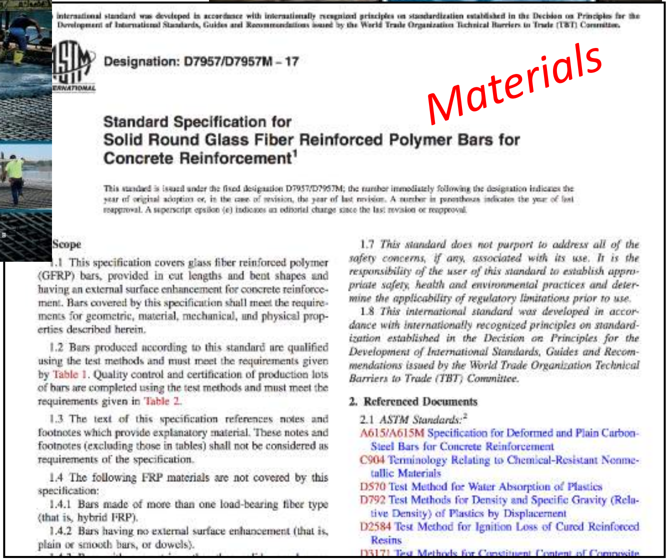
1st Edition


GFRP

2009

AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings

Materials


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.

Designation: D7957/D7957M – 17

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.

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).

1.7 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

ACMA
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Council Completed and Ongoing Activities

- **Codes**
  - **ACI Rebar Code -** ongoing support in development of code
  - **TMS 402/602** Building Code Requirements for Masonry Structures for 2022.
    - Completed Experimental validation tests
    - Inclusion of Appendix D
- **Standards**
  - **ASTM D30.10 –** ongoing support in update and development of standards
  - **TxDOT** - updated the design of the IGFRP-17 standard drawings for single mat reinforcement
  - **FDOT** – ongoing support in update and development of standards

Council Priority Initiatives in 2020 & 2021

Category	Strategic Objective
Standards	a) Support development of ✓ **ACI** GFRP rebar design code ✓ **ASTM** test methods (rebar, dowel bar) ✓ **TMS -** Inclusion of FRP bars in Masonry Design Code ✓ Industry standard for non-structural applications b) Collaborate with **NIST** on developing needed durability testing for industry standards related to FRP rebar in concrete
Education	Engage State DOT designers, engineers, and specifiers to educate and assist DOT on the proper use and incorporation the use of FRP
Outreach	Support ACMA initiatives to educate and lobby Congress and other Federal agencies on funding and inclusion of FRP rebar in infrastructure
Marketing	Develop online resources for the education and awareness of codes, standards, technical data, and field applications on the use of FRP rebar in concrete applications.

Working with NIST on standards activities

- **ACMA Supported US House and Senate bills introduced to current Congress**
  - $11 Million in funding – Composites Research
  - *Expected to pass the Senate in early August and the House in late September/early October*
- **National Institute for Standards and Technology (NIST)**
  - Has a unique ability to facilitate the development of durability testing and identify key criteria that can contribute to design guidelines and standards to allow for broader use of FRP composites in critical civil infrastructure
  - NIST role can serve as a clearinghouse to identify, gather, validate and disseminate existing design criteria, tools, guidelines, and standards.
- **Design Data Clearinghouse**
  - Engineers and designers rely on design guides and data tables that have been proven reliable through years of experience and testing.
- **Development of Durability Testing**
  - Composites need accelerated testing, data, and protocols to optimize the design and engineering values for every application
  - Need to **develop a testbed, gather data, and develop protocols** that would result in screening and acceptance tools and a set of minimum allowable design data that can be converted into design tools.

ACMA
American Composites Manufacturers Association

IMAGINE Act and Federal Innovation - Update

- **ACMA leads a coalition of materials trade associations to promote the use of long-lasting, low-maintenance innovative construction projects**
- **Group is unified around promoting the IMAGINE Act (S. 403/H.R. 6495)**
  - Led by Sens. Whitehouse (D-RI) and Alexander (R-TN) and Reps. Cicilline (D-RI) and Davis (R-IL) among many cosponsors. Key elements:
  - Interagency collaboration on strategy to clear standards barriers or innovative materials
  - Expanded federally funded research
  - $650 million for innovative bridge and innovative water/wastewater programs
- **ACMA and partners are working to gain inclusion of full legislation in final surface transportation (highway) and water infrastructure packages**
- **Elements of the bill have already been included in House and Senate proposals. We remain active to achieve the rest.**
- **For highways, a FAST Act extension is imminent due to COVID priorities and fall elections. Full reauthorization likely delayed until 2021.**

ACMA
American Composites Manufacturers Association

Featured Infrastructure Speaker at CAMX 2020

Date: Wednesday, September 23, 2020

Time: 1:35 pm – 2:20 pm EASTERN

NOTE: This featured speaker session will be followed by featured panel on infrastructure from 2:25 pm – 3:40 pm EASTERN

Title: ***Game Changing Infrastructure Challenges: New Solutions & Opportunities***

Speaker: **Tim Lattner, PE – Director of Design**

Description: Expectations for infrastructure service life and asset maintenance strategies have changed significantly since the Interstate Act was signed into law in 1956. The resulting expressways eliminated at grade crossings substantially increasing the nation's bridge inventory. Originally no target service life expectations were specifically set, but by the 1970's observations from fatigue damage failures forced engineers to consider the number of heavy truck wheel load cycles – selecting 50 years are as design life. In the late 1990's with the recognition of a growing inventory maintenance challenge AASHTO set the minimum design life to 75 years. Most recently the AASHTO Committee on Bridges and Structures approved publication of a new Guide Specification for 2020 that assigns three target service-life limits (75-, 100-, and 150-years). In recent years, Florida DOT interest in innovation and application of materials like FRP composites has led to many successful installations with the objective of building better with better materials. **This presentation will provide an overview of FDOT research and implementation using FRP composites and attendees will learn about FDOT vision for the future for transportation infrastructure.**

AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION

Featured Infrastructure Panel at CAMX

Date: Wednesday, September 23, 2020

Time: 2:25 pm – 3:40 pm EASTERN

NOTE: This featured panel follows the infrastructure featured speaker – Tim Lattner that goes from 1:35 pm – 2:20 pm EASTERN

Title: Building Bridges Along the Atlantic

Description: Recent bridge design and construction projects will be highlighted showing the willingness of transportation agencies along the east coast of North America to embrace the use of FRP for more than just rehabilitation and strengthening. With a focus on improved Life Cycle Cost and reduced maintenance liability this panel will discuss the needs of the infrastructure community to integrate Composites reliably and economically into their business practices particularly for concrete structures.

Moderator: **Antonio Nanni, PhD., P.E.,** Inaugural Senior Scholar, Professor and Chair, Dept. of Civil, Arch. & Environ. Engineering University of Miami

Panelists:

- Engineer/Owner –
  - **Darrell Evans, P.Eng.** A/Assistant Director, Prince Edward Island Department of Transportation, Infrastructure & Energy
- Engineer/Owner –
  - **Wayne Frankhauser Jr., PE,** Bridge Program Manager, Maine Department of Transportation
- Engineer/Owner –
  - **Steven Nolan, P.E.**, Senior Structures Design Engineer, State Structures Design Office, Florida DOT
- Construction Materials Specialist/Engineer –
  - **Chase C. Knight, Ph.D., P.E.,** Corrosion & Composite Materials Engineer, FDOT - State Materials Office
- Construction Contractor –
  - **Steve McNamara,** President, ANZAC CONTRACTORS, INC.

AMERICAN COMPOSITES MANUFACTURERS ASSOCIATION

Thank you

- **CAMX is virtual!**
  - Free sessions, Tutorials, Technical Papers, Educational Sessions, Keynotes, and exhibit hall
  - Starting in August, continues in September
- **More in technical program and registration – www.thecamx.org**

Composites 101 Webinar

Whether you are new to the composites industry or are interested in an overview of all aspects of composites materials and manufacturing, this is the program for you! The webinar provides basic information on the technical components of composites including the most common materials and manufacturing processes. Learn more and register here.

ACMA
American Composites Manufacturers Association

REGULATORY RESOURCES

A QUALITY ASSURANCE PARTNER FOR DOTs

RICHARD KROLEWSKI BACKGROUND

- Founder of Regulatory Resources LLC
- A registered federal lobbyist, promoting the benefits of sustainable, resilient concrete construction
- Facilitates information exchange between the regulatory community and the concrete industry.
- An appointed representative of the U.S. DOT, Rich coordinates the DOT Advisory Board, a group of DOT officials seeking to advance the transfer of data for enhanced quality assurance on DOT projects.
- Has worked with the FHWA, FAA, U.S. DOD, Army Corps of Engineers, most state DOTs, and many local governments, specifying agencies and engineering firms.
- Past successes include a three-year project with the Federal Aviation Administration to update FAA specifications to align with ASTM standards.
- Rich has also worked extensively with the Federal Highway Administration on Buy America provisions and other key issues.

REGULATORY RESOURCES

A QUALITY ASSURANCE PARTNER FOR DOTs

REGULATORY RESOURCES LLC	BENEFIT TO DOTS
Founder Richard Krolewski has been working closely with DOTs for nearly two decades.	Relieves pressure on DOT personnel for QA/QC of FRP material.
Deep experience in facilitating third party certification programs, working between NPCA, producers and DOTs.	Creates a level playing field for FRP suppliers to DOTs.
Has worked with more than 400 precast plants on certification details.	Creates and promotes 3rd party certification to raise awareness and develop industry standards.
Has strategic partnerships and strong relationships throughout the industry and government.	Program is process-specific, not product-specific.
Created DOT Advisory Board chaired by Cabell Garbee, P.E., NCDOT-Materials and Tests Unit	Includes education and training conducted by experts in FRP reinforcement.

CONTACT: Richard Krolewski (rkrolewski4@gmail.com) 317.603.5380

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

ROY COOPER
GOVERNOR

J. ERIC BOYETTE
SECRETARY

July 1, 2020

Dear Colleague:

As the chairman of the newly formed DOT Industry Advisory Board, I would like to invite you to participate with our organization as a board member. This group consists of representatives from State Departments of Transportation who have a stake in the specification process and interact with certifying bodies such as NPCA, PCI and ACPA.

The objective of the Board would be to assist the organizations by enhancing their understanding of the certification needs of the Departments, facilitate transfer of data, and harmonize state acceptance criteria. Both the industry and every Department of Transportation are relying more and more on remote computing, RFID/Barcode tracking of materials, and third-party audits. Thus, there is an opportunity to leverage the experiences of the producers and the states to streamline and enhance processes and procedures while preserving the integrity of information and the acceptance processes.

Additionally, the Advisory Board will serve as a resource for companies enhancing or creating applications for materials, products, and certification tracking, by providing a sounding board for review of features, needs, and usability.

The DOT Industry Advisory Board is facilitated by Richard Krolewski, who is the founder of Regulatory Resources LLC. A federally registered lobbyist, Rich's role is to represent the best interests of DOTs and FHWA as a liaison to the concrete industry. He has nearly two decades working in this capacity and was responsible for implementing certification programs with 42 state DOTs, during which time he created strong relationships throughout the DOT community. Rich works to create winning solutions both for the state and federal agencies and the industry.

There are no fees associated with membership on the Advisory Board. Meetings will be via conference call for the foreseeable future so there will be no travel involved at this time. If you are willing to participate, please return the acceptance form on the next page to me at your earliest convenience. If you have any questions, please contact me at NCDOT Materials and Tests, cgarbee@ncdot.gov or (919) 329-4000.

Sincerely,

W. Cabell Garbee, II, PE
Manufactured Products Engineer
NCDOT - Materials and Tests Unit

cc: T. W. Whittington, PE, NCDOT, State Materials Engineer

DOT ADVISORY BOARD

I am willing to serve as a member of the DOT Advisory Board for the 24-month period beginning July 1, 2020 and ending June 30, 2022.

I will actively participate in meetings and respond to correspondence during my term and will freely and honestly express my views as a member of the board.

Name:

Title:

Organization:

Address:

City/State/Zip:

Telephone:

Email:

Website:

Signature:

Date:

FDOT-FRP Industry 4th RC/PC Workshop

August 4th 2020, 9:30am – 2:30pm, On-line

International Perspectives - CANADA - Standards & Specifications

Dr. Brahim Benmokrane, P.Eng.
Professor of Civil Engineering
Tier-1 Canada Research Chair
NSERC/Industry Research Chair
University of Sherbrooke, Sherbrooke, QC, CANADA

Dr. Khaled Mohamed, P.Eng.

MITACS Postdoctoral Researcher

University of Sherbrooke, Sherbrooke, QC, CANADA

Outline of presentation

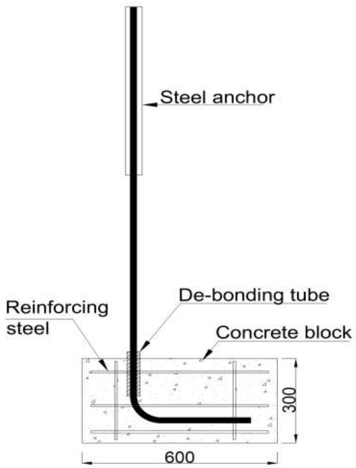
- **Introduction- FRP Reinforcement in Canadian Codes and Standards: Recent Developments**

- **New Editions of CAN/CSA Standards & Specifications : CSA S807-19 and CSA S6-19**

FRP Reinforcement in Canadian Codes and Standards: Recent Developments

60 GPa Modulus GFRP Bent Bars Manufactured with a New Process

60 GPa Modulus GFRP Bent Bars Manufactured with a New Process



Modulus of Elasticity: 63 GPa (9 msi)

Tensile Strength of straight portion: 1160 MPa (168 ksi)

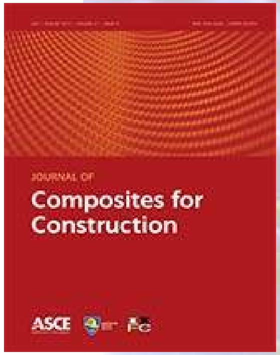
Tensile Strength at bend: 700 MPa (100 ksi)

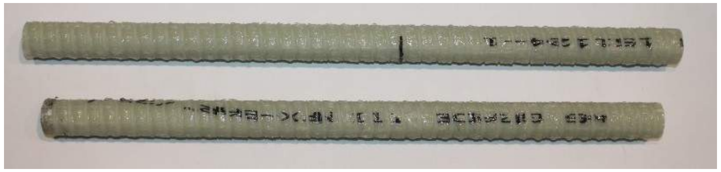
Recent Developments in GFRP Bars

Bendable GFRP bars with <u>thermoplastic resins</u>

Physical, Mechanical, and Durability Characteristics of Newly Developed Thermoplastic GFRP Bars for Reinforcing Concrete Structures

Manuscript submitted to the ASCE journal of composite for construction

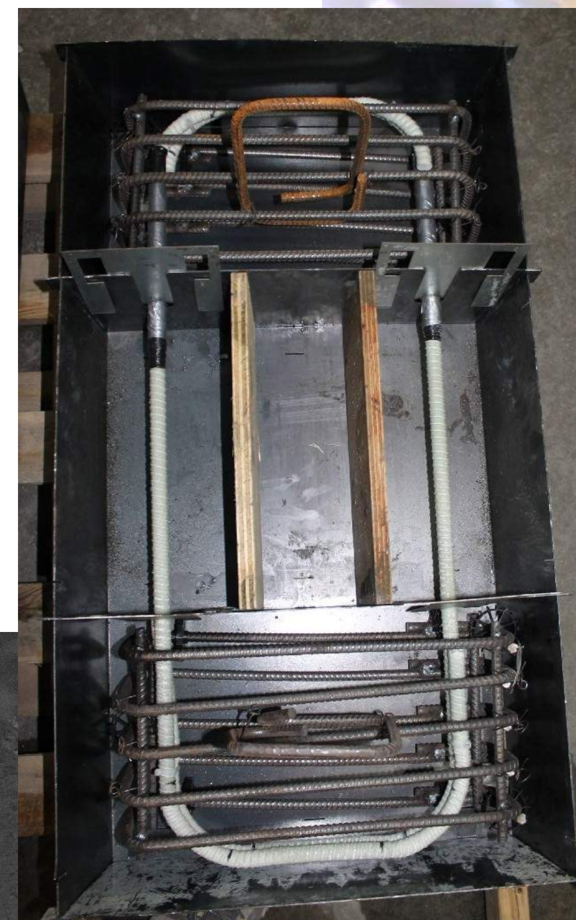


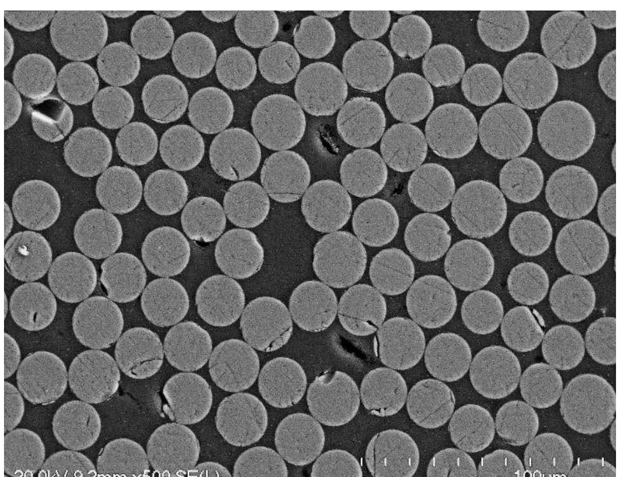


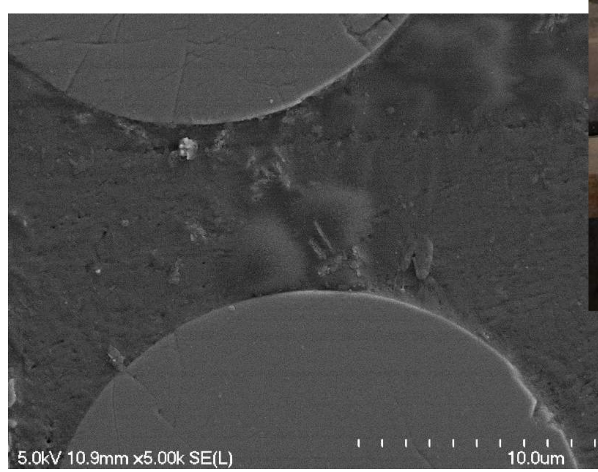
Recent Developments in GFRP

Bendable GFRP bars with thermoplastic resins

Property	Thermoplastic bars		
	#3	#5	#6
Tensile strength (MPa)	1,421	1,062	1,033
Tensile modulus (GPa)	65.4	61.5	62.5
Tensile strain (%)	2.17	1.65	2.14
Transverse shear strength, (MPa)	207	186	-
Interlaminar-shear strength, S_u (MPa)	66.6	46.0	45.1
Bond strength (MPa)	-	27.3	-







Recent Developments in FRP Bars

Basalt FRP bars with superior resistance to alkali attacks

Property retention after conditioning in alkaline solution for 3 months at 60°C:

Property	Status	Average (MPa)	Retention (%)
Tensile Strength	Reference	1263	**103 %**
	Conditioned	1306	
Tensile Modulus	Reference	51.2	**100 %**
	Conditioned	51.3	
Interlaminar shear strength	Reference	40	**107 %**
	Conditioned	43	

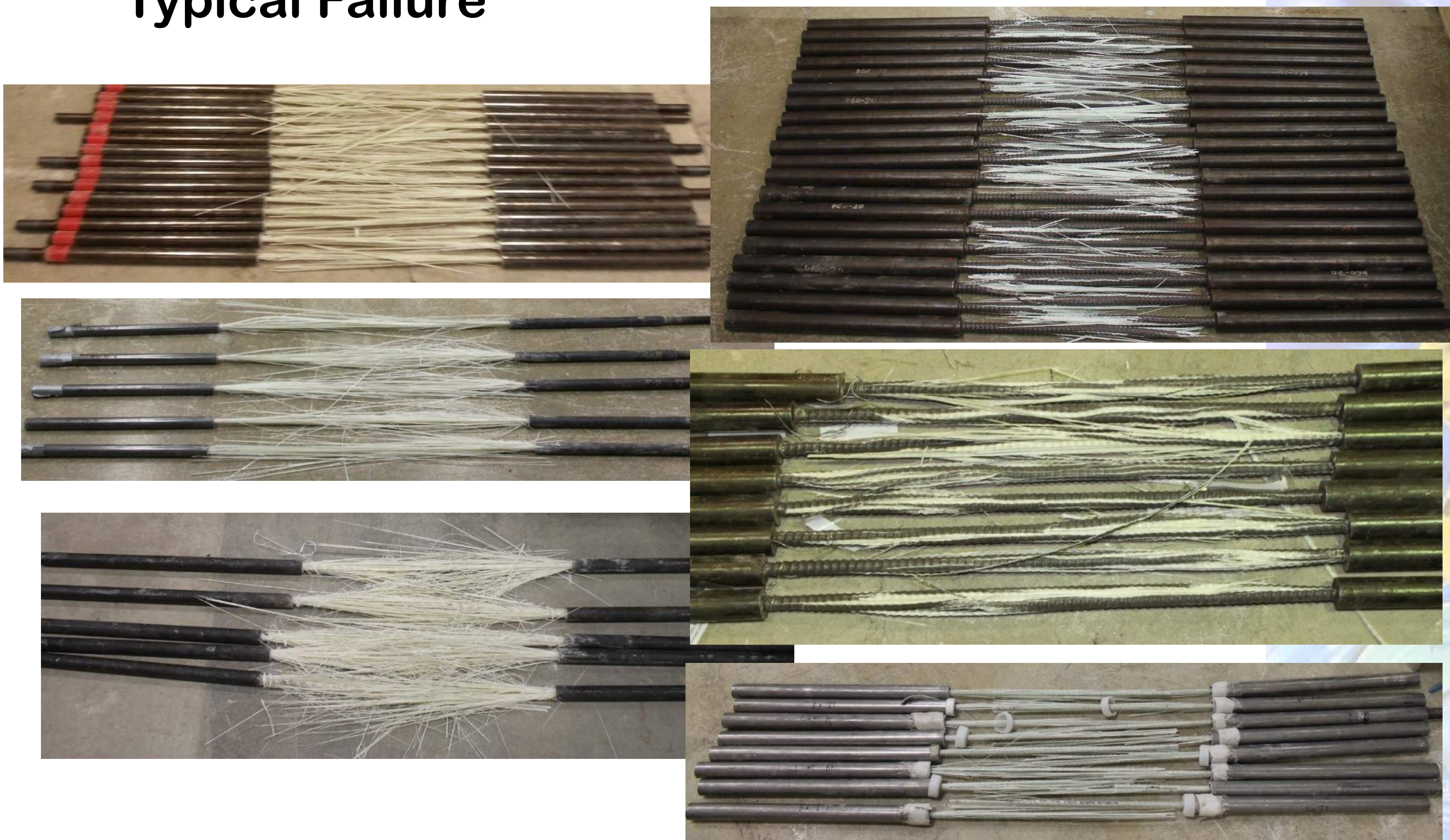
Creep Rupture and Alkali Tests under high Stress and Temperature

GFRP Bars of Large Sizes (up to 25 mm)

Creep Rupture and Alkali Tests under high Stress and Temperature

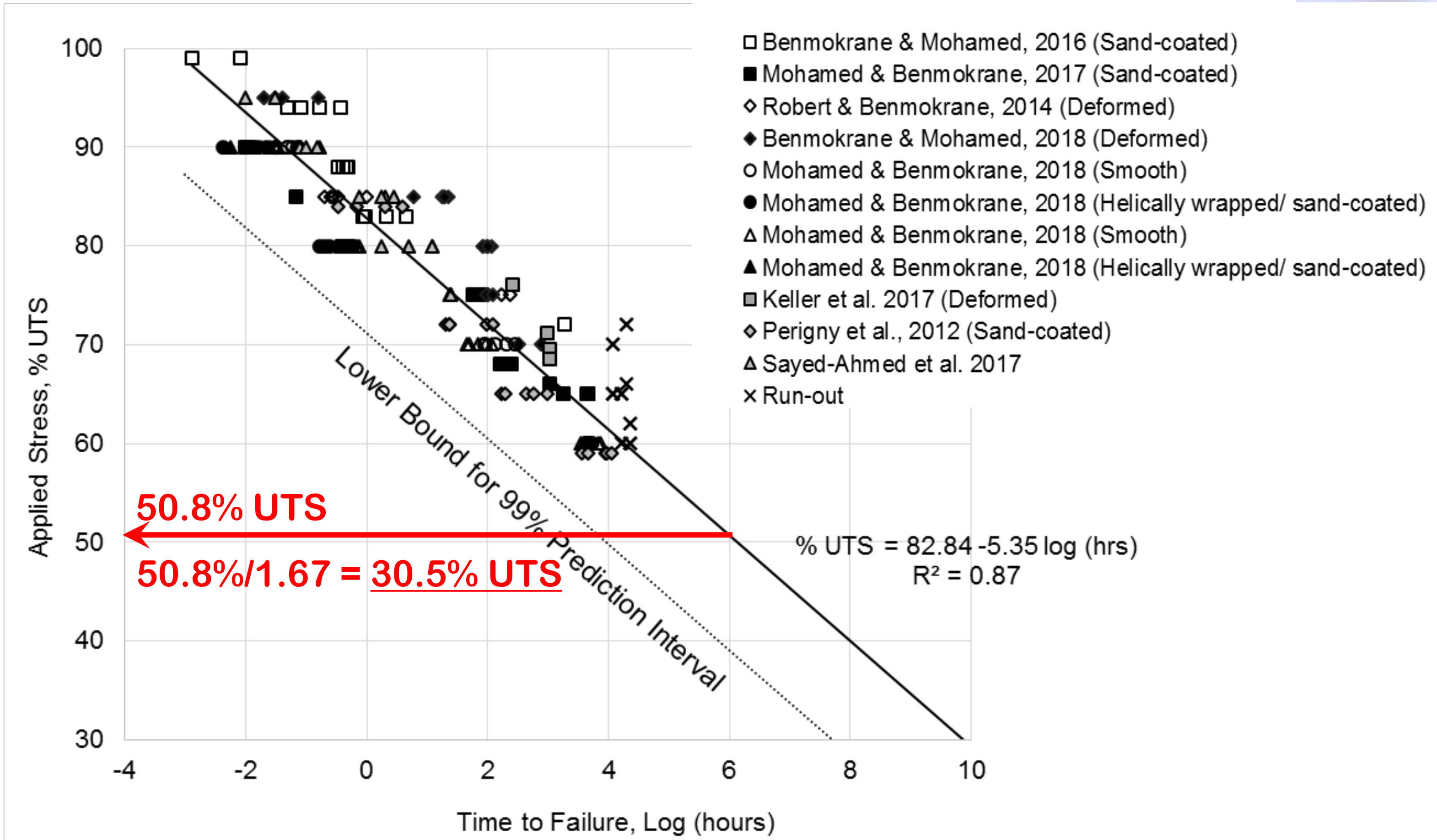
Results

Typical Failure



Creep Rupture and Alkali Tests under high Stress and Temperature

Creep-rupture stress limit for GFRP bars increased to <u>0.3 x design tensile strength</u> (ACI 440-H and AASHTO LRFD); Paper published in ASCE JCC 2020



Environmental Reduction Factor, CE:

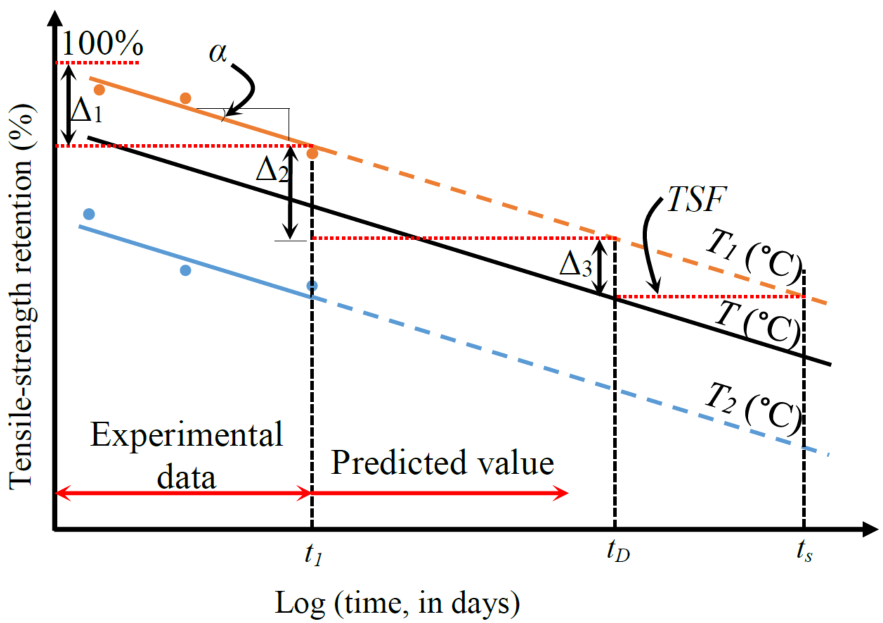
CE increased from 0.7 to 0.85 (ACI 440-H); **Paper published in ASCE JCC 2020**

Prediction Model:

$$C_E = 1 - [\Delta_1 - \alpha . \log(DL . TSF)] . n_H$$

$$TSF = e^{[B/(T1+273.15)] - [B/(T+273.15)]}$$

The model was adopted as it incorporates the effects of seasonal temperature fluctuations, service year, and relative humidity (RH) of exposure into the environmental reduction factor (CE),

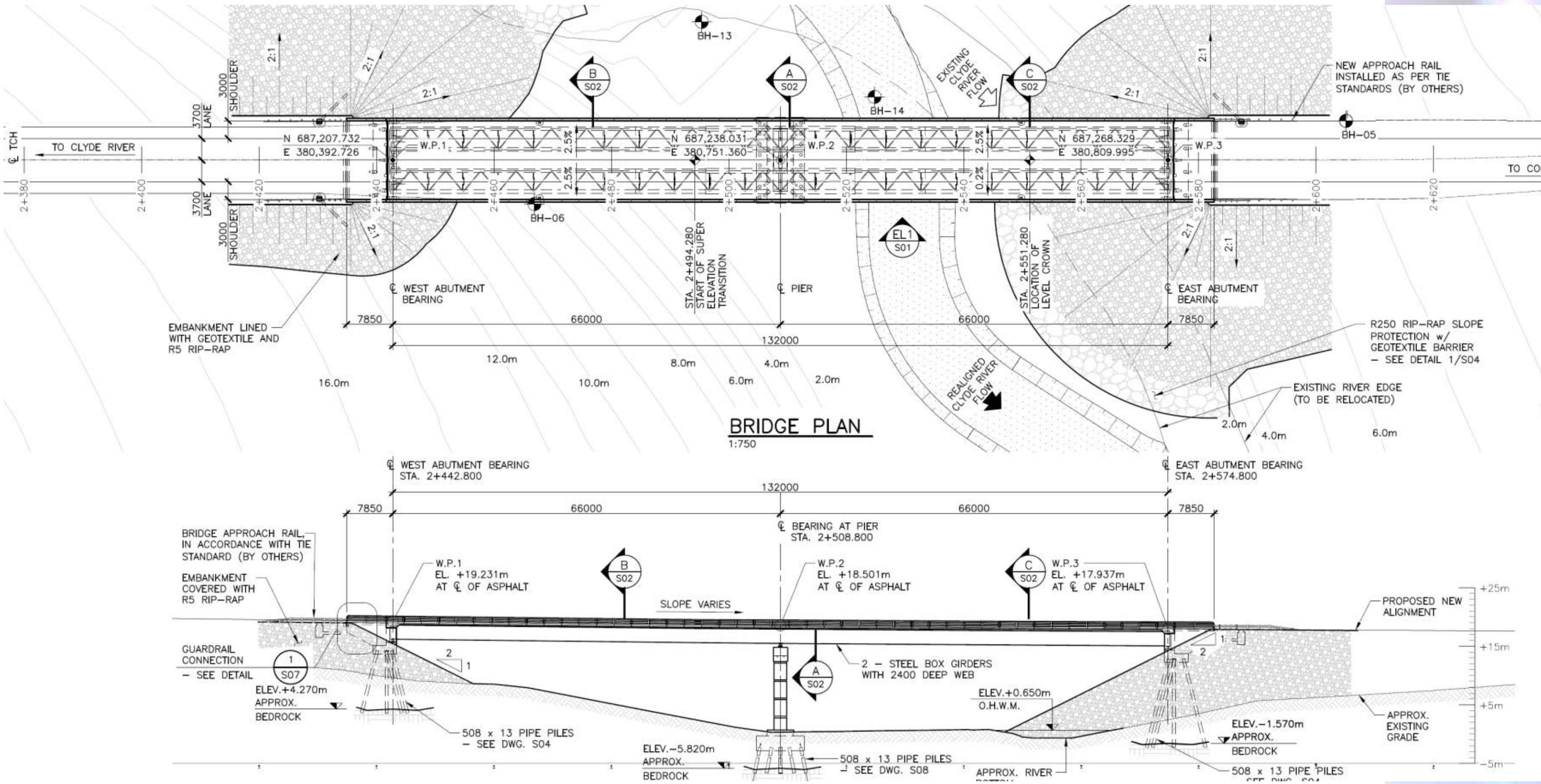


Current Field Applications in Canada using GFRP Bars

- Bridges – decks, barriers/parapets, ret walls, sidewalks, app slabs, precast on ped bridges
- Transit (LRT/BRT) – bridge structures, platforms, slabs, plinths, track beds, non-conductive components
- Tunnelling – soft-eyes; slurry and D walls, caissons, secant piles
- Buildings – distribution slabs, warehouse & heated slabs, garage slabs
- Precast components – structural and architectural
- Hydro/substations – chambers/vaults, duct banks, slabs

B&B FRP Manufacturing, Pultrall, TUF-BAR Canada, SFTec, Pultron, etc.

Clyde River Bridge – Prince Edward Island, Canada



CLYDE RIVER BRIDGE – ABUTMENT GFRP BARS
REF. DWG. SHEET S24, S25 & S27

MARK	TYPE	A	B	C	D	E	F	G	H	J	K	O	R	LENGTH	QTY.
A1001	ST	1050												1050	180
A1501	2	1375	1375											2750	288
A1502	17		560	1400	560									2520	144

CLYDE RIVER BRIDGE – WINGWALL GFRP BARS (CONT.)
REF. DWG. SHEET S26 & S27

MARK	TYPE	A	B	C	D	E	F	G	H	J	K	O	R	LENGTH	QTY.
W2091	17		2400	400	2400									5200	2
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
TO	17	22 BARS 'B' & 'D' CUT IN STEPS 50												TO	2

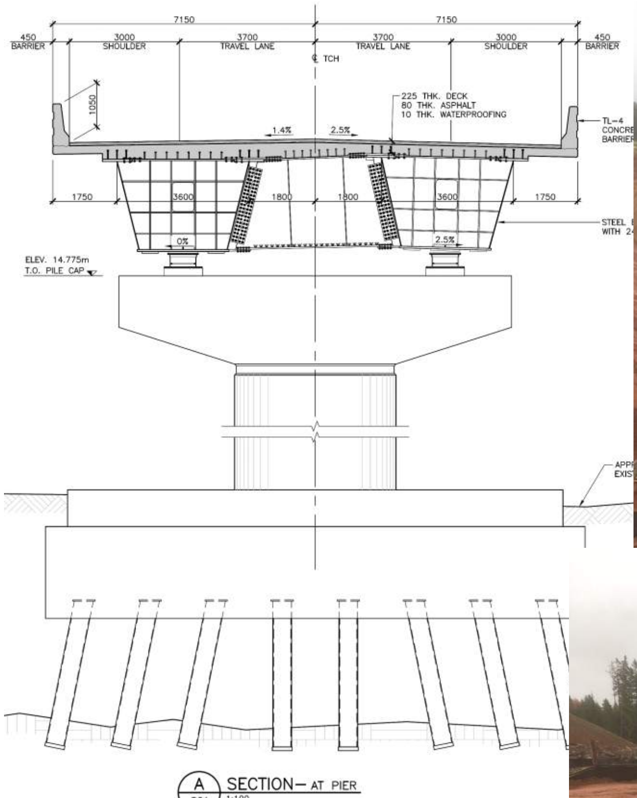
CLYDE RIVER BRIDGE – WINGWALL GFRP BARS
REF. DWG. SHEET S26 & S27

MARK	TYPE	A	B	C	D	E	F	G	H	J	K	O	R	LENGTH	QTY.
W1301	ST	1655												1655	180
W1302	ST	1330												1330	4
W1501	ST	3900												3900	48

CLYDE RIVER BRIDGE – PIER GFRP BARS
REF. DWG. SHEET S28 & S29

MARK	TYPE	A	B	C	D	E	F	G	H	J	K	O	R	LENGTH	QTY.
P2201	10	1100	3142	1100								2000	978	5342	134
P2202	T7			1445	540	1310					133			3295	268
P2203	T7			1500	495	1210					294			3205	268

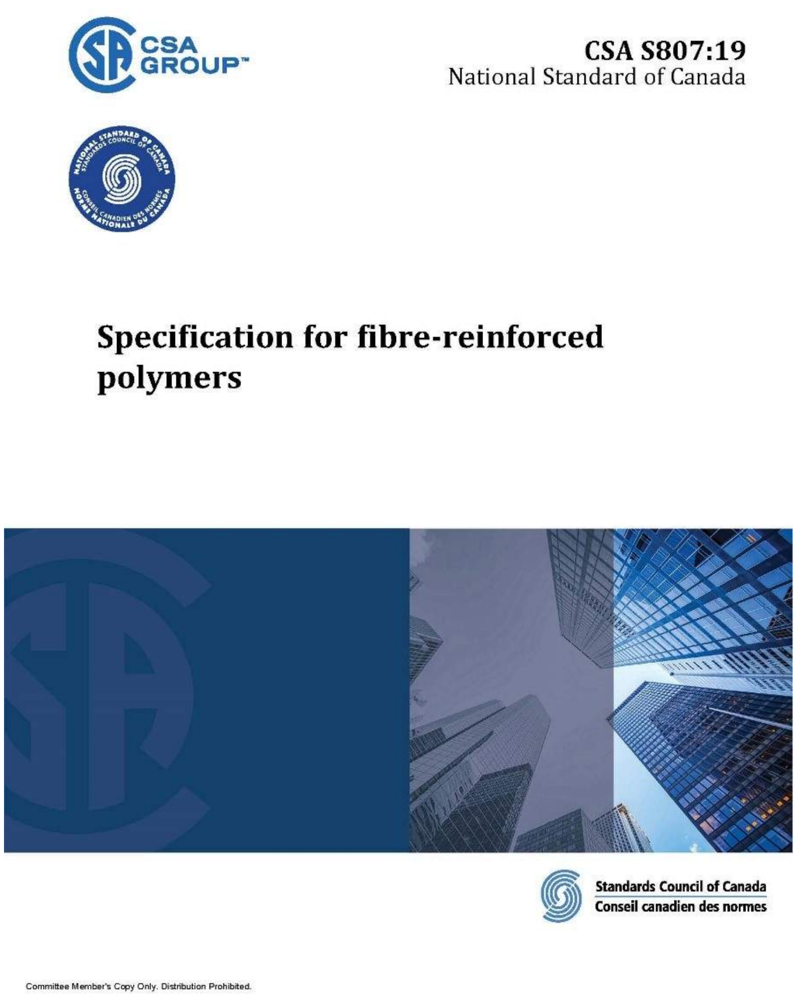
Clyde River Bridge – Prince Edward Island, Canada



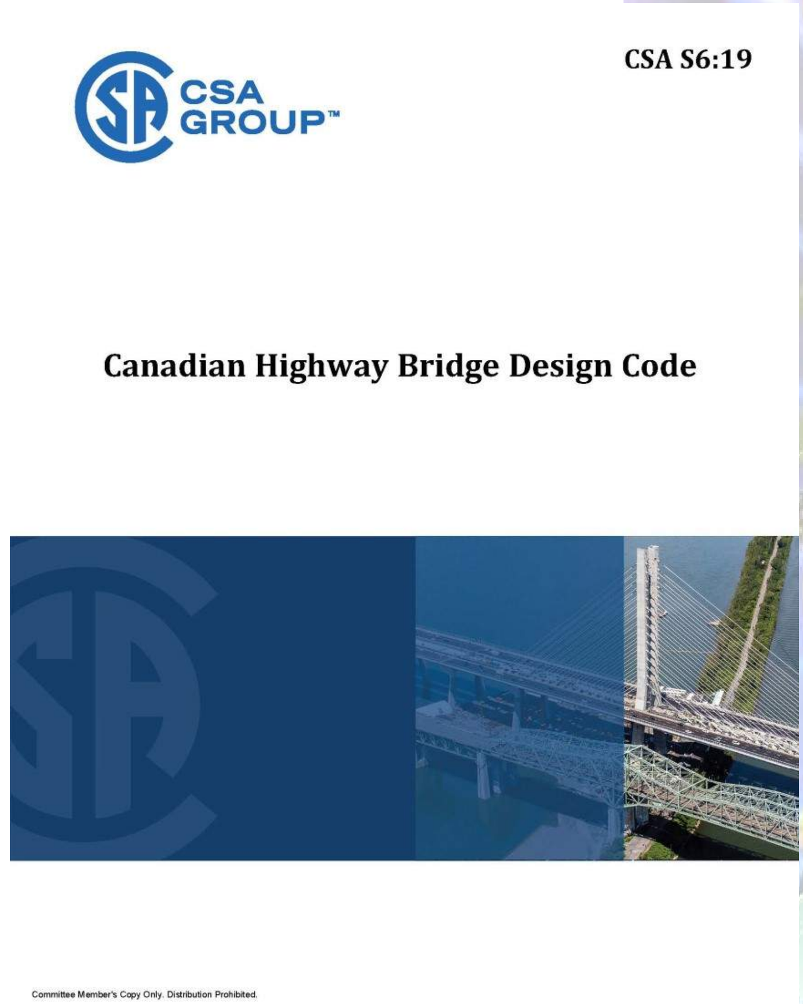
Owner: Province of Prince Edward Island

Contractor: Noye & Noye LTD

FRP Recent CSA Standards & Specifications

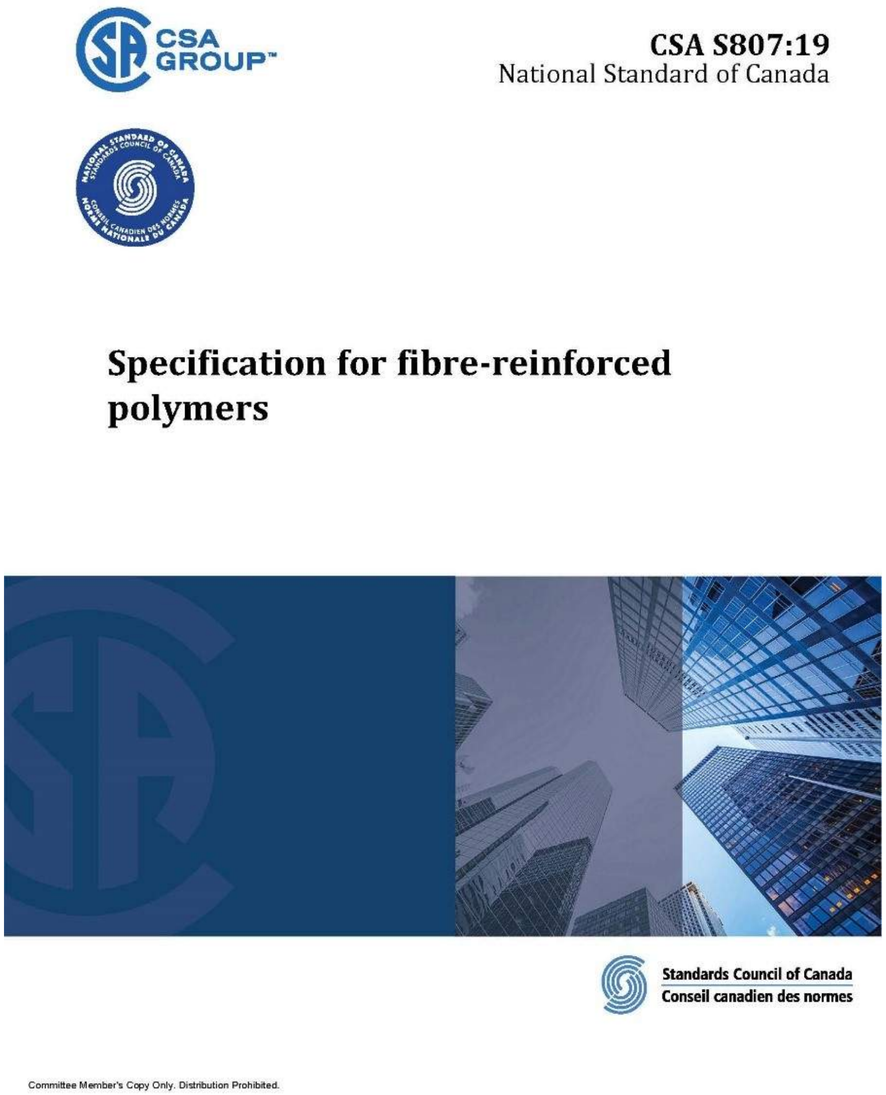


CSA S807-19



CSA S6-19

FRP Recent CSA Standards & Specifications


CSA GROUP

CSA S807:19
National Standard of Canada

Specification for fibre-reinforced polymers

Standards Council of Canada
Conseil canadien des normes

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CSA S807

- First edition in 2010
- Re-approved in 2015
- New Edition in 2019 (Second Edition)

CSA S807-19

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.

CSA S807:19 Specifications for fiber reinforced polymers Recent Modifications

1 Scope *9*

2 Reference publications *9*

3 Definitions *12*

4 General requirements *14*
4.1 Materials *14*
4.1.1 General *14*
4.1.2 Polymers *14*
4.1.3 Fibres *14*
4.1.4 Fillers *14*
4.1.5 Additives *14*
4.1.6 Fine aggregate for sand coating *15*
4.2 Manufacturing *15*
4.2.1 Method *15*
4.2.2 Production lot size *15*
4.2.3 Production changes *16*
4.3 Quality control *16*

5 Quality of work and finish *16*

6 Handling and storage *16*

7 Packaging and marking *16*

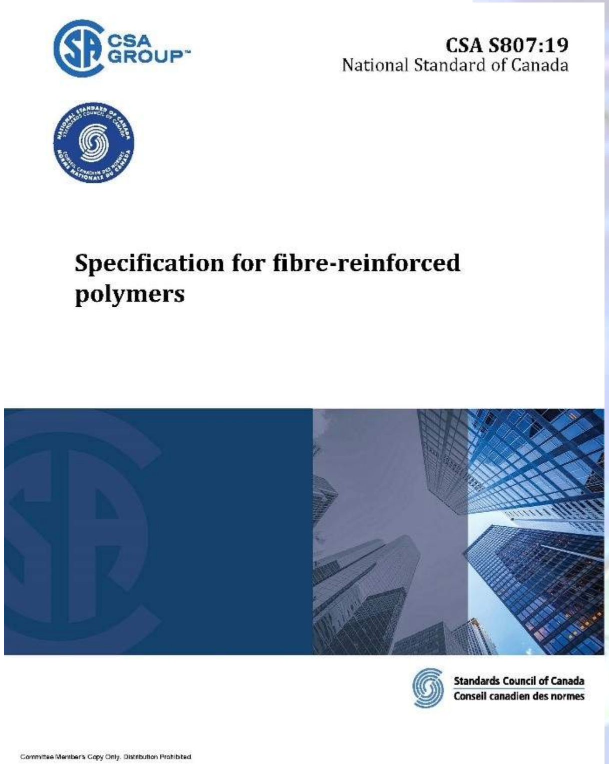
8 Classification of products *17*
8.1 General *17*
8.2 Classification based on tensile strength *18*
8.3 Classification based on minimum modulus of elasticity (only applies for tests at room temperature) *18*
8.4 Classification based on durability *18*

9 Quality control, quality assurance, and qualification testing *19*
9.1 Quality control during manufacturing *19*
9.2 Owner's quality assurance testing and inspection *19*
9.3 Qualification testing *19*

10 Determination of properties *20*
10.1 Number of samples *20*

Changes to this edition of S807 include the following:

- change to the scope of the Standard to include material properties of FRPs and the introduction of basalt fibers and specification of E-CR glass;
- addition of fine aggregate for sand coating; and
- addition of production lot size for straight, bent, and anchor-headed bars.



CSA S807:19 Specifications for fiber reinforced polymers
Recent Modifications

4.2.2.1

The manufacturer shall define the production lot size for the production method used for the FRP (e.g., by weight, area of cross-section, and linear measurement). The manufacturer shall record values for the amounts of materials used in each lot. The production lot size of straight bars shall be divided in sub-lots of 20 000 m of bars up to a maximum of 60 000 m of bars of the same diameter. The manufacturer's quality control tests and samples shall be in accordance with Tables 7 and 8 for the first sub-lot of 20 000 m of bars of each production lot. For the two subsequent sub-lots of 20 000 m each, the manufacturer's quality control tests shall include

a) fibre content;
b) glass transition temperature;
c) cure ratio;
d) water absorption for one week; and
e) apparent horizontal shear strength.

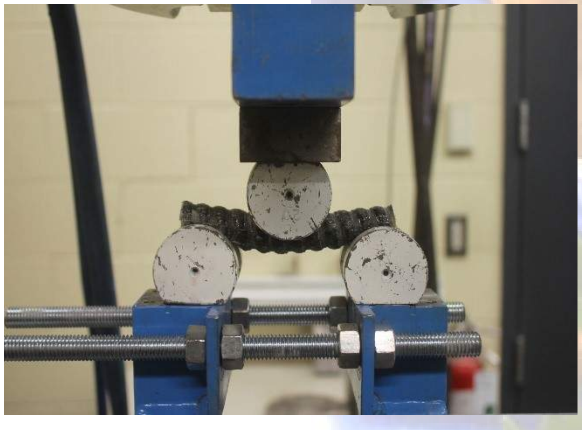


Table 7 (Concluded)

Property	Number and details of test specimens required: Qualification test	Manufacturer's QC	Owner's QA	Provided if needed for special applications†	Test method	Specified limits
Apparent horizontal shear strength by the short-beam method*	24 tests from 3 production lots for 10, 13, 15, 20, 25, and 32 mm or only the sizes manufactured by the supplier	5 tests for each bar size per lot used on project	5 tests for each bar size per lot used on project	N/A	ASTM D4475	≥ 35 MPa for Grade I bars ≥ 40 MPa for Grade II bars ≥ 45 MPa for Grade III bars
Apparent horizontal shear strength in high pH solution at 60 °C (alkali resistance)*	24 tests from 3 production lots for 10, 13, 15, 20, 25, and 32 mm or only the sizes manufactured by the supplier	N/A	N/A	N/A	ASTM D4475 Test duration: 3 months	The average from testing shall not be less than 85% of the average from room temperature testing for qualification (Table 7).

CSA S807:19 Specifications for fiber reinforced polymers
Recent Modifications

Table 9
Minimum pullout capacity of anchor-headed bars
(See Table 7.)

Fibre	Diameter, mm	Minimum pullout capacity, kN	Slip at loaded end limits
Glass	15	100	At 100 kN no more than 0.5 mm
	20	120	At 100 kN no more than 0.5 mm

Table 7 (Concluded)

Property	Number and details of test specimens required: Qualification test	Manufacturer's QC	Owner's QA	Provided if needed for special applications†	Test method	Specified limits
Pullout capacity of anchor-headed glass fibre-reinforced polymer bars	24 tests from 3 production lots for 15 and 20 mm or only the sizes manufactured by the supplier	N/A	N/A	5 tests on bar size requested	ASTM D7913/D7913M A 300 × 300 × 300 mm concrete block shall be used.	Minimum values defined in Table 9.
Durability characteristic of anchor-headed glass fibre-reinforced polymer bars	24 tests from 3 production lots for 15 and 20 mm or only the sizes manufactured by the supplier	N/A	N/A	5 tests on bar size requested	Test method in Annex F	The average from testing shall not be less than 80% of the average unconditioned testing for qualification (this Table).

CSA S807:19 Specifications for fiber reinforced polymers
Recent Modifications

Production lot size

The production lot size of straight bars shall be divided in sub-lots of 20,000 m of bars up to a maximum of 60,000 m of bars of the same diameter.

QC tests as indicated in Tables 3 and 4 for the first sub-lot of 20,000 m.

For the two subsequent sub-lots of 20,000 m each, the QC tests shall include:

- fibre content;
- glass transition temperature;
- cure ratio;
- water absorption for one week; and
- apparent Horizontal Shear Strength.

CSA S807:19 Specifications for fiber reinforced polymers Recent Modifications

Production lot size

The production lot size of bent bars of congruent shape and anchor-headed bars shall be divided in sub-lots of 2000 pieces up to a maximum number of 6000 pieces.

QC tests as indicated Tables 3 and 4 for the first sub-lot of 2000 pieces.

For the subsequent two sub-lots of 2000 pieces each, the QC tests shall include:

- fiber content;
- glass transition temperature;
- cure ratio;
- water absorption for one week; and
- apparent Horizontal Shear Strength.

CSA S807:19 Specifications for fiber reinforced polymers
Recent Modifications

- **Alkali resistance in high pH solution (without load), the tensile capacity retention ≥ increased from 80% to 85% UTS.**

- **Alkali resistance in high pH solution (with load), the tensile capacity retention ≥ increased from 70% to 75% UTS.**

CSA S807:19 Specifications for fiber reinforced polymers Recent Modifications

Table 1A
Designated Bar Diameter and Nominal Area
(Same as ASTM D7957/D7957M – 17)

Diameter mm	Nominal cross-sectional area (mm2)	Minimum measured cross-sectional area (mm2)	Maximum measured cross-sectional area (mm2)
8	50	48	79
10	71	67	104
13	129	119	169
15	199	186	251
20	284	268	347
22	387	365	460
25	510	476	589
30	645	603	733
32	819	744	894
36	1006	956	1157

CSA S807:19 Specifications for fiber reinforced polymers
Recent Modifications

MinimumTensile Strength for GFRP Rebars (Grade III)

Minimum tensile strength for straight bars (#4 to #8) :
1000 MPa (145 ksi)

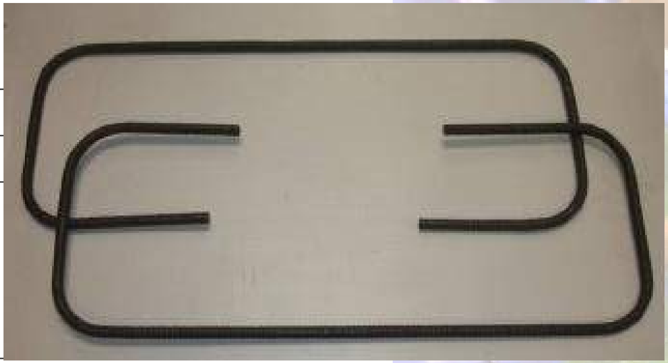
Minimum tensile strength for straight portion of bent bars (#4 to #8) :
1000 to 850 MPa (145 to 125 ksi)

Minimum tensile strength for bent portion of bent bars (#4 to #8) :
450 to 390 MPa (65 to 57 ksi)

CSA S807:19 Specifications for fiber reinforced polymers
Recent Modifications

Table 6
Grades of FRP bent bars corresponding to their minimum modulus of elasticity of the straight portion, GPa
(See Clauses 8.3 and 10.1 and Table 7.)

	Grade IB	Grade IIB	Grade IIIB
Designation	**Individual bars**	**Individual bars**	**Individual bars**
AFRP	50	60	65
BFRP	50	55	60
CFRP	80	100	120
GFRP	40	45	50



Annex E (normative)
Method of test for determining the strength of the bent portion of FRP reinforcing bars

Note: *This Annex is a mandatory part of this Standard.*

E.1 Scope

E.1.1
This test method is used to determine the force in the straight portion of a bent fibre-reinforced polymer (GFRP) bar, used as internal reinforcement for concrete structures, when rupture occurs in the bend.

Annex E (normative)
Method of Test for Determining the Strength of the Bent Portion of FRP Reinforcing Bars

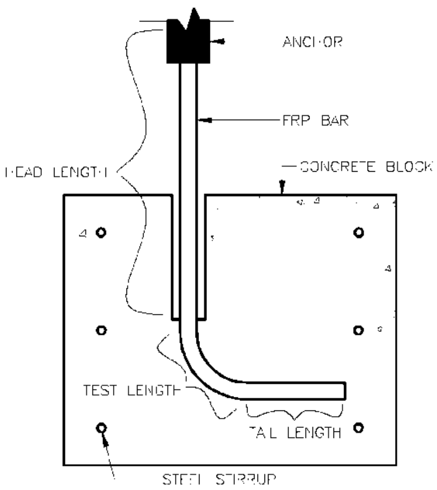


Figure 1 – General Arrangement

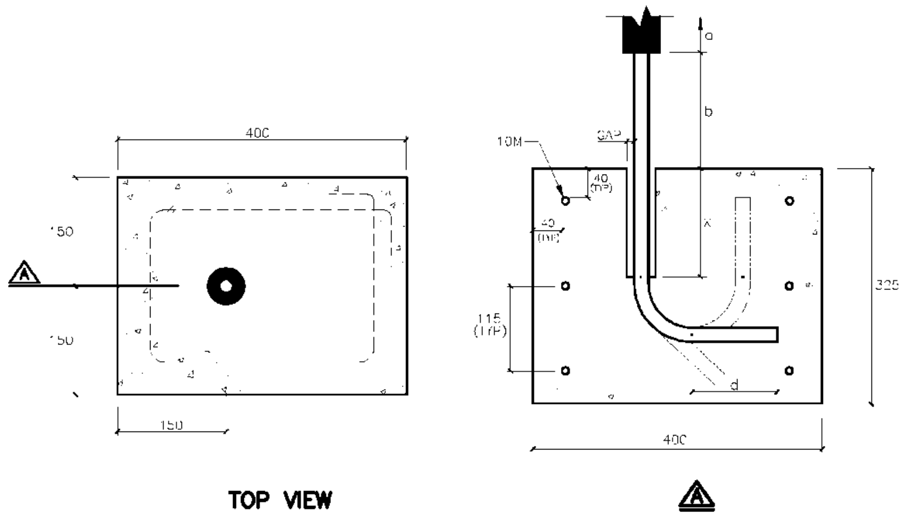


Figure 2 – Dimensional Arrangement of the Block
(nominal diameter of 20 mm or less, bent at an angle between 0 and 180 degrees, and manufactured with a bend-radius-to-bar-diameter ratio of 4 or less)

CSA S807:19 Specifications for fiber reinforced polymers
Recent Modifications

GFRP #5 Lot #	Ultimate Load (kN)	Ultimate Stress (MPa)	Tensile Modulus (GPa)	Ultimate Strain (%)
1	335	1180	63	1.9
2	307	1082	62	1.8
3	318	1118	64	1.7

GFRP #6 Lot #	Failure load (kN)	Bend Strength (MPa)	Strength Reduction Factor (%)
1	182	639	54
2	179	630	58
3	187	659	59

FRP Recent CSA Standards & Specifications

CSA S6:19

Canadian Highway Bridge Design Code

Committee Member's Copy Only. Distribution Prohibited.

CSA S6-19

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.

New Clauses in Chapter 16 of CSA S6-19 (in red)

- 16.1 Scope
- 16.2 Definitions
- 16.3 Abbreviations and symbols
- 16.4 Durability
- 16.5 Fibre-reinforced polymers
  - 16.5.1 FRP bars and grids
  - 16.5.2 FRP strengthening systems
  - 16.5.3 FRP tendons
  - 16.5.4 Material properties
  - 16.5.5 Confirmation of the specified tensile strength
  - 16.5.6 Resistance factor
  - 16.5.7 Minimum bend-radius-to-bar-diameter ratio of bent FRP bars

CSA GROUP™

New Clauses in Chapter 16 of CSA S6-19 (in red)

- 16.6 Fibre-reinforced concrete
- 16.7 Externally restrained deck slabs
- 16.8 Concrete beams, slabs and columns
    - 16.8.2.4 Deflections and rotations
    - 16.8.4.2 Development length of FRP bundled bars
    - 16.8.4.3 Development length of FRP bent bar

  – 16.8.5 Development of headed FRP bars and grids
    - 16.8.5.1 Anchorage of headed FRP bar
    - 16.8.5.2 Development length for FRP grids

  – 16.8.7 Design for shear and torsion
  – 16.8.9 Compression components
  – 16.8.10 Cast-in-place deck slabs with FRP stay-in-place structural forms
  – 16.8.11 Strut-and-tie model for deep beams, corbels, and short walls

New Clauses in Chapter 16 of CSA S6-19 (in red)

- **16.9 Stressed wood decks**
- **16.10 Barrier walls**
  - 16.10.1 FRC barrier wall design details
  - 16.10.2 Barrier wall design details with front and back reinforcement
  - 16.10.3 Test Level 1, 2, 4, and 5 barrier wall design details
  - 16.10.4 Factored punching shear resistance of concrete barrier to transverse traffic
- **16.11 Repair of damaged bridge barrier walls, curbs, and slabs reinforced with FRP bars**
- **16.12 Rehabilitation of existing concrete structures with FRP**
  - 16.12.4 Retrofit for enhancement of concrete confinement
  - 16.12.5 Retrofit for lap splice clamping

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New Clauses in Chapter 16 of CSA S6-19 (in red)

- *Annex A16.1 (informative)740*

Installation of FRP strengthening systems

- *Annex A16.2 (normative)743*

Quality control for FRP strengthening systems

- *Annex A16.3 (informative)*

GFRP composite bridges

Durability/Material properties/New structural materials

16.5.3 Resistance factor (phi factor)

phi factor of GFRP bars increased from 0.55 to 0.65

Rational:

Durability of GFRP bars has been enhanced during the last few years:

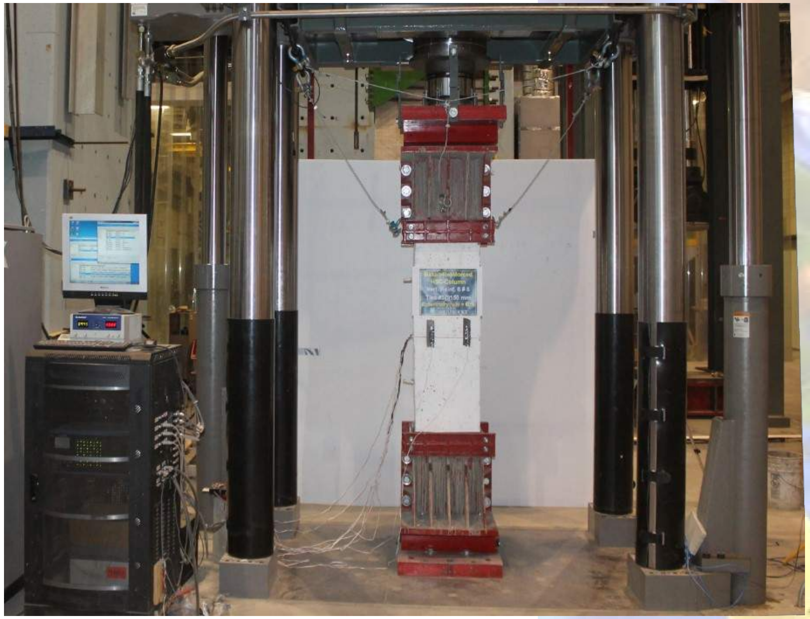
1. Better manufacturing process and quality control
2. Better constituents : 1) ECR-Glass versus E-Glass; Most of the GFRP bar manufacturers are using boron-free glass fibres (ECR, commercial name Owens Corning), 2) High-performance resins (advances in polymer chemistry)
3. Durability tests in alkaline solution show high strength retentions without load and under loads (CSA S807): 1) greater than 90-95% (without load), 2) greater than 83-90% (with load).
4. Recently the MTQ took cores for in-service bridges (more than 15 years). No degradation.
5. Durability of GFRP versus durability of concrete? The phi for concrete in the CHBDC is 0.75.

New Clauses in Chapter 16 of CSA S6-19

Maximum Axial Capacity

$$P_0 = \phi_c \alpha_1 f_c' A_g + \phi_f f_f A_f$$

$$f_f = 0.002 E_f$$

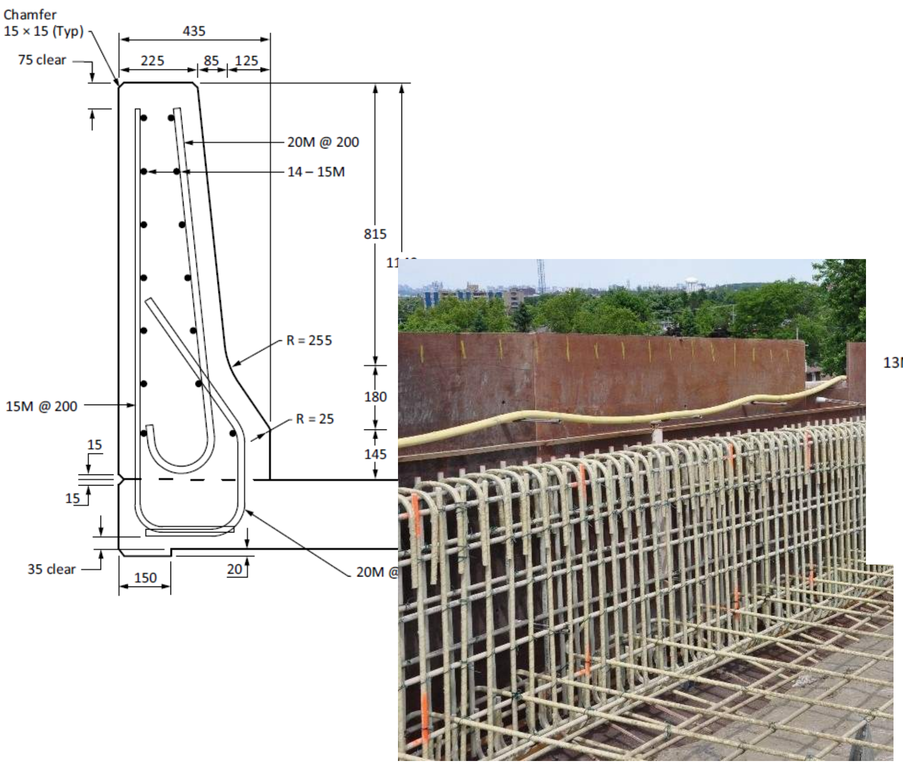


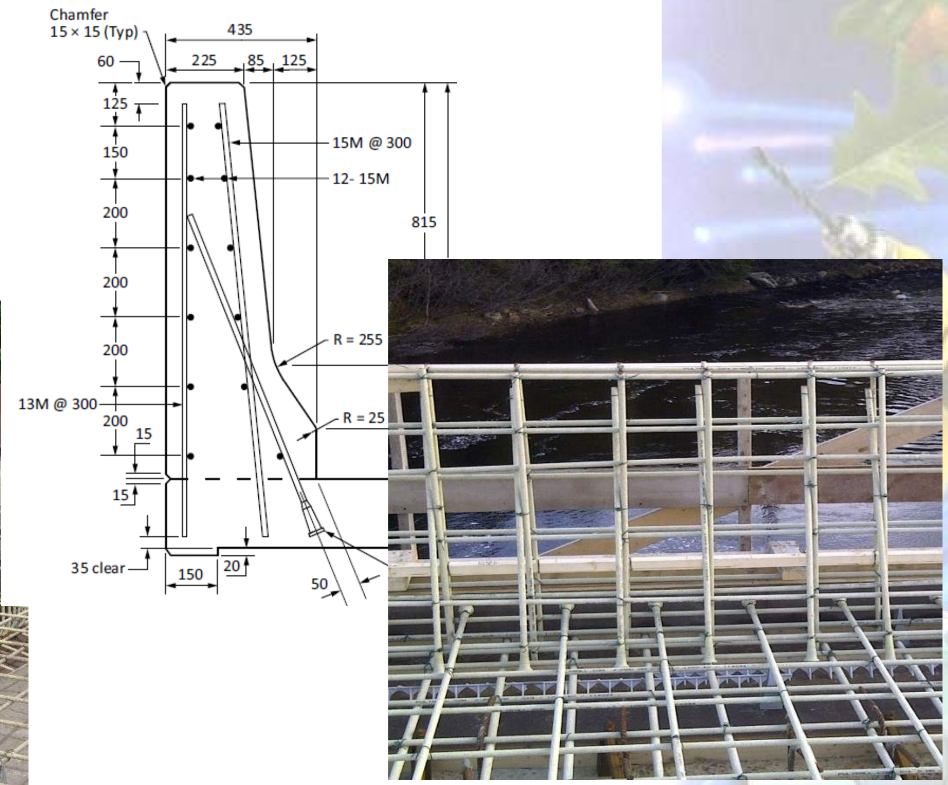
Longitudinal FRP reinforcement may be used in members subjected to combined flexure and axial load. However, the compressive strength of FRP reinforcement shall be limited to a stress corresponding to a strain of 0.002 in the calculation of the factored axial and flexural resistance of reinforced concrete members.

New Clauses in Chapter 16 of CSA S6-19

Barrier walls

The use of headed bars is now allowed for double-face reinforced concrete barriers





CSA S413 Parking Structures
New edition is under preparing


CSA GROUP™

S413-14
(reaffirmed 2019)

Parking structures

REVISED APRIL 2018

Objective:

Inclusion of FRP Reinforcing as an alternative reinforcing to traditional black steel rebars in the New Edition of S413

CSA S900.2 Structural Design of Wastewater Treatment Plants

S900.2

CSA Group

Structural Design of Wastewater Treatment Plants – Seed Document

Objective:

Inclusion of FRP Reinforcing as an alternative reinforcing to traditional black steel rebars in the New Edition of CSA S900.2

Thank you for your attention

Contact:

E-mail:brahim.benmokrane@usherbrooke.ca

UNIVERSITY OF SOUTHERN QUEENSLAND
AUSTRALIA

GFRP Bars for Reinforced Concrete Structures –
Review of current practice in Australia

Dr Allan Manalo
Professor in Civil Engineering (Structural)
Associate Head - Research, School of Civil Engineering and Surveying, Faculty of Health, Engineering and Sciences
Theme Leader – Civil Composites, Centre for Future Materials (CFM)
University of Southern Queensland
Toowoomba, Queensland 4350, Australia

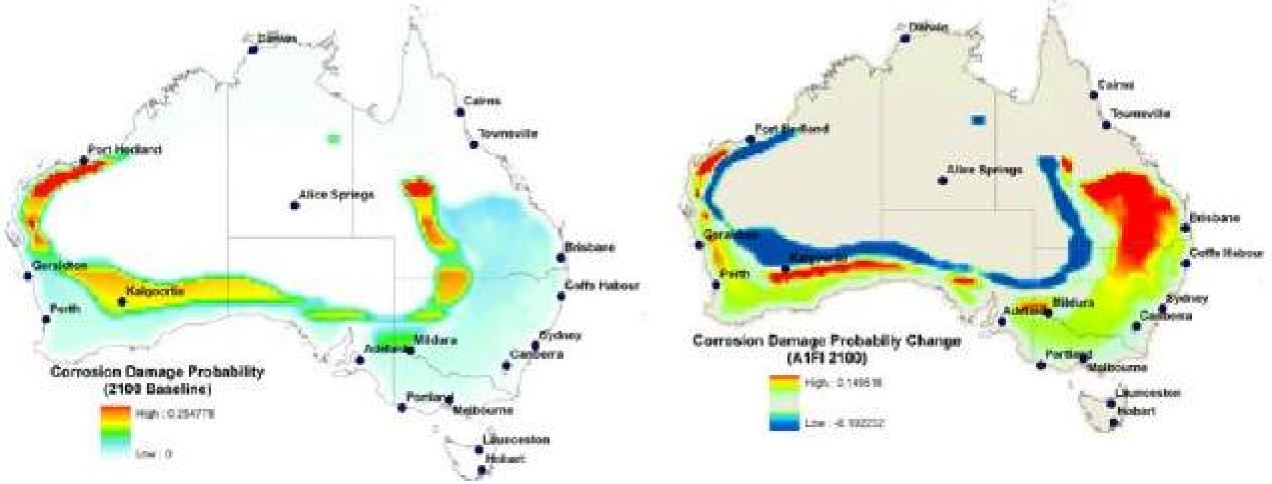
Centre for Future Materials

USQ AUSTRALIA

The need for FRP bars

Corrosion of steel reinforcement

- Most concrete bridge infrastructure starts to deteriorate only after 30 years of service (Austroads, 2016).
- Repair or replacement costs associated with steel corrosion in Australia are estimated at **AU$13 billion per year**.
- The risk of corrosion is likely to increase significantly due to climate change (Wang et al. 2012).

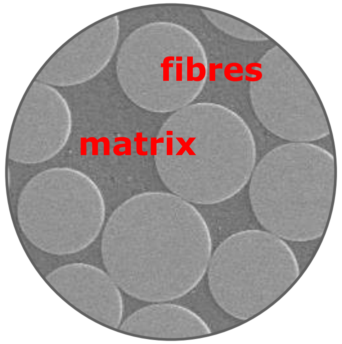


Probability of corrosion damage by 2100 (Wang et al. 2012)

http://www.cairnspost.com.au/realestate/warning-to-check-for-concrete-cancer-in-older-unit-high-rise-complexes/story-fnjuflgv-1226802351244

Centre for Future Materials

The solution



Fibre reinforced polymer (FRP) bars

Advantages

- Impervious to chloride ion and chemical attack
- Tensile strength greater than steel
- 1/4th weight of steel reinforcement
- Transparent to magnetic fields and radio frequencies
- Electrically and thermally non-conductive

Centre for Future Materials

Current applications

- GFRP bars are used in Australia mainly as reinforcement in concrete structures exposed to harsh environmental conditions.
- 20% of market are for electrical and magnetic non-conductive applications including rail signal loops, hospital MRI's and nuclear science buildings
- Market penetration targets are **marine infrastructure**, **precast concrete** and **electrical** applications.

Anthon Jetty Wyndham, WA

Seawall replacement, Sylvania Waters Sydney

Annex extension, Toowoomba City Hall refurbishment project

Detector loop at Goldcoast Light Rail project

erials

Recent applications

Pinkenba Wharf in Brisbane

- 252m long, 16m wide wharf comprising of **191 precast geopolymer concrete deck reinforced with GFRP bars**.
- Largest use of GFRP bars in Australia in a single job, i.e. 305 km (**152 tonnes**) of 16 mm, 19 mm, and 22 mm diameter bars.
- Designed following the **CSA S806-12** with reference to relevant AS standards, i.e. AS3600 and loading codes.

Recent applications

Molecular Horizons Building, University of Wollongong

- Specified for electromagnetic neutrality and sensitive electrical research equipment. Tested and certified for fire performance.
- Designed following the **CSA S806-12** with reference to relevant AS standards, i.e. AS3600 and loading codes.
- Uses over **50 tonnes** of GFRP bars in 14 m deep piles, pile caps, ground slabs, columns and walls through to the 2^{nd} story and first floor suspended slab.

Lifting and installation of pile cage


Pile cage in position


Pile cage in bored pier hole

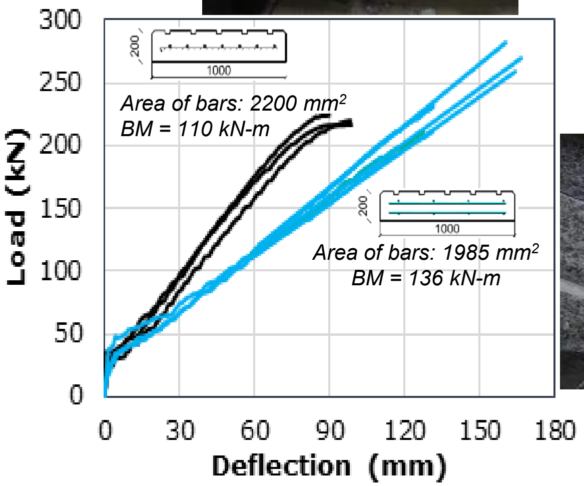

Pilecap

Recent applications

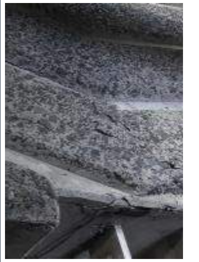
Precast boat ramp planks

- Optimal design of precast concrete ramp planks reinforced with GFRP bars.
- Has the potential to eliminate the use of expensive silica fume in concrete mix.

Test set-up for boat ramp planks



Load and deflection behaviour



Mesh fabrication and mesh installation of GFRP reinforced is **30% faster** than GS reinforced (121.36 vs 173.82 worker minutes per 30 planks):

Installation of planks at Parkyn Parade boat ramp in Mooloolaba, Sunshine Cost.

Standard drawings approved by TMR:

[SD4003 - Precast planks for boat ramp - Type RG4000 FRP (PDF, 459 KB)]

Published at:

https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications

Centre for Future Materials

Advanced Qld Industry Fellowship

GFRP-reinforced precast concrete in boating and marine infrastructure

Precast concrete pontoons

https://styrouae.com/insulation-and-construction/styro-eps-for-pontoon-and-buoy/

Wharves and jetties

https://www.xypex.com.au/Flinders-Ports-Berth-8-Outer-Harbour-Grain-Wharf~572

Precast concrete marine piles

https://lockesolutions.com/wp-content/uploads/2017/08/4.jpg

Floating walkway

http://yallabook.com/guide/en/show.php?nid=2355&china-s-hongshui-river-floating-walkway-twice-length-manhattan

Rehabilitation of marine infrastructure

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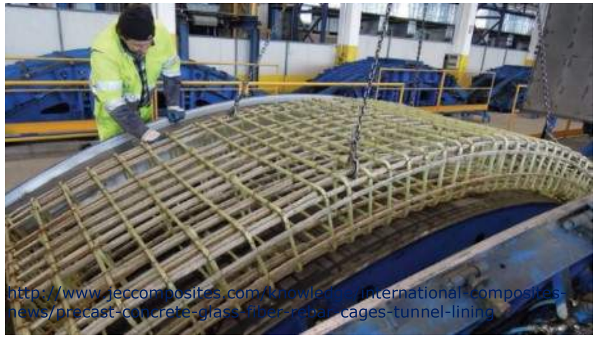
Other opportunities

GFRP-reinforced precast concrete in tunnels and railways

Challenges:

- Significant outlay for government
- Severe atmospheric condition, *i.e. sulphur dioxide fumes from diesel powered engines*
- Stray current corrosion in electrified railway systems
- Aggressive soils, high moisture and seepage
- Costly maintenance



GFRP reinforced concrete culverts

Ballastless track reinforced with GFRP bars

Continuously GFRP reinforced concrete track slabs

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USQ
AUSTRALIA

Education and Training

CIV8803 – Mechanics and Technology of Fibre Composites
Online course offered by USQ

Technology workshops:

to provide practising Australian engineers and civil engineering firms, as well as engineering students, with the knowledge necessary to ***design concrete structures with GFRP reinforcing bars***.

Technology transfer:

Practical design and application of GFRP bars in construction including handing, installation and assembly.

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Design codes/specifications

BD-108 Fibre-Reinforced Polymer (FRP) Bars

new Australian Standard for 'Design of concrete structures using Fibre-Reinforced Polymer (FRP) bars'
(proposal under review by members of BD-108 and other interested stakeholders and for consideration by Standards Australia)

Nominating Organisations :

- **University of Southern Queensland**
- Australian Institute of Building
- AUSTROADS
- Cement Concrete & Aggregates Australia
- Composites Australia Inc
- National Precast Concrete Association Australia
- Concrete Institute of Australia
- Consult Australia
- University of Melbourne

Current Australian market

- GFRP bars are commonly used in Australia, with basalt FRP bars are now being introduced.
- Between 2012 and 2017, there were more than ***1.5 million meters*** of GFRP bars installed in actual construction projects.
- Market for GFRP bars increases by ***13% per year***, and with an estimated market value of around AU$7.0 million in 2020.

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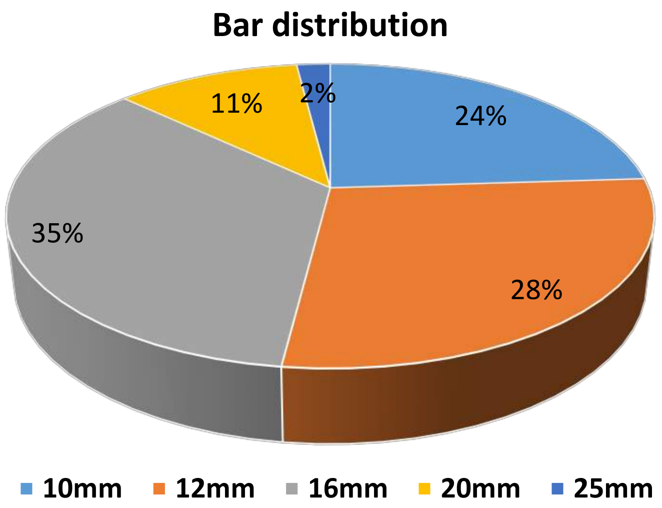
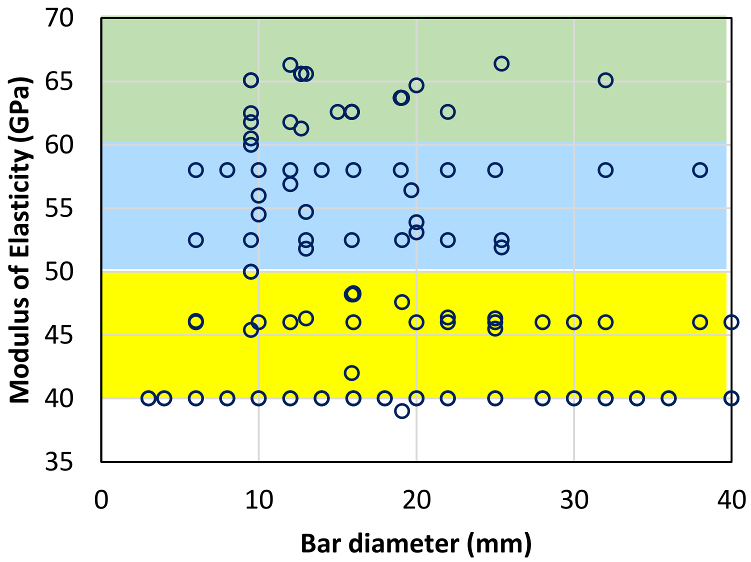
State-of-the-current practice

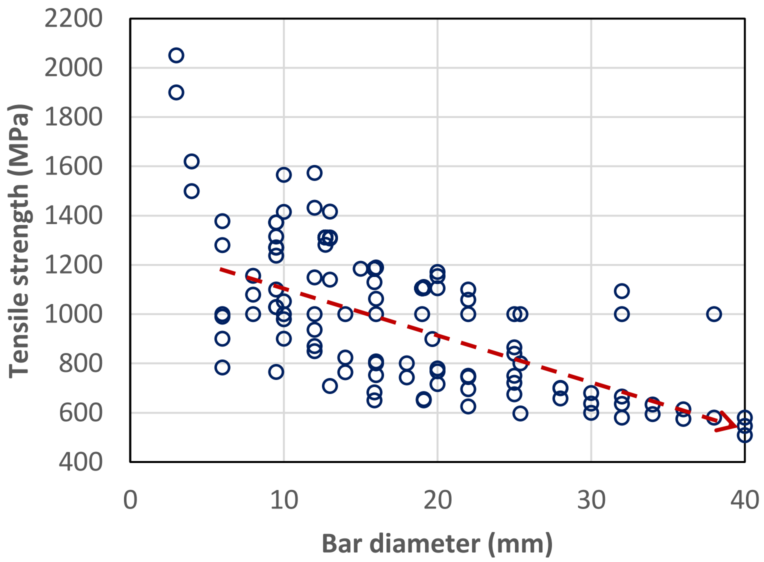
- 3 grades of FRP bars

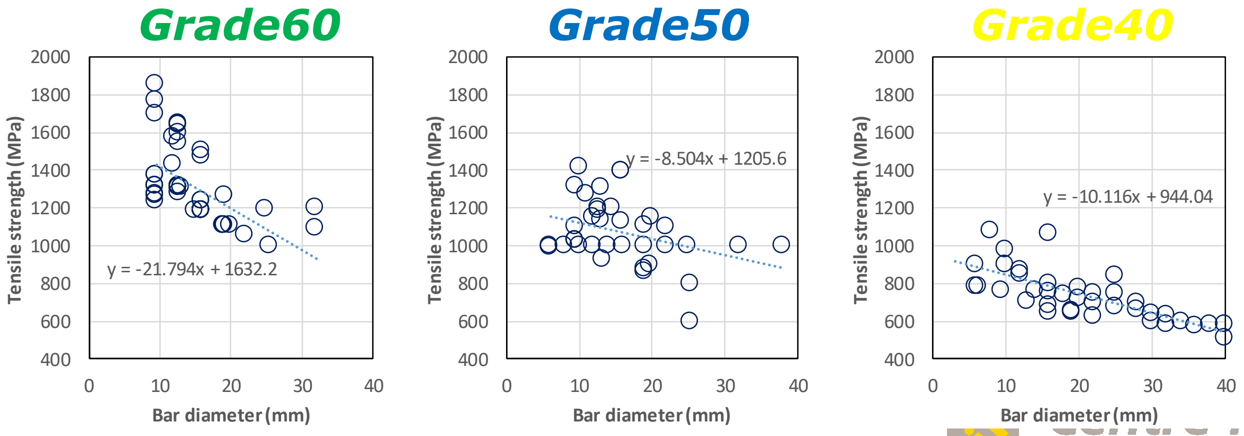
Grade40: 40 GPa $\leq$ E < 50 GPa
Grade50: 50 GPa $\leq$ E < 60 GPa
Grade60: E $\geq$ 60 GPa

- Tensile strength: 500-2000 MPa
- Tensile strain: 1.1 to 2.7%





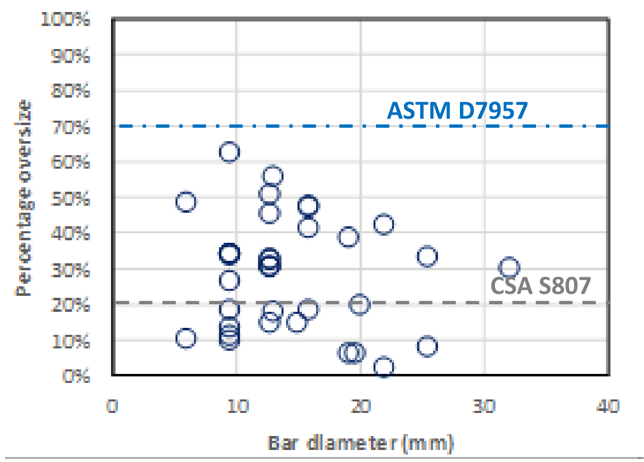




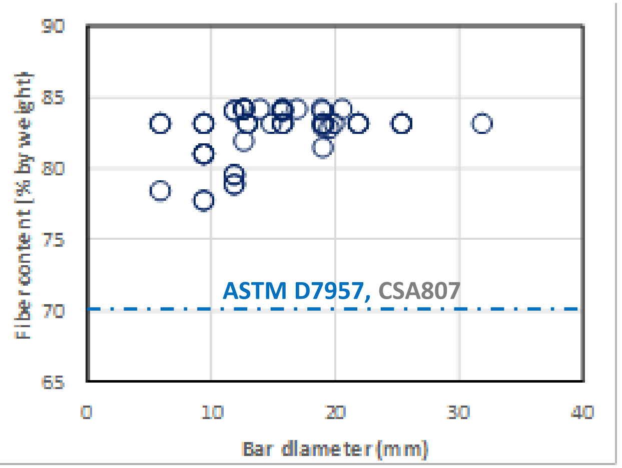
Tensile strength of FRP bars based on MOE

Future Materials

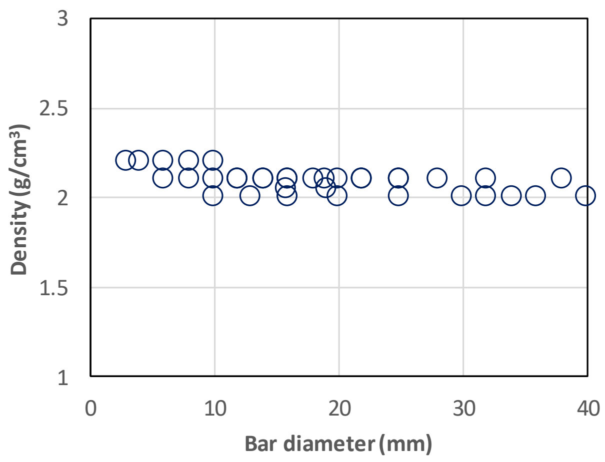
State-of-the-current practice



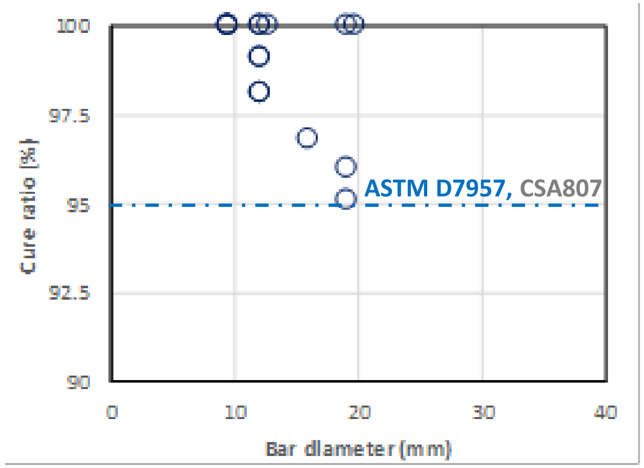
Percentage oversize



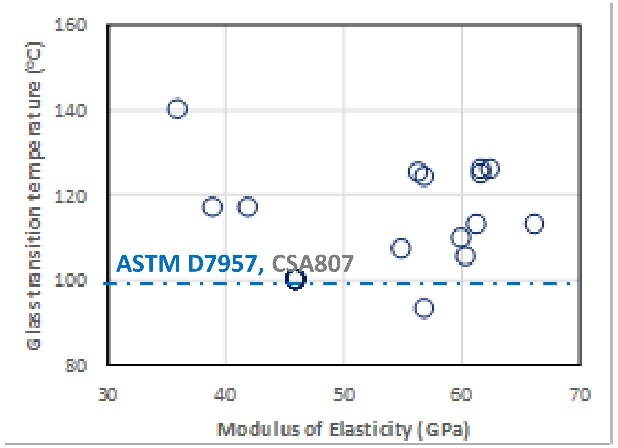
Fibre content (% by weight)



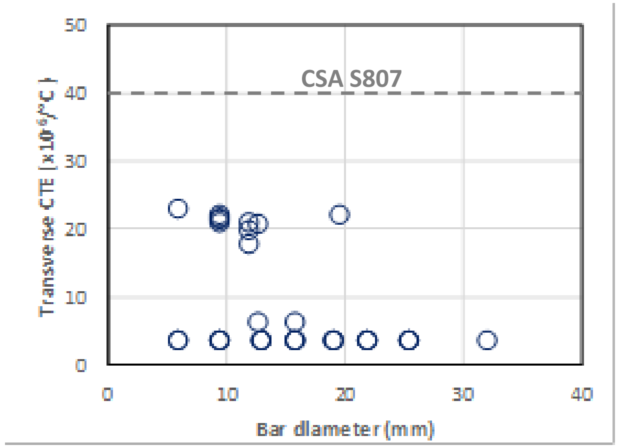
Density



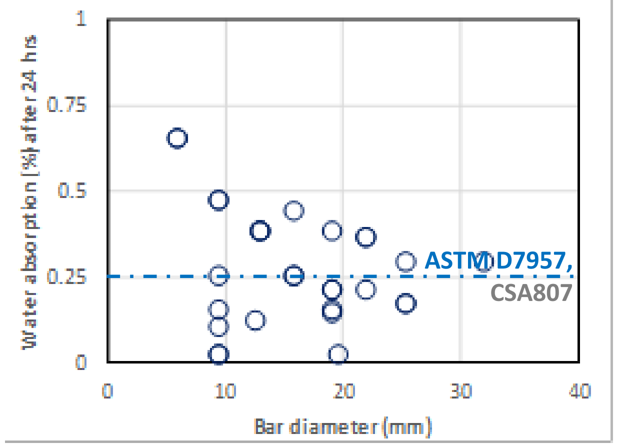
Cure ratio



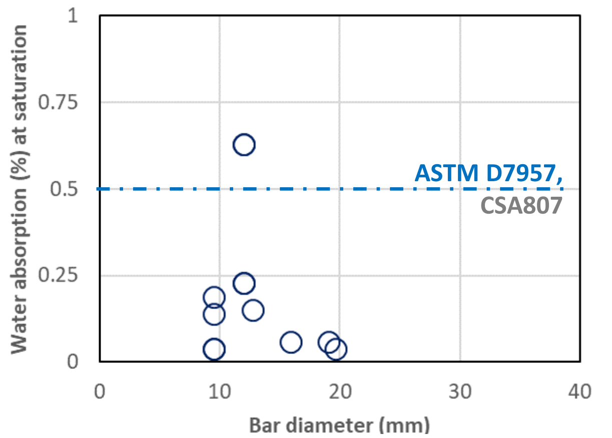
Glass transition temperature



Transverse CTE



Moisture absorption at 24 hrs

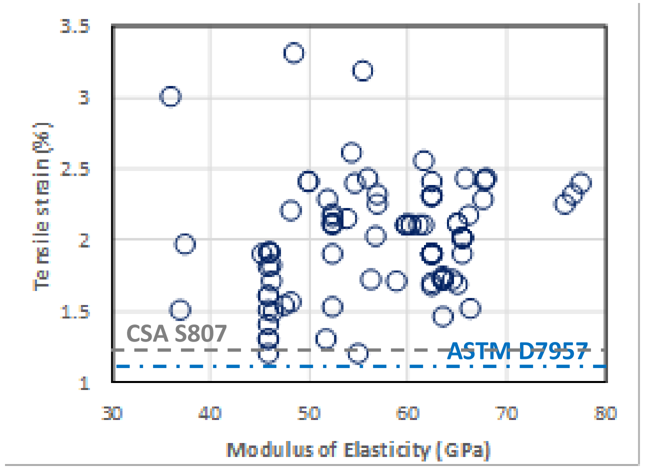


Moisture absorption at saturation

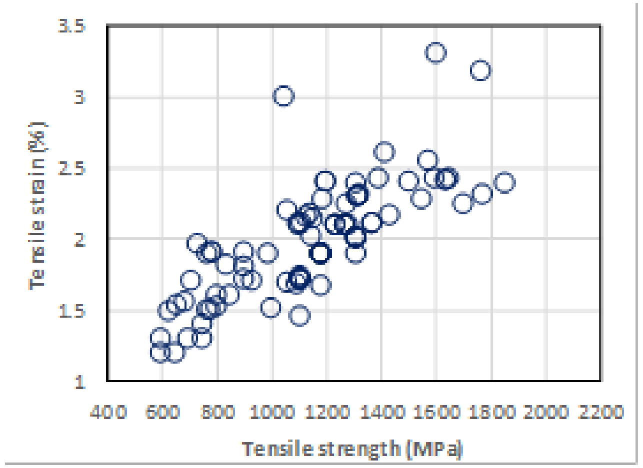
Physical properties of GFRP bars

USQ AUSTRALIA

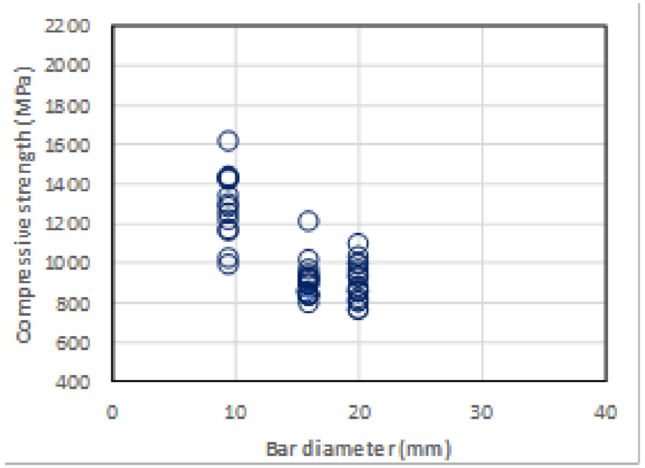
State-of-the-current practice



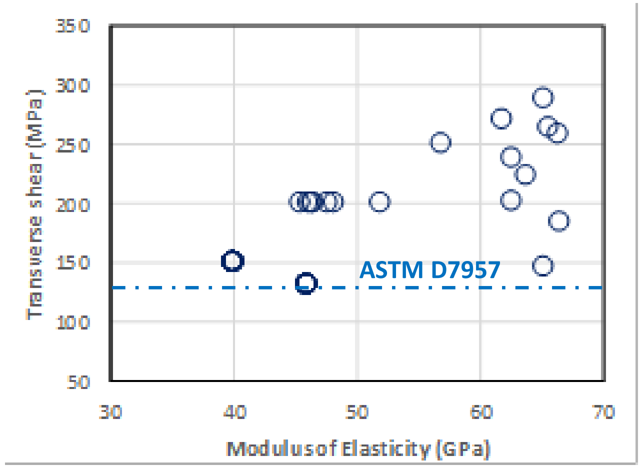
Tensile strain vs MOE



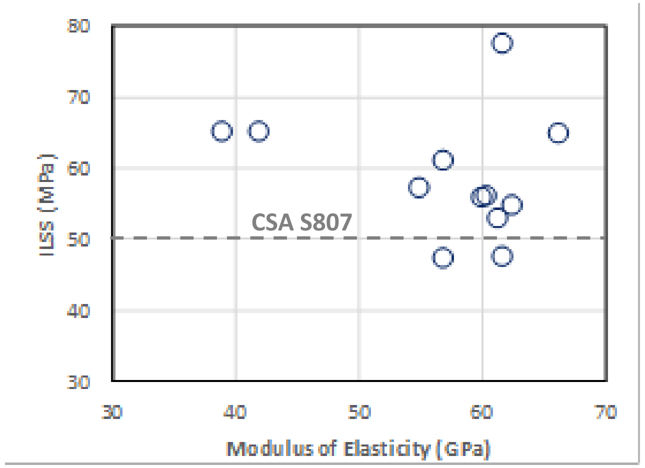
Tensile strain vs strength



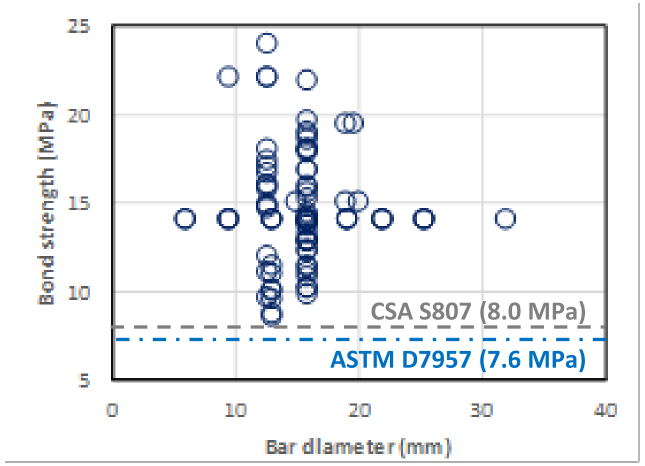
Compressive strength vs bar diameter



Transverse shear strength vs MOE



ILSS vs MOE



Bond strength vs bar diameter

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Mechanical properties of GFRP bars

Summary:

- GFRP bar is an emerging technology that can play a significant role in the Australian construction and civil infrastructure industries.
- There is a high variability on the physical and mechanical properties of GFRP bars available in the Australian market, majority of which are solid round bars that are made from glass fibers and vinylester resin.
- FRP bars should comply with the minimum requirements for geometric, material, physical, mechanical, and durability properties for their effective use as internal reinforcement in concrete structures.
- The properties of GFRP bars available in Australia are in alignment with the property limits suggested by CSA S807 and ASTM D7957.

UNIVERSITY OF SOUTHERN QUEENSLAND
AUSTRALIA

Thank you.

Find out more:

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Trends and Development of Codes and Specifications on GFRP Bars for Concrete Structures in Europe

Emmanuel FERRIER

LMC² - Université LYON 1

[d]International Workshop on GFRP bars for Concrete Structures

+

Laboratoire des Matériaux Composites pour la Construction EA 7427

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Outline

- Trends of GFRP used in Europe
- Codes and specifications
- AFGC Working group
- Conclusions

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Pile foundation FRP reinforcement

sireg

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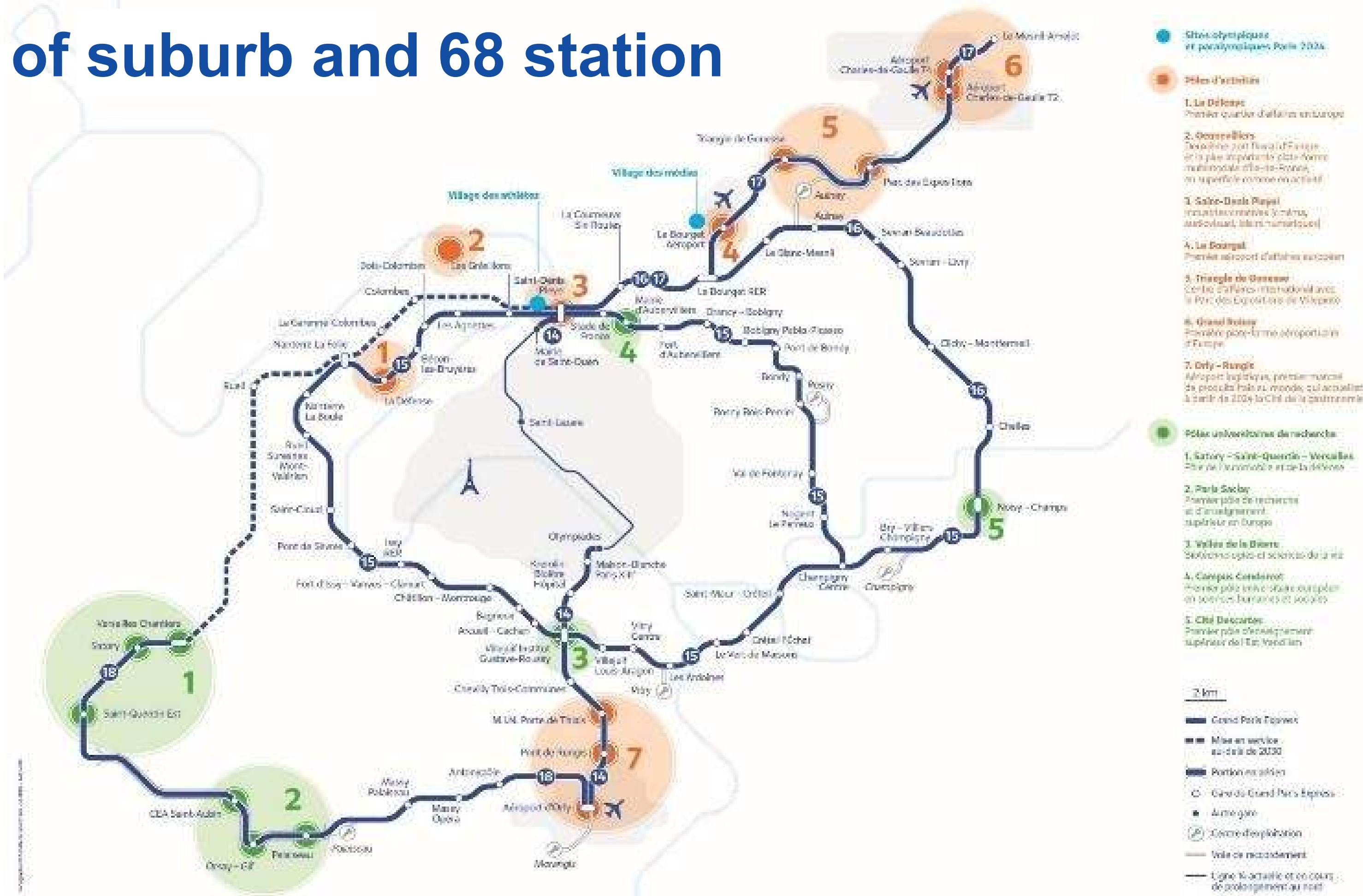
Grand PARIS PROJECT

200 kms of suburb and 68 station



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Grand PARIS PROJECT

GFRP in foundation walls

Installation de cages d'armature en fibres de verre Combar© au droit d'un tympan de sortie de tunnelier en gare de FIVC.

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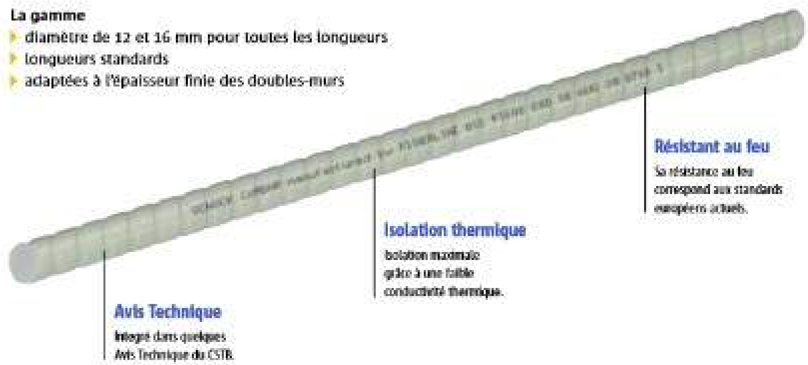
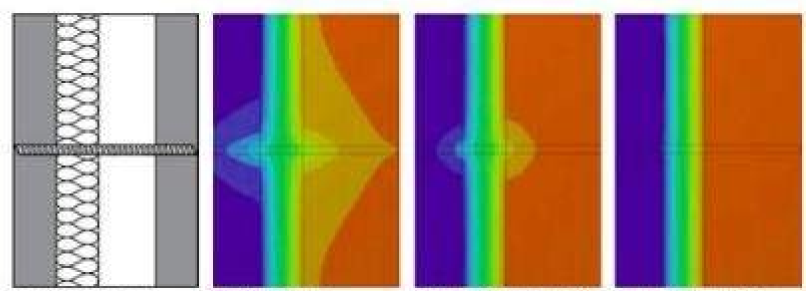
Soft Precast wall bolt





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Soft Precast wall bolt

FFB FEDERATION FRANÇAISE DU BATIMENT

Le Bâtiment, une richesse pour la France

La FFB | Qui sommes nous | Contact | Réseau FFB | French building federation | Adhérer | Annuaire | Salle de presse | Médiathèque | Actualités | Le Bâtiment et vous | En chiffres | Artisanat | GPS Artisan

Vous êtes ici > Accueil > La FFB > Médiathèque > Bâtimétiers

Bâtimétiers N° 8 - 2007 | Gros oeuvre/structure

LE PRÉMUR, ALTERNATIVE AU BÉTON BANCHÉ ?

Livré sous forme de panneaux sur le chantier, le prémur peut être intéressant pour réaliser certains types d'ouvrages ou certaines parties de bâtiment. Sous Avis technique du CSTB, sa mise en œuvre est exigeante et les entreprises doivent se poser la question de son coût.

Depuis une dizaine d'années, il existe une alternative au béton banché pour construire des murs porteurs : le prémur. Préfabriqué en usine, il se compose de deux parois minces en béton armé (4,5 à 7,5 cm), généralement sans acier en attente, maintenues espacées par des raidisseurs métalliques horizontaux. Une fois positionnés et stabilisés, les panneaux de prémur font office de coffrage : on y glisse des armatures de liaison et on y coule du béton prêt à l'emploi, ce qui garantit la stabilité de la construction. Cette technique peut être employée pour réaliser différents murs porteurs de bâtiments industriels, de bureaux ou d'habitations, pouvant comporter plusieurs niveaux de sous-sols, ou pour des murs de soutènement ; elle répond aux exigences de la construction en zone sismique. En fonction des contraintes qui lui sont demandées, l'épaisseur du prémur varie de 16 à 40 cm, tandis que sa hauteur varie de 1 à 12 m, pour une largeur de panneaux allant jusqu'à 3,80 m. S'il s'agit encore d'un marché de niche, avec un petit nombre de fabricants, l'intérêt des entreprises de maçonnerie pour cette technique va croissant. Avec 1,2 million de m2 en 2006, le prémur représente 7 % du total des murs construits.

With 1,2 million of m^2 in 2006, precast wall represent 7 % of the total building wall.

Source FFB

If all conector are made of FRP that make 6 million of conector or 1,2 million of linear meter per year!

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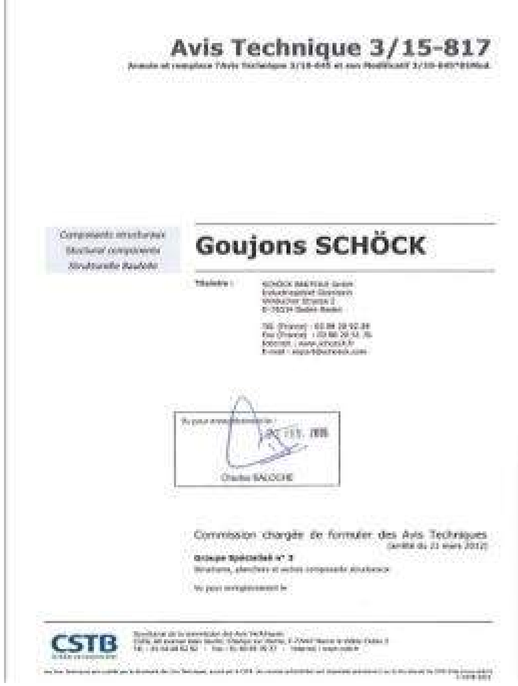
Soft Precast wall bolt


Avis Technique 3/15-817

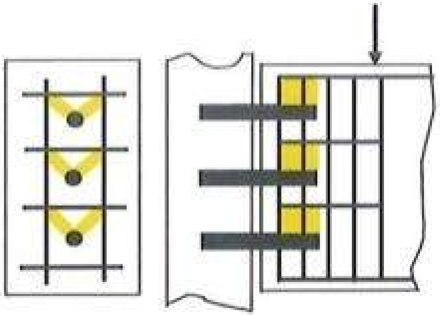
Goujons SCHÖCK

Commission chargée de formuler des Avis Techniques

CSTB

Logements Bellerive

Figure 2-6: FRP rebars (Schöck Bauteile GmbH)



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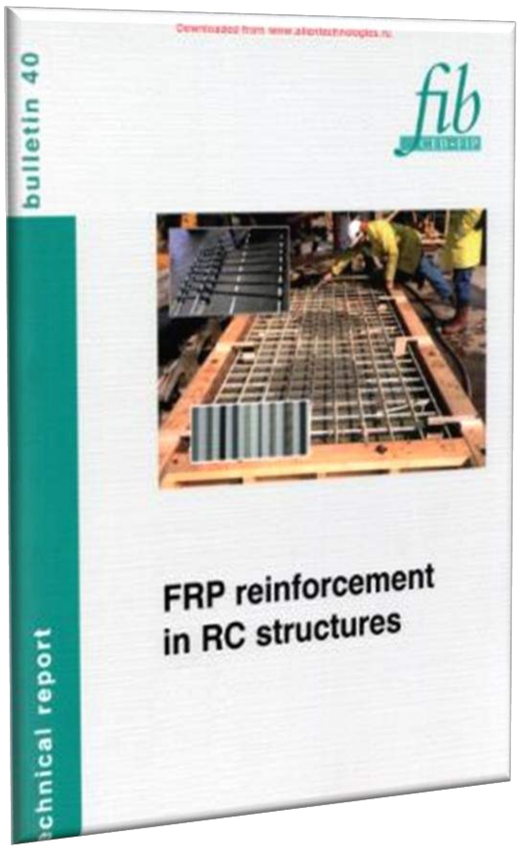
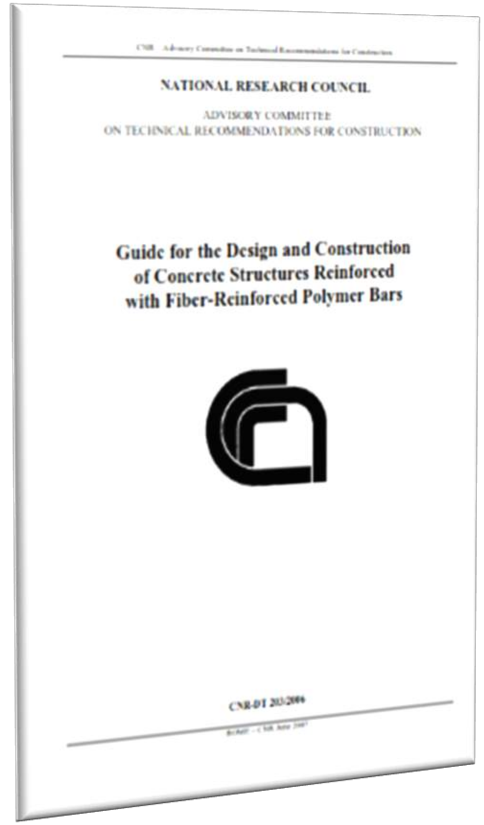
Outline

- Trends of GFRP used in Europe
- Codes and specifications
- AFGC Working group
- Conclusions

Codes and specification in Europe





French AFGC working group 2018-2021

Outline

- Trends of GFRP used in Europe
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- Conclusions

Association Française de Génie Civil

GC'2019

Groupe de travail:

Utilisation d'armatures composites (à fibres longues et à matrice organique) internes pour le renforcement du béton armé dans le cas de nouvelles structures

Coordinateurs:
Sylvain Chataigner *(IFSTTAR)*, **Laurent Michel** (*Université Lyon* I)

Animateurs:
Karim Benzarti (*IFSTTAR*), Emmanuel Ferrier (*Université Lyon* I), Elhem Ghorbel (*Université Cergy* Pontoise), Marc Quiertant (*IFSTTAR*), Arnaud Rolland (*CEREMA*)

64 participants

Université, Grandes Ecoles		
Ferrier	Emmanuel	LMC²
Michel	Laurent	LMC²
Jurkiewiez	Bruno	LMC²
Foret	Gilles	Ecole des Ponts
Ghorbel	Elhem	IUT Cergy Pontoise
Feraille	Adélaide	Ecole des Ponts
Benmekrane	Brahim	Université Sherbrooke

Centre de recherches et d'études techniques		
Rolland	Arnaud	CEREMA
Benzarti	Karim	IFSTTAR
Quiertant	Marc	IFSTTAR
Chataigner	Sylvain	IFSTTAR
Bouteille	Sebastien	CETU
Berthoz	Nicolas	CETU
Roth	Jeremy	CEREMA
Pineau	François	ANDRA
Le Roy	Corentin	CEREMA
Meyer	Caroline	CEREMA
Tessier	Christian	IFSTTAR
Philippot	Bertrand	IFSTTAR
Henriques	David	CSTB
Junes	Angel	CSTB
Desbois	Tiffany	CEREMA
Deme	Baila	Société du Grand Paris
Priol	Gréhoire	Société du Grand Paris
Beaufond	Thierry	Société du Grand Paris

Entreprises du Bâtiment et des Travaux Publics		
Simon	Alain	Eiffage
Sabir	Najeeb	FREYSSINET
Louchart	Jean-Noel	Etandex
Ayme	Adrien	Etandex
Vimond	Erik	Etandex
Bayzelon	Allison	Etandex
Degeorge	Reynald	Soletanche Bachy
Mercier	Julien	FREYSSINET
Romagon	Mathieu	Soletanche Bachy
Champlon	Jordan	TES TECHNIFOR
Mace	Charles-Eric	Eiffage

Bureaux d'étude, de contrôle		
Vivier	Aurélie	SYSTRA
Jandin	Philippe	CEREMA
Pruvost	Anthony	CEREMA
Mazaheri	Daruis Amir	Dam Design
Castellan	Bernard	AC4S
Caniac	Eric	AFCAB
Lanza	Matthias	NGE Fondations
Martigny	Benoit	NGE Fondations
Babahouari	Zineb	SEFI-INTRAFOR
Tchombou	Guy	APAVE

Entreprises productrices d'armatures		
Gaufillet	Faustin	Schoeck
Mathelet	Benoit	Schoeck
Drouin	Bernard	Pultrall
Mandelli	Claudio	Sireg
Gicquel	Yvon	SIKA
Valkai	Dorian	Epsilon Composites
Sedan	David	MAPEI
Blaise-Martin	Xavier	MAPEI
Millet	Leonard	DEXTRA
Gourlet	Olivier	DEXTRA
Braun	Jean Jacques	DEXTRA
Barragan	Bryan	OWENS CORNING
Reynaud	Philippe	S et P
Tixier	Mickael	S et P
Doucet	Samuel	Pultrall
Hofmann	Pierre	DEXTRA
Seynave	Xavier	Pultrall
Spitz	Christoph	H-Bau
Goubin	Tristant	SIKA
Arduini	Marco	CoForce
Balconi	Gabriele	Sireg
Seynave	Xavier	Pultrall
Renshaw	Peter	Pultron Composites
Saade	Julien	Pultron Composites

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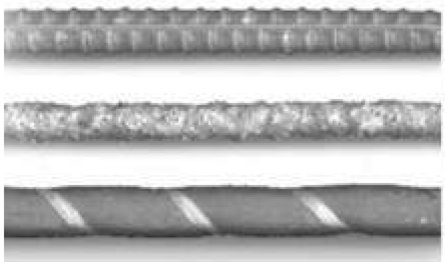
Materials design value



$$X_d = \eta \frac{X_k}{\gamma_m},$$

Exposure conditions	Type of fiber / matrix*	η_a
Concrete not-exposed to moisture	Carbon / Vinylester or epoxy	1.0
	Glass / Vinylesters or epoxy	0.8
	Aramid / Vinylesters or epoxy	0.9
Concrete exposed to moisture	Carbon / Vinylesters or epoxy	0.9
	Glass / Vinylesters or epoxy	0.7
	Aramid / Vinylesters or epoxy	0.8

* The use of a polyester matrix is allowed only for temporary structures.

(1) For ultimate limit states, the partial factor γ_m for FRP bars, denoted by γ_f, shall be set equal to 1.5.

(2) For serviceability limit states, the value to be assigned to the partial factor is $\gamma_f = 1$.

(3) The partial factor prescribed by the current building code shall be assigned for concrete.

SLS : Crack opening limit

$$w_k = \beta \cdot s_{rm} \cdot \varepsilon_{fm}, \qquad s_{rm} = 50 + 0.25 \cdot k_1 \cdot k_2 \cdot \frac{d_b}{\rho_r}, \qquad \varepsilon_{fm} = \frac{\sigma_f}{E_f} \cdot \left[1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{fr}}{\sigma_f} \right)^m \right],$$

- k_1 is a coefficient accounting for the bond properties of the FRP bars, to be set equal to 1.6;

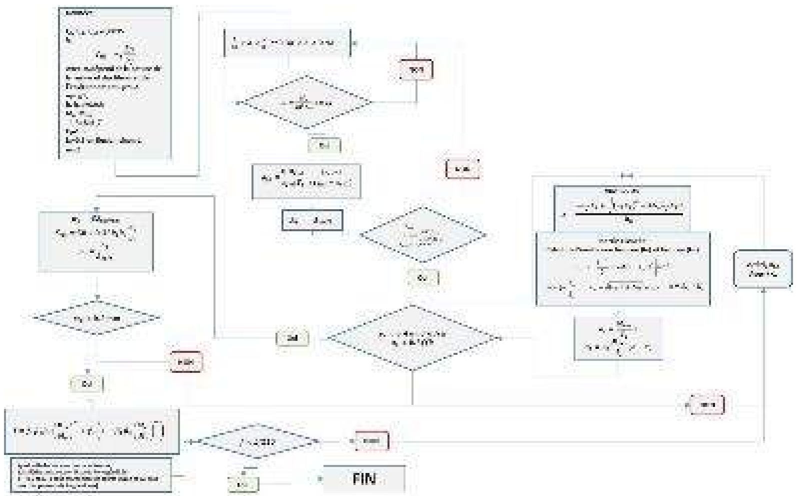
- k_2 is a coefficient depending upon the strain diagram (0.5 for flexure, 1.0 for pure tension);

- d_b is the equivalent diameter of the FRP bars, in mm; if bars of different diameter are used, their average value can be considered;

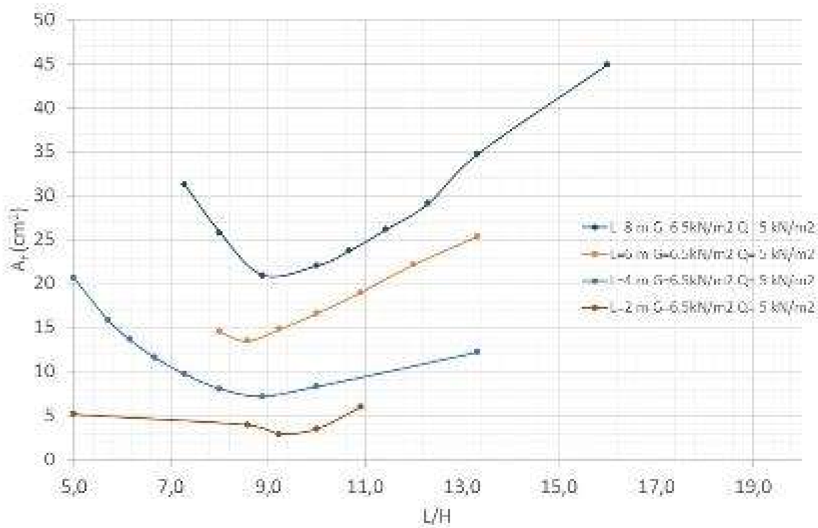
- ρ_r is the effective reinforcement ratio, equal to $A_f / A_{c,eff}$, where $A_{c,eff}$ is the effective area in tension defined as the concrete area surrounding the tensile FRP reinforcement, having depth equal to 2.5 times the distance between tension fiber and bars centroid (EC2).

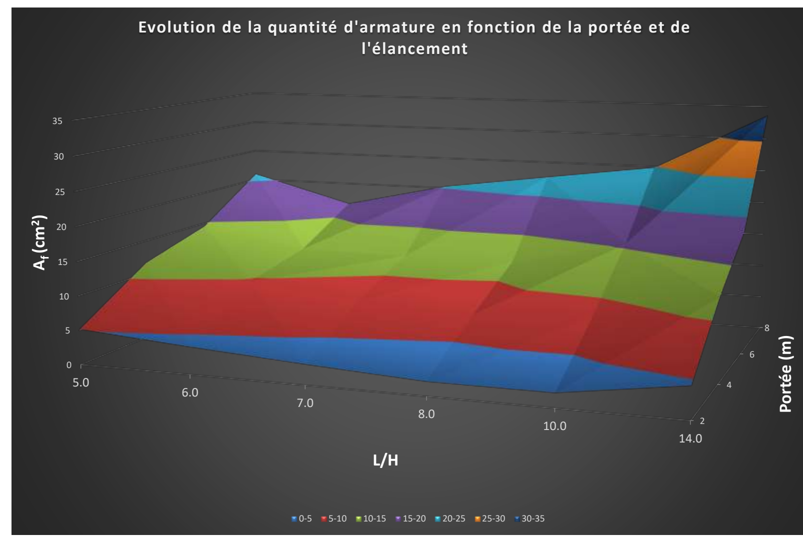
Eurocode 2	Steel	Normal	0.3 mm
Model Code 1990	Steel	Normal	0.3 mm
JSCE (1997)	FRP		0.5 mm
ACI 440.1R-06 CSA (2002)	FRP	Interior	0.7 mm
ACI 440.1R-06 CSA (2002)	FRP	Exterior	0.5 mm
IStuctE (1999)	FRP	Close to observer Away from observer	0.3 mm >0.3 mm

DESIGN COMPARISON



		COMPARISON BETWEEN DESIGN CODE			
				b=0,16 m, h=0,40 m	d=0,36 m
FERRIER, 14/06/2020			Concrete fck=30 MPa	Mu=50,1 kN.m Mser=36 kN.m	
			Ec=13000 Mpa	G=13 kN/ml Q=5 kN/ml	
				Span 4 m	
Criterions	**Minimum amount of reinforcement (mm2)**				
	ACI 1R.03	**CNR-DT 203/2006**	**CSA 806-02**	**AFGC 2020**	**AFGC 2020 juin**
Tensile strength of GFRP	**1000**	**1000**	**1000**	**1000**	**1000**
facteur sur les propriétés caracétrisatiques	**CE=0,8**	**γf=1,5**	ϕfrp=0,75	**γf=1,5**	**γf=1,3**
Valeurs de calcul	**800**	**666,6666667**	**750**	**666,6666667**	**769,2307692**
Coefficient suplémentaire	**ϕ=0,7**	**ηa=0,8**	**0,5**	**αf=0,80**	**αf=0,70**
	560	**533,3333333**	**375**	**533,3333333**	**538,4615385**
limite en service	**0,3 ffd**	**γf=1 et ha=0,8**		**0,30ffk**	**0,25ffk**
Tensile stress of GFRP in service	**240**	**800**	**225**	**300**	**250**
Flexural resistance moment	610	450	610	610	610
Service stress limit	610	450	610	610	610
Crack width limit	796	1194	796	762	762
Short term deflection	**1450**	**1450**	**1450**	**1450**	**1450**
All criterions	1450	1450	1450	1450	1450





CASE STUDY

- PART 4: CASE STUDY (Emmanuel Ferrier, Laurent Michel)

Outline

- Trends of GFRP used in Europe
- Codes and specifications
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- Conclusions

Conclusions

- FRP bars have started to be used in Europe
- Codes are based on North American approach
- Specific use may be found in building and road pavement
- Original research has been done combining FRP and UHPC

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Thanks

Any questions?

Laurent MICHEL, Emmanuel FERRIER
LMC² - Université LYON 1

Laboratoire des Matériaux Composites pour la Construction EA 7427

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End of Presentations

**** Coffee Break (5 mins) ****

Other State DOT activities

NCDOT

Harkers Island Bridge Replacement.

- Originally scheduled for mid-2020 letting.
- Delayed until April 2021?
- Presentation and SP Paper on this project to be given at **ACI Fall 2020 Convention** (virtual) – Special Session *"Field Applications of Non-conventional Reinforcing and Strengthening…"*

VDOT

"VDOT is interested; we are moving forward.

I don't see us rolling this out as quickly as we switched to Corrosion Resistant Rebar (MMFX and SS rebar).

And I don't see this overtaking CFRP in prestressing in the near future. ***We have concerns related to bent bars, MASH barriers (combination with steel rebar****? Need for crash test if we change to FRP? To my knowledge, only one test out there)* ***and lack of coupler options for future widening****.*

We are looking at some research projects, as well as potentially offering DB contracts the option to use FRP in place of some steel reinforcement in specific conditions (mostly T&S in low risk locations (Abutments); could also be places like approach slabs. "

Andrew M. Zickler, PE
Complex Bridge and ABC Support Program Manager

Next Level of Activities based on Needs – Construction Issues (h)

1. Unit costs for GFRP are very high for small quantities. Presumably due to the project testing requirements. ($2500 - $3000/ LOT). Latest local project bids (South Maydell Drive) 449 LF of #5 Bars @ $12/LF, almost 10 times FDOT SDG 9.2 (BDR) cost estimates?
2. Many Contractors do not understand the lead times involved.
3. Modulus of elasticity can improve competitiveness of GFRP vs. other Corrosion-Resistant solutions. Flagler Beach Seawall required $\boldsymbol{E_f}$ = 7500 ksi >> standard 6500 ksi.
4. Stirrup bends and closed shapes or multiple bends.
5. Tie-wire (plastic ties are slower, more expensive, and less secure)
6. Coupling bars for phased construction.
7. Adhesive anchor testing issues, especially with bent bars.
8. Shear Reinforcing close spacings and multiple legs overlapping
9. Lifting Devices
10. Replacement of damaged bars

Next Level of Activities based on Needs – Construction Issues (h)

1. Unit costs for GFRP are very high for small quantities. Presumably due to the project testing requirements. ($2500 - $3000/ LOT). Latest local project bids (South Maydell Drive) 449 LF of #5 Bars @ $12/LF, almost 10 times FDOT SDG 9.2 (BDR) cost estimates?

Discussion Points

- SN: suggested that a separate payment item for testing, would preserve a more accurate unit rate cost history.
- This level of testing cost is not imposed for steel & SS rebar and strand.

Next Level of Activities based on Needs – Construction Issues (h)

2. Many Contractors do not understand the lead times involved.

Discussion Points

- SN: suggested that this be made clear at the pre-construction meeting.
- Contractors expectations for quick turn around times when problems occur, may not be full appreciated by the FRP rebar industry.
- AN: It is the unforeseen small issues (damaged bars, incorrect bends etc.) that slow down the project and potentially give FRP a difficult reputation.
- BH: Field bending capability with TP resins may be one solution

Next Level of Activities based on Needs – Construction Issues (h)

5. Tie-wire (plastic ties are slower, more expensive, and less secure)

Discussion Points

- SN: Can we use black-steel tie-wire? Zip-ties often don't create a very rigid connection and lots of plastic debris.
- DG: Industry promotes plastic/PVC/Epoxy coated tie-wire. SN: FDOT allows this but still not as secure as uncoated wire, especially with non-sand coated bars surfaces.
- CE: Has DOT consider polycarbonate clips? SN: Yes, we currently allow them but the cost is more and complex shapes and bar size combinations become a challenge.

Next Level of Activities based on Needs – Construction Issues (h)

9. Lifting Devices

Discussion Points

- SN: Maintaining the same level of durability at the lifting points is a challenge for cost effective and readily available corrosion-resistant hardware/anchors.
- BM: suggested looking to the heavy timber construction industry for rigging that is non-abrasive.
- SN: More concerned about the embedded anchorages corrosion protection to match the 100+ year assumed design life.

Next Level of Activities based on Needs – *Moderated Discussion*

i. **Bar Properties**

- *SW#3* - FDOT 2021 proposed increase in Elastic Modulus and Tensile design limits for ***FDOT Specification 932-3***
- *SW#6* - What to do about **Bent Bars**, at least for the intermediate future?

Discussion Points

- DG: ACMA-FRP Rebar council is working on consensus between producers before entering formal ASTM revision Work Item process.
- It appears many manufacturers are comfortable with higher limits matching CSA 806 Grade III properties for straight bars (Ef = 60 GPa/8700 ksi), and 50 GPa/7250 ksi for bent bars.
- BH: Different manufacturers will have different capabilities, so for now a simplified approach would help the industry expand. DG: looking at standard bend coding for ASTM doc probably under a different number to straight bars.

Next Level of Activities based on Needs – *Moderated Discussion*

j. Project level testing

- How much and how to pay for it?

Discussion Points

- The quantity and LOT definition was not discussed, but BB: presented CSA LOT definitions for bent bars based on resin batch and continuing not bar shape.
- SN: Suggested separate payment item for project testing would better reflect unit rates and overhead costs for estimation purposes. If the quantity and frequency of the testing varied, this would be captured separately rather than assumed into the LF unit rate per bar size.

Next Level of Activities based on Needs – *Moderated Discussion*

h. Barriers to seamless deployment

- Lifting hardware,
- couplers,
- splicing,
- replacement of damaged bars

Discussion Points

- AN/SN: Lifting hardware needs to be developed for surface exposed pick points. Current practice of carbon-steel anchorages, cut below surface and epoxy patch is not a sustainable approach. Stainless may be cost prohibitive. We need better solutions to ensure member durability as intended.
- Several state DOT's (OH, TX, NC) have expressed a desire for FRP rebar coupling before they can embrace GFRP-RC design for bridge decks and precast elements
- SN: Damage of extended GFRP bars as been experienced on a # of projects. Need quick and effective repair methods. Adhesive Anchors has been effectively used on several Florida project: MIC 2011; HRB 2019; Sunshine Skyway Seawall extension 2020.

Agenda - Part B

1:15 - 2:15pm FRP Industry Discussion - Strategic Workplan Items and Roadmap Planning
(moderated session)

a. Endurance Limits, Characteristic Curves and Testing (***Strategic Workplan*** Items #1 & #2)
b. Refine FDOT Workplan Priorities for expanded FRP deployment opportunities –
c. Review remaining ***Strategic Workplan*** items:
   - ~~**3. Increasing Material Property Qualification Thresholds and Design Limits**~~ **(see Part A)**
   - **4. Establishing Consistency**
   - **5. Cost Estimating**
     1. OC initiative for ACMA FRP-RMC
     2. FDOT SDG Chapter 9 update
   - **6. Bar Bends**
     1. Complex Shapes
     2. FDOT Index D21310
   - **7. Minimum Bar Sizes for Design Elements**
   - **8. Life-Cycle Cost Guidance**
   - **9. Minimum Concrete Class**
   - **10. Shear Resistance**

d. Synergies with ***AASHTO COBS T-6*** Strategic Plan to accelerate progress
e. ***EDC-6*** (2021-2022) Any potential for FRP-RC?
f. Establish how FRP Manufacturing Industry can immediately contribute to advancing efforts (a & b)

2:15 - 2:30pm Future Workshops and Action Items *(Nolan)*

a. Action Item Summary
b. Future Workshop opportunities and suggestions:
   - i. 5th FDOT-FRP RC/PC Industry Workshop (dates & location/delivery format)
   - ii. FRP-RC/PC Designer Training *(August 2020)*
   - iii. 3rd International Workshop on FRP-RC, University of Sherbrooke *(August 2021)*
   - iv. TRB 2020 Workshop ABK10/AFF80 *(January 2022)*

c. Closing Statements

Adjourn – For Lunch 12:00 – 1:15pm

NO text.

NO call.

NOTHING

is worth losing a life over.

PUT IT DOWN

IT'S THE LAW