Third International Workshop on FRP Bars for Concrete Structures (IW-FRPCS3)

Workshop Theme: "Advances in concrete reinforcement"

Date: August 3-4th, 2021

DAY 1 Tuesday, August 3rd

Session 3: Standards & Specifications Perspective on the use of FRP Rebar (2:00-4:00 pm EDT)

(Is there a path to harmonization?)

RoundTable discussion preceded with 5-minute introduction by panelists.

Moderator: Tony Nanni (UM)

Panelists (5 mins)

Americas

- CSA: Brahim Benmokrane (US)
- ACI: Vicki Brown (Widener)
- AASHTO T6/T10: Tanarat Potisuk (Oregon DOT)
- ASTM: Bakis, Charles Bakis (PSU)
- ICC-ES: Mahmut Ekenel
- USACE: Robert Moser

Europe

- Emmanuel Ferrier (for AFGC)

Australia

- Allan Manalo (USQ)

THIRD INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURS

"Advances in concrete reinforcement"

August 3-4, 2021 - Virtual

Session 3: Standards & Specifications Perspective on the use of FRP Rebar (2:00-4:15pm EDT)

CSA Design Codes & Specifications

Brahim Benmokrane

University of Sherbrooke, QC, CANADA

VIII ACMBS MCAPC

UNIVERSITÉ DE SHERBROOKE

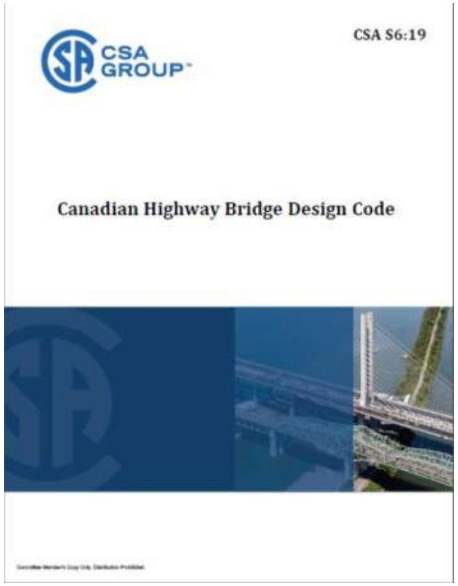
UNIVERSITY OF MIAMI

Center for Integration of Composites into Infrastructure

FDOT

CSA S807

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



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 Edition in 2025

CSA S806

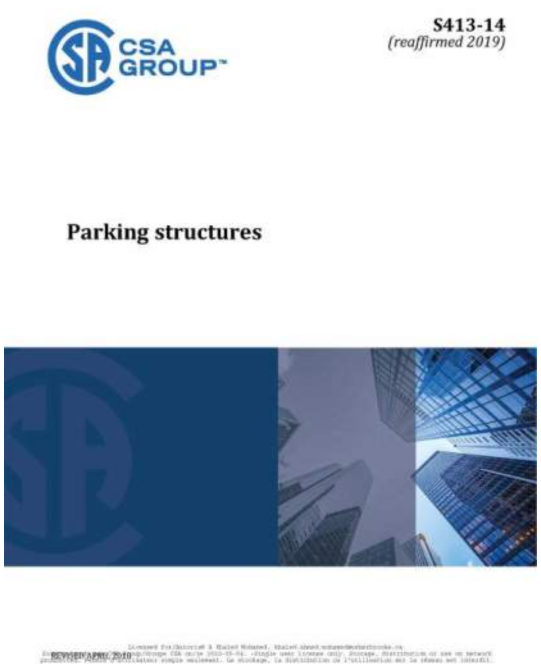
- First edition in 2002
- Re-approved in 2012
- Re-approved in 2017
- New Edition in 2023 (Third Edition)

New editions

1) **CSA S413-21 (2021)** Parking Structures

2) **CSA S900.2 (2021)** Structural Design of Wastewater & Water Treatment Plants

Inclusion of GFRP reinforcing bars as an alternative reinforcing to traditional black steel rebars


CSA GROUP
S413-14
(reaffirmed 2019)
Parking structures


S900.2
CSA Group
Structural Design of Wastewater Treatment Plants – Seed Document

CSA Material Specifications (CSA S807)

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

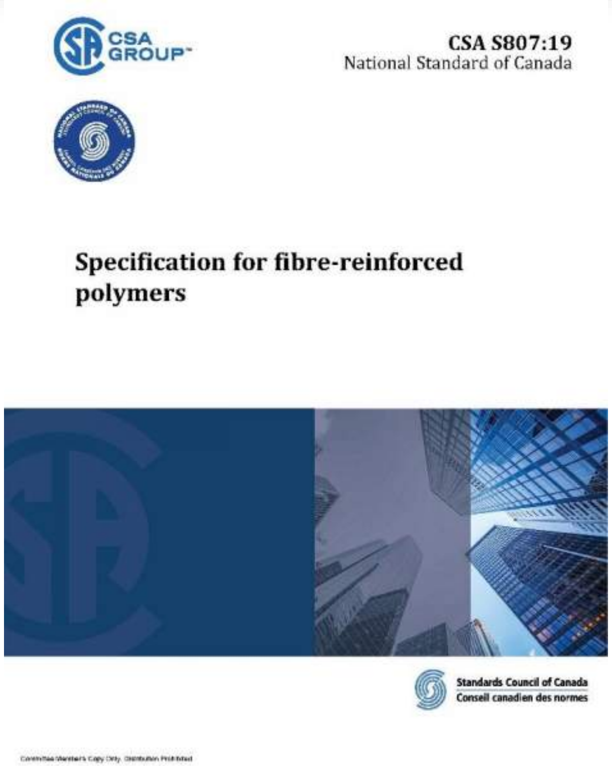
Provides provisions governing testing and evaluation for product qualification and QC/QA.

CSA S807:19 Specifications for fiber reinforced polymers

Recent Modifications

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

Minimum Tensile 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)

Minimum Modulus of Elasticity for GFRP Rebars (Grade III)

Minimum modulus of elasticity for straight bars (#4 to #8) :
60 GPa (8.7 msi)

CSA S807:19 Specifications for fiber reinforced polymers

Recent Modifications

Annex E (normative)

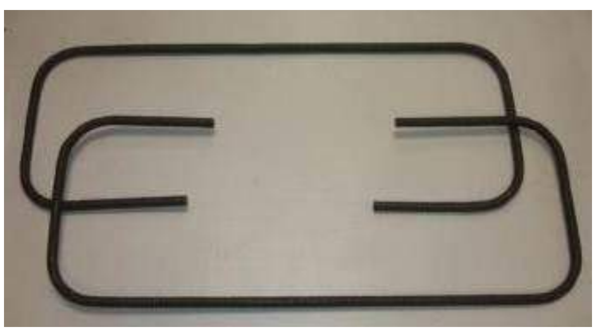
Method of test for determining the strength of the bent portion of FRP reinforcing bars

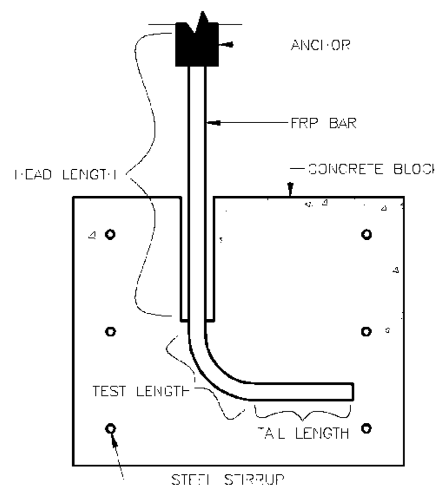
Note: *This Annex is a mandatory part of this Standard.*

E.1 Scope

E.1.1

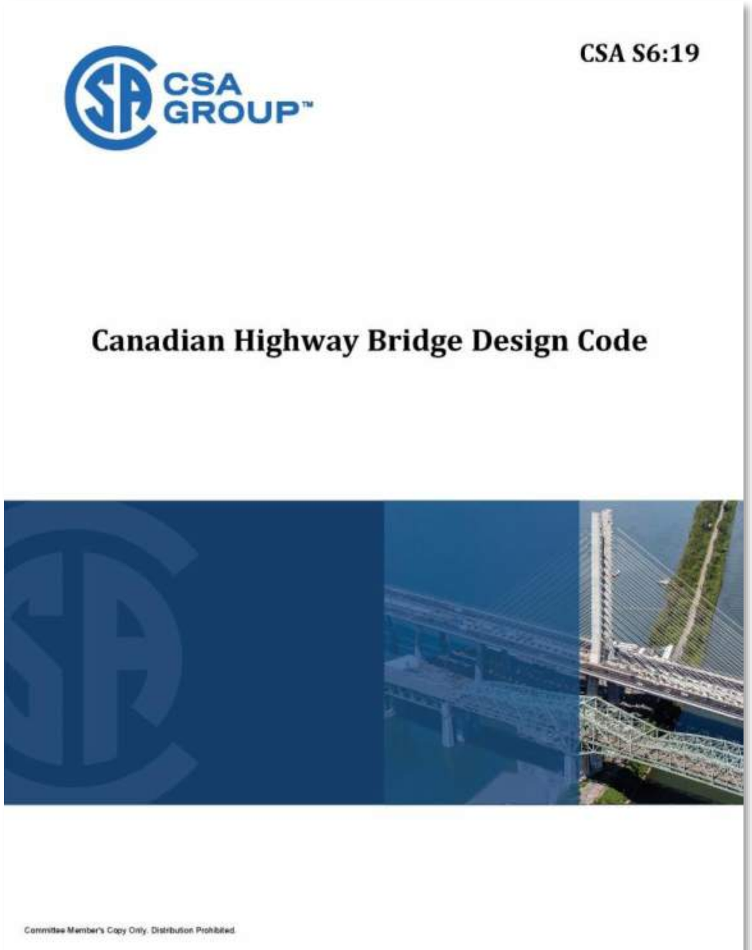
This test method is used to determine the force in the straight portion of a bent fibre-reinforced polymer (GFRP) bar, used as internal reinforcement for concrete structures, when rupture occurs in the bend.





CSA S6-19 (CHBDC)

- **Fourth Edition published in 2019** (Resistance factor, compression members, circular beams, strut-and-tie model, barrier walls, etc.).



CSA S6-19

New Clauses in Chapter 16 of CSA S6-19

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

Maximum Axial Capacity

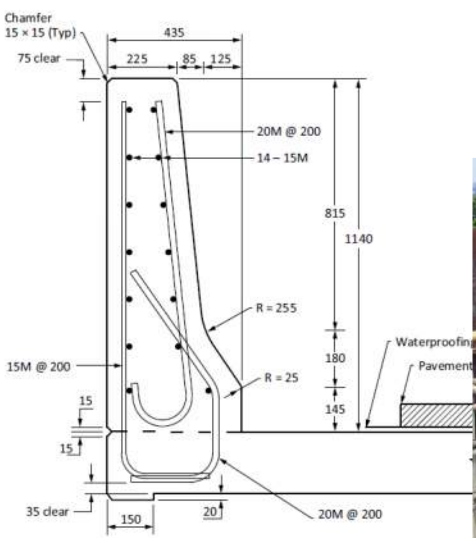
$$f_f = 0.002 E_f$$

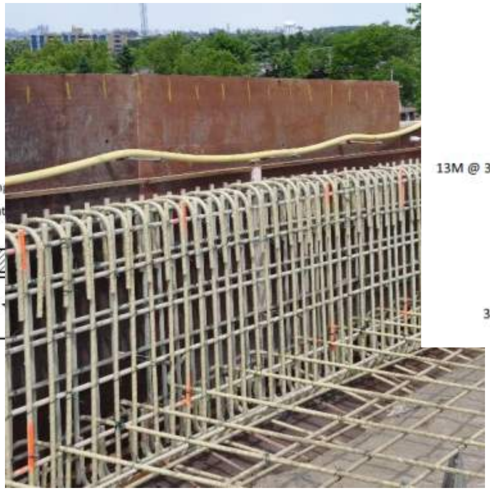
Longitudinal FRP reinforcement may be used in members subjected to combined flexure and axial load. However, the compressive strength of FRP reinforcement shall be limited to a stress corresponding to a strain of 0.002 in the calculation of the factored axial and flexural resistance of reinforced concrete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

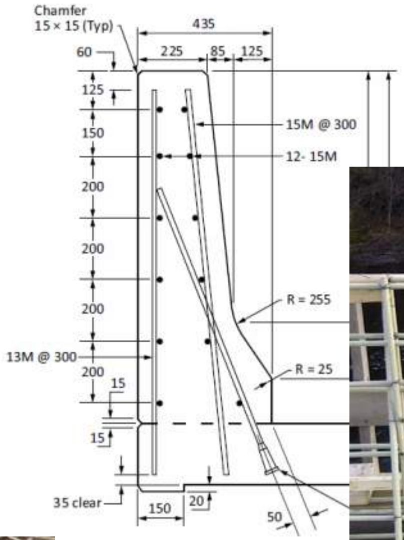
New Clauses in Chapter 16 of CSA S6-19

Concrete Barrier walls Reinforced with GFRP Bars

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







CSA S6-25 (New Edition in 2025; currently under development)

- Develop new clauses for basalt FRP reinforcement (based on the new edition of CSA S807-19)
- Develop new clauses for concrete members reinforced with hybrid reinforcement (FRP-steel) in particular for columns and piers
- Develop design provision for negative moment reinforcement using bent bars as in rigid frames and integral abutment.
- Develop design provisions for slender concrete bridge compression members (columns, piers, and piles)
- Modification of creep rupture stress limit.

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ACI EFFORTS TOWARDS THE DEVELOPMENT OF A GFRP-RC STANDARD BUILDING CODE

VICKI L. BROWN, WIDENER UNIVERSITY, USA

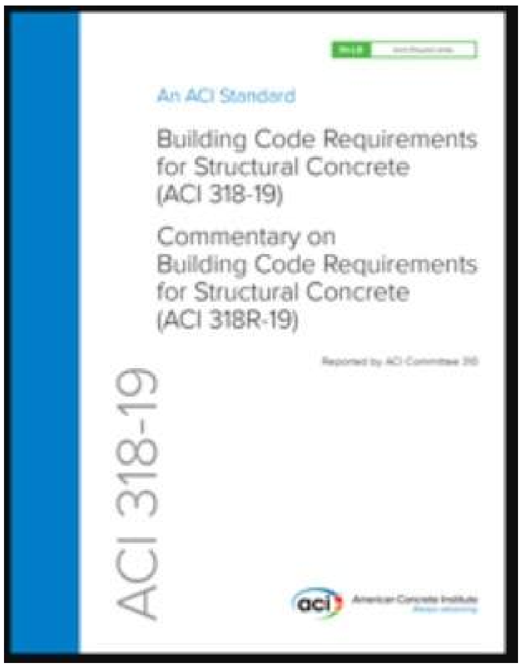
UNIVERSITÉ DE SHERBROOKE

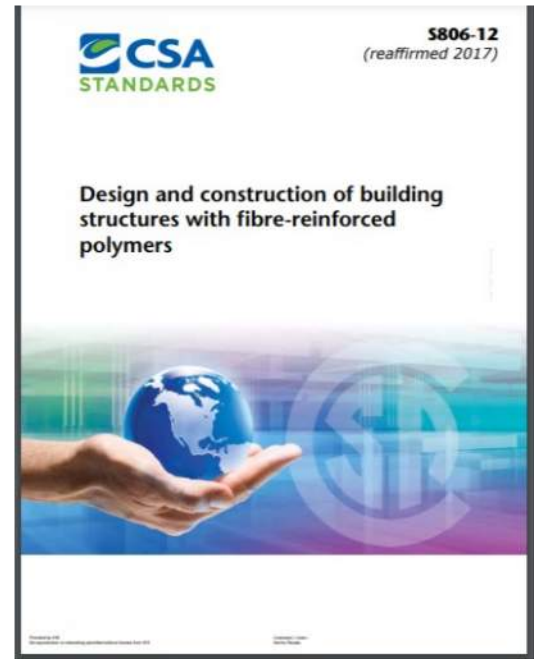
UNIVERSITY OF MIAMI

Center for Integration of Composites into Infrastructure

FDOT

- Published design guides/model codes in U.S. and Europe
- Published design standard in Canada
- ACI's standard will be dependent on ACI 318





Chapter 1 – General

Chapter 2 - Notation and Terminology

Chapter 3 - Referenced Standards

Chapter 4 – Structural System Requirements

Chapter 5 – Loads

Chapter 6 - Structural Analysis

Chapter 7 – One-Way Slabs

Chapter 8 – Two-Way Slabs

Chapter 9 – Beams

Chapter 10 – Columns

Chapter 11 – Walls

~~Chapter 12 – Diaphragms~~

Chapter 13 – Foundations

~~Chapter 14 – Plain Concrete~~

Chapter 15 – Beam-Column & Slab-Column Joints

Chapter 16 - Connections between Members

~~Chapter 17 – Anchoring to Concrete~~

~~Chapter 18 – Earthquake-Resistant Structures~~

Chapter 19 – Concrete: Design and Durability Requirements

Chapter 20 – GFRP Reinforcement Properties, Durability, and Embedments

Chapter 21 – Strength Reduction Factors

Chapter 22 – Sectional Strength **(includes torsion)**

~~Chapter 23 – Strut &Tie Models~~

Chapter 24 – Serviceability Requirements

Chapter 25 – Reinforcement Details

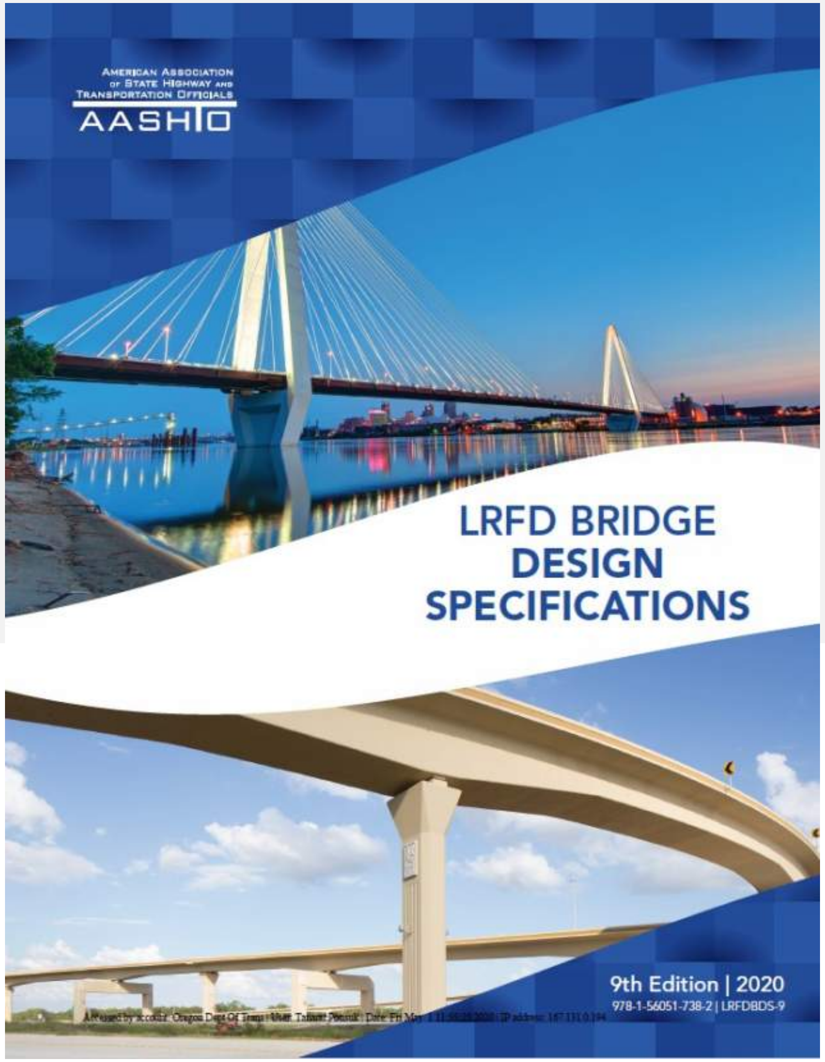
Chapter 26 – Construction Documents and Inspection

~~Chapter 27 – Strength Evaluation of Existing Structures~~

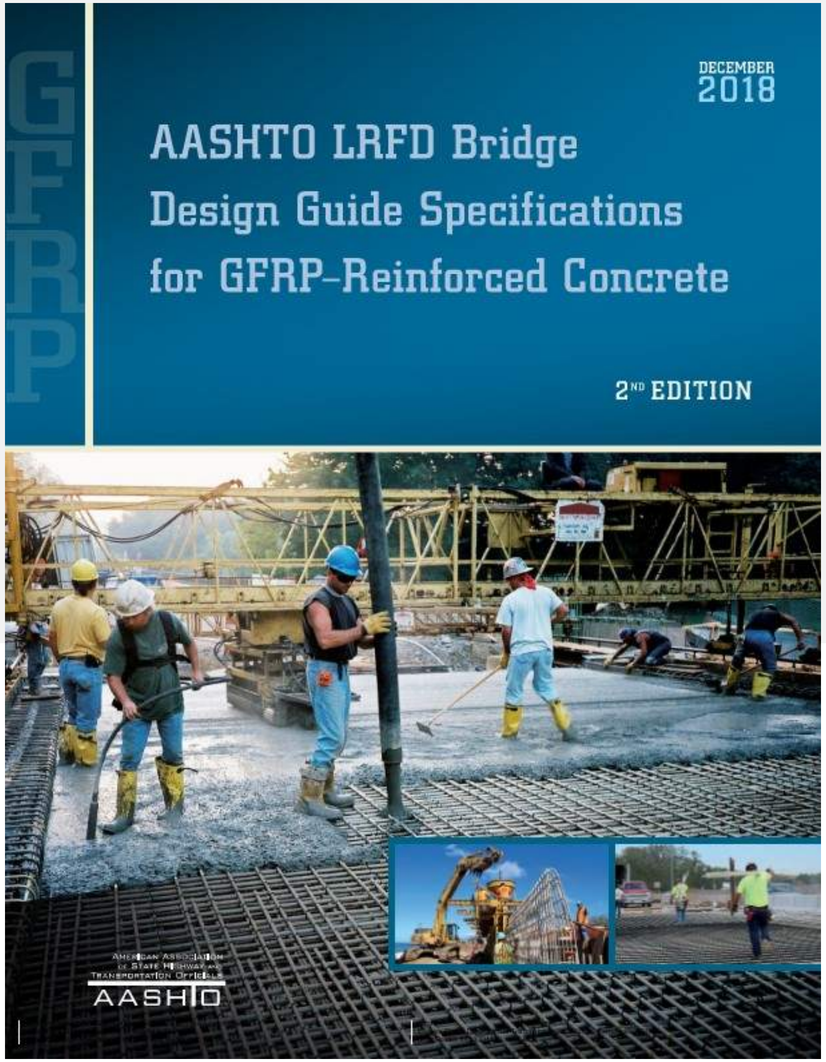
Updates from 440.1R-15 *Guide* to Code:

- GFRP reinforcement must conform to ASTM D7957
- Environmental Factor C_E increased to 0.85
- Creep rupture stress limit increased from $0.2f_{fu}$ to $0.3f_{fu}$
- Lower bound of 0.16 applied to the k_{cr} term in V_c equation
- Size dependent factor added to V_c equation, consistent with changes to 318-19
- GFRP compression reinforcement permitted (i.e. column design)
- Design for torsion included

Bridge Design Specifications

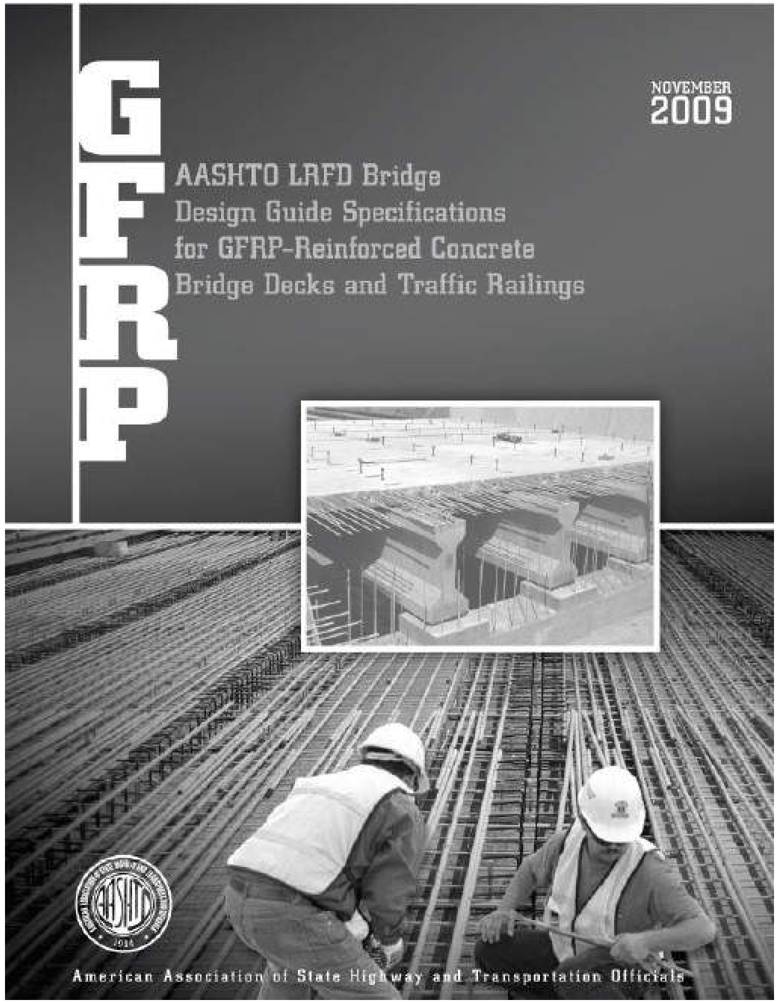


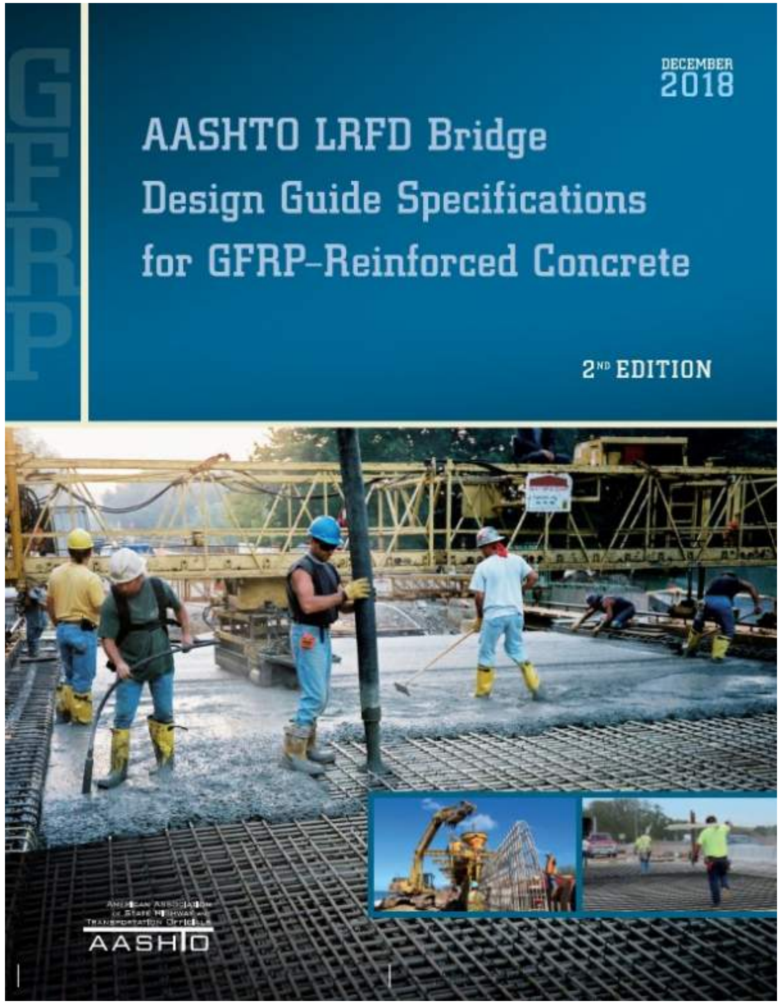
GFRP-RC Guide Specifications



- Loads and load factors
- 2-column format
- Section 5 Concrete Structures
- Possible integration

2018 Update AASHTO GFRP Guide Specification





2018 Update AASHTO GFRP Guide Specification

- More element types
- Input from other guide documents (ACI, CSA)
- Harmonization with AASHTO-BDS
- Material specifications according to ASTM D7957-17

Chapter/Section	AASHTO-18 2nd Ed	AASHTO-09 1st Ed	ACI 440-15	CSA-14
2. Concrete Structures				
• Flexural members	o	o	o	o
• Compression members	o			
• Shear	o	o	o	o
• Torsion	o			
3. Decks	o	o		o
4. Substructures	o			
5. Railings	o	o		o
6. Material & Construction	o	o	o	o

2018 Update AASHTO GFRP Guide Specification

- More element types
- Input from other guide documents (ACI, CSA)
- Harmonization with AASHTO-BDS
- Material specifications according to ASTM D7957-17

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.

INTERNATIONAL

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.

1. Scope

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

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

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

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

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

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

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

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

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

1.6 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials
D570 Test Method for Water Absorption of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D3171 Test Methods for Constituent Content of Composite Materials
D3878 Terminology for Composite Materials
D7205/D7205M Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
D7617/D7617M Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars
D7705/D7705M Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction
D7913/D7913M Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing
D7914/D7914M Test Method for Strength of Fiber Reinforced Polymer (FRP) Bent Bars in Bend Locations

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

Current edition approved Aug. 1, 2017. Published August 2017. Originally approved in 2017. DOI: 10.1520/D7957_D7957M-17.

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

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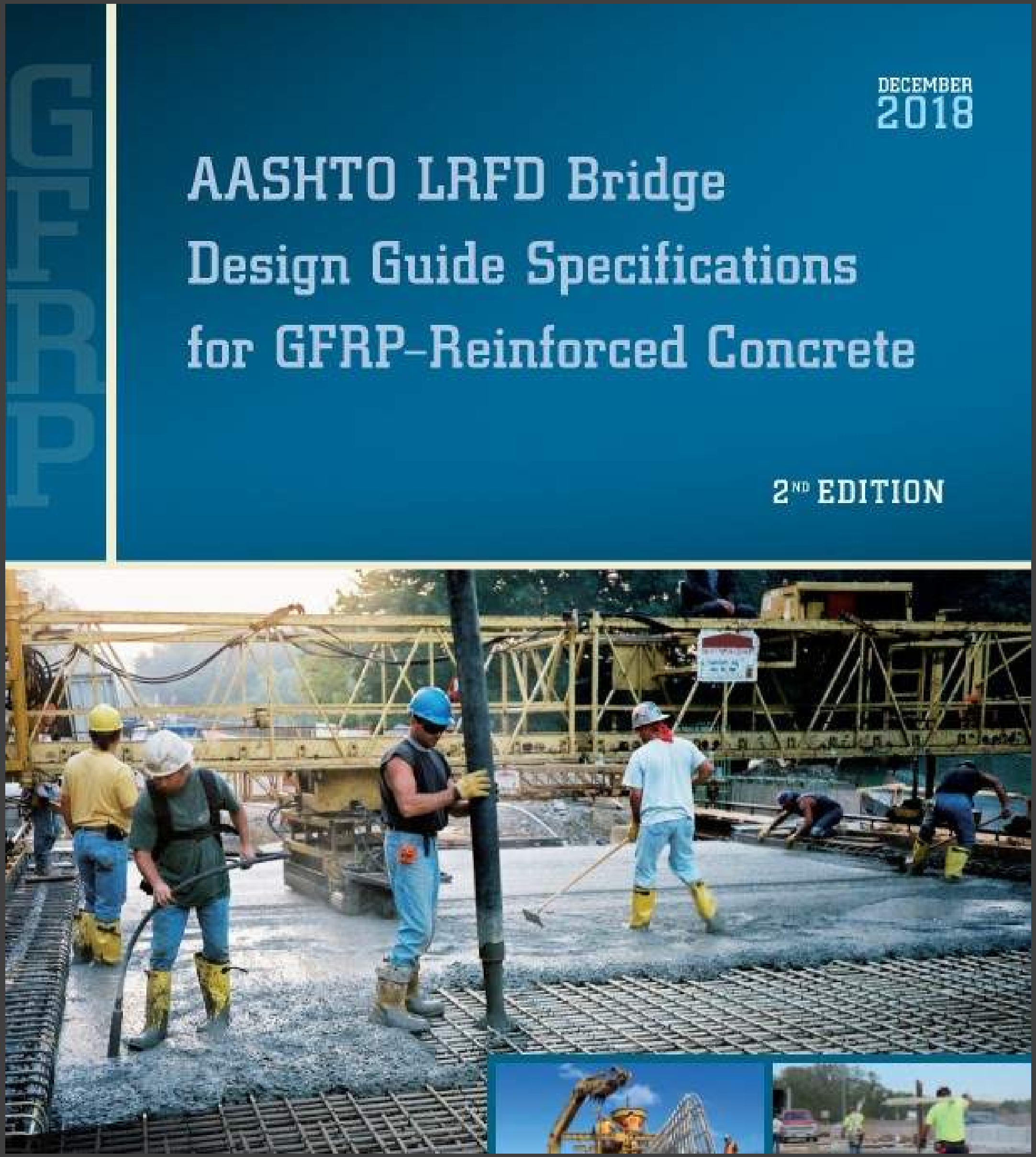
- Geometric, material, mechanical, and physical properties
- External surface enhancement
- Vinyl ester/epoxy glass FRP
- Test methods for QC and certification

Critical Design Factors

- The reliability approaches for the various codes could be different thus resulting in different factors

	AASHTO-18 2nd Ed	AASHTO-09 1st Ed	ACI 440.1R-15	CSA-14	
f_{fu}^*	99.73	99.73	99.73	**95.0**	Percentile guaranteed strength
Φ_C	**0.75**	**0.65**	0.65	0.75	Resistance factor – concrete crushing
Φ_T	0.55	0.55	0.55	0.55	Resistance factor – FRP rupture
Φ_S	0.75	0.75	0.75	0.75	Resistance factor – shear failure
C_E	0.70	0.70	0.70	**1.0**	Environmental factor
C_C	**0.30**	**0.20**	0.20	0.25	Creep factor
C_f	**0.25**	**0.20**	0.20	0.25	Fatigue factor
k_b	**1.2**	**1.4**	1.4	**1.0**	Bond coefficient
w	**0.028**	**0.020**	0.028	0.020	Crack width
$c_{c,stirrups}$ (in.)	1.5	1.5	2.0*	1.5	Clear cover
$c_{c,primary}$ (in.)	2.0	2.0	2.5*	1.5	Clear cover
$c_{c,slab}$ (in.)	1.0	0.75	2.0*	1.5	Clear cover

*ACI 440.5-08 Table 3.1



Discussions

- Harmonization to the extent possible within the existing Specification requirements
  - Load and resistance factors are not always interchangeable
- Harmonization is difficult when the material development continues to be fluid
  - New improved materials are available
- Current T6 goals
  - Operations and Maintenance Activities (Load Rating, Inspection, Evaluation, Repair, etc.)
- T6/T10 possible collaboration to begin discussion on incorporation into the AASHTO BDS
  - Material behavior and design goals are different

THIRD INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURES

"Advances in concrete reinforcement"

August 3-4, 2021 - Virtual

Standards Activity on FRP Reinforcement Bars in ASTM D30

Charles E. Bakis, Pennsylvania State University, USA

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

D30.10 Composites for Civil Structures

- Initiated activities in 2012
- Scope: transition ACI 440 test methods to ASTM; write new test & material standards for FRP used as concrete reinforcement

Membership, as of Spring '21
Chair: T. Russell Gentry
Vice-Chair: Charles Bakis (now Francisco De Caso)

	Producer	User	Consumer	General Interest	Unclassified	Total
Official Voting Members	31	0	1	37	0	69
Non Official Voting Members	2	0	0	3	6	11
TOTAL	33	0	1	40	6	80

Each organization entitled to one official voting member

12 current test standards

Green – recent update

*Currently in review for balloting

Topic	ACI 440	ASTM D30
Bar Cross-Section	B1	D7205-21
Bar Tension	B2	
Bar Anchors	App. A.	
Bar Concentric Pullout	B3	D7913-14(2020)
Bar Transverse Shear	B4	D7617-11(2017)*
Bar Strength at Bends	B5	D7914-21
Bar Alkaline Tension	B6	D7705-19
Bar Creep Rupture	B8	D7337-19
Lam/Concrete Bond - Normal	L1	D7522-21
Laminate Tension	L2	D7565-10(2017)*
Laminate Calculations	App. B	
Laminate Lap Shear	L3	D7616-11(2017)*
Lam/Conc. Bond – Beam	--	D7958-17*
Lam/Conc. Bond – Lap Shear	--	D8337-21
Characteristic Values	--	D7290-06(2017)*

1 current material specification

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

*Currently in review for balloting

Current & prospective work on new FRP bar standards

- New specification for "glassy" FRP reinforcement bars
  - Under discussion: different fiber and matrix types, graded modulus, additional testing, different testing, refined property requirements dependent on diameter
- Specification for "glassy" dowel bars
- Specification for CFRP bars
- Long-term relaxation of FRP bars (ACI B.9)
- Bar anchorage (ACI B.10)
- Bar tensile fatigue (ACI B.7)
- Tensile properties of deflected FRP bars (ACI B.11)
- New test method for bend strength

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EVALUATION OF FRP BARS & MESHES FOR BUILDING CODE COMPLIANCE IN THE U.S.A

Mahmut EKENEL, Ph.D., P.E., FACI

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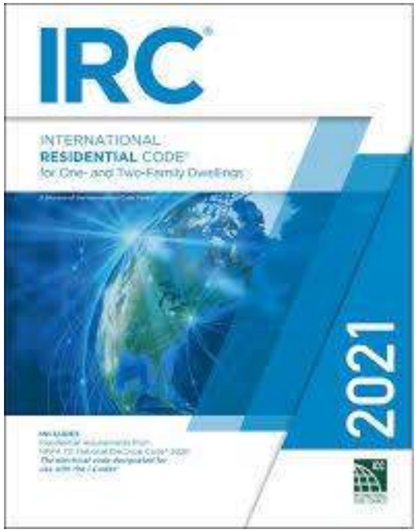
Model Building Codes

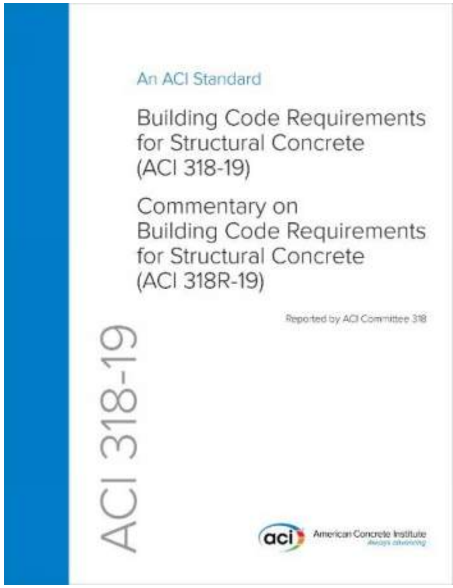
In the United States, where the power to regulate construction is vested in local authorities, a system of model building codes is used.

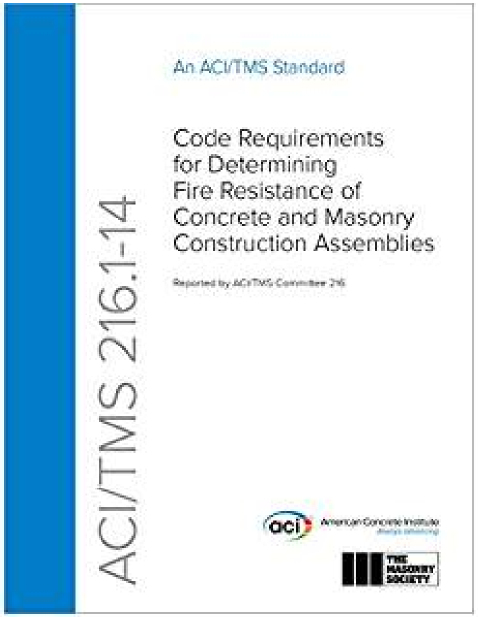


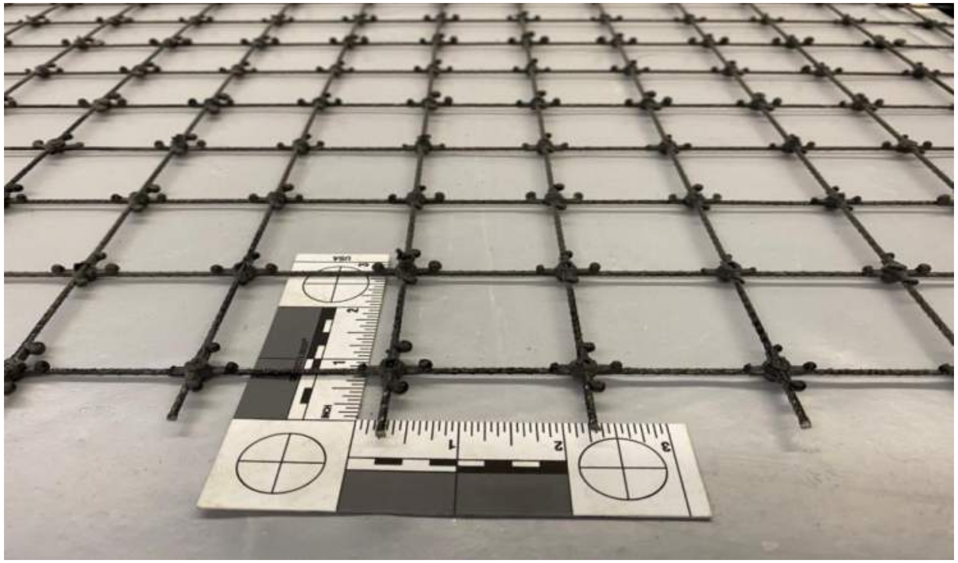
IBC Code Adoption Map 2021

IBC referenced ACI documents:

- ACI 216 (Fire resistance of concrete and masonry)
- ACI 318 (Building
- code requirements for structural concrete)







In 2021, neither IBC/IRC, nor ACI 318 addresses use of FRP bars and meshes as reinforcement for concrete members. Therefore, they are considered alternative materials.

What happens if there is a new construction material or system that is an alternative to that covered in the building codes?

IBC/IRC Code Change Process

Anyone can submit a code change proposal:

- Reason for change
- Description of change
- Supporting material

* To this end, ACI Committee 440 is actively working on the development of an ACI 318-dependent, mandatory language design code aimed to be adopted by the IBC in the future.

What happens if there is a new construction material that is an alternative to that covered in the building codes?

(IBC SECTION 104.11) Alternative materials, designs and methods not specifically addressed in the code can be approved by the building official when they comply with the intent of the provisions of the building code:

- Quality
- Strength
- Effectiveness
- Fire resistance
- Durability
- Structural safety

* research reports, issued by approved sources can assist in the approval process.

Research (evaluation) reports are issued in accordance with an acceptance criteria.

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

AC454

Approved December 2020

AC454: FRP bars as internal reinforcement of structural concrete members

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

AC521

Approved October 2020

AC521: FRP bars and meshes as internal reinforcement of non-structural concrete members

ICC-ES acceptance criteria are consensus documents approved by an independent committee during an open public meeting.

* AC454: Reference for material testing in AC454 is primarily based on ASTM D7957, and reference for design provisions is based on ACI 440.1R. Criteria also addresses special inspection, fire resistance and quality control surveillance.

* AC521: FRP bars and meshes are alternative to the shrinkage and temperature reinforcement for plain concrete footings and for plain concrete slabs-on-ground. Criteria contains provisions for shrinkage cracking testing. Also addresses special inspection and quality control surveillance.

* So far, three code compliance evaluation reports have been issued: ESR-4526, ESR-4648, and ESR-4664.

THANK YOU

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MEKENEL@ICC-ES.ORG

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US Army Corps of Engineers

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The views, opinions, and findings contained in this presentation are those of the author and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

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"Advances in concrete reinforcement"

Military Missions

Military Construction

COCOM Support, Overseas Contingency Operations (OCO)

Installation Support, Environmental, Energy and Sustainability

Federal / State / Local

"Whole of USACE" Capabilities

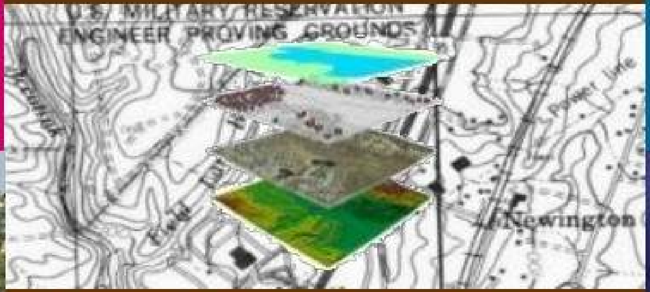
Capacity Development

International and Interagency

Navigation, Flood Control, Disaster Response, Shore Protection, Hydropower, Water Supply, Regulatory, Recreation, Environmental Restoration

Civil Works

Geospatial Support



Common Operating Picture / Environment

Civil Works Programs

Military Programs

Emergency and Contingency Operations

Contingency Operations

"Whole of Government" Disaster Response and Recovery

Life-Cycle Flood Risk Management

Critical Infrastructure

Warfighter

Installations and Energy

Environment

Water Resources

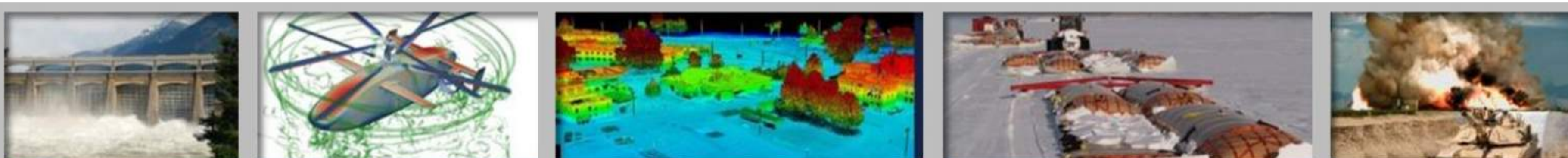
Research and Development

Real Estate – Acquire, Manage and Dispose / DoD Recruiting Facilities / Contingency Operations

THE POWER OF ERDC

DELIVERING SOLUTIONS

ERDC'S RESEARCH AND DEVELOPMENT AREAS (RDAs) FOCUS POWERED BY CORE COMPETENCIES



- CIVIL WORKS
- ENGINEERED RESILIENT SYSTEMS
- GEOSPATIAL RESEARCH & ENGINEERING
- INSTALLATIONS AND OPERATIONAL ENVIRONMENTS
- MILITARY ENGINEERING

RESEARCH AND DEVELOPMENT AREAS

CORE COMPETENCIES

SPECIALIZED ERDC KNOWLEDGE THAT ENABLES OUR RESEARCH AND DEVELOPMENT AREAS

- BATTLESPACE TERRAIN MAPPING AND CHARACTERIZATION
- BLAST AND WEAPONS EFFECTS ON STRUCTURES AND GEO-MATERIALS
- CIVIL AND MILITARY ENGINEERING
- COLD REGIONS SCIENCE AND ENGINEERING
- COASTAL, RIVER, AND ENVIRONMENTAL ENGINEERING
- COMPUTATIONAL PROTOTYPING OF MILITARY PLATFORMS
- MILITARY INSTALLATIONS AND INFRASTRUCTURE

Materials and Manufacturing R&D

Supporting Army S&T, USACE, and Military and Civilian Stakeholders and Partners in ERDC Core Competencies:

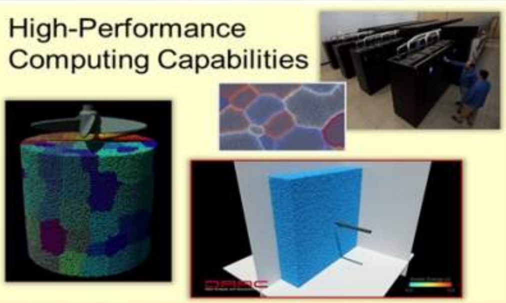
- *Blast and Weapons Effects on Structures and Geomaterials*
- *Civil and Military Engineering*
- *Military Installations and Infrastructure*
- *Cold Regions Science and Engineering*

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Cutting-Edge Blast, Impact, and Penetration Testing Equipment

Large-Scale Structural Testing Systems

High-Performance Computing Capabilities



Materials Analysis and In-Situ Mechanics

Force Protection and Weapons Effects

- Advanced weapons effects
- Multi-functional materials
- Structural hardening
- Indigenous materials

Force Projection and Maneuver Support

- Rapid repair and retrofit
- Lightweighting
- Indigenous materials
- Remote assessment

Infrastructure, Installations & Environment Quality

- Sustainability
- Operational energy
- Life-cycle durability / performance
- Environmental impacts

Cross-Cutting Technologies

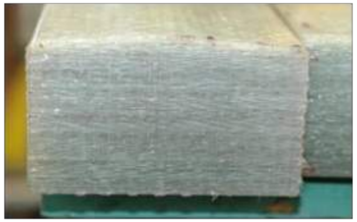
- Additive / advanced manufacturing
- Multi-scale modeling
- Robotic platforms
- Artificial Intelligence
- Advanced measurement science

Leveraging Extramural Research Partnerships and Advanced High-Performance Computing Capabilities

FRP Miter Blocks

H. Chittenden Locks - Seattle District

- Replaced severely corroded steel.
- Easy to install due to light weight.
- Cost competitive with steel.
- Minimal wear after 4 years.
- Initial Savings = $0
- 50 Year Savings = $2M



Polymer Slides

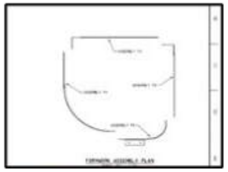
Bankhead L&D - Mobile District

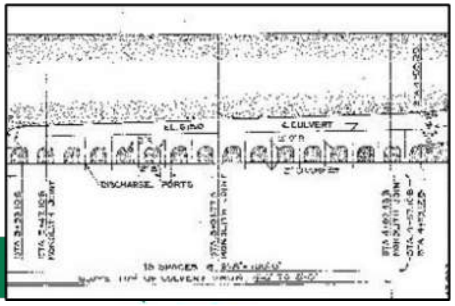
- Reaction rollers prone to seize up from corrosion.
- Replaced with UHMW slides.
- Cheaper by two magnitudes.
- Initial Savings = $2.7 M (20 gates)
- 50 Year Savings = $11M

FRP Wrap Repair

Chickamauga L&D – Nashville District

- ASR caused cracking in discharge port columns.
- Steel jackets installed by divers weighed 358 lbs.
- Repaired with polymer mastic grout and water-cured FRP composite wrap.
- Rapid repair – short lead time.
- Initial Savings = $430k (30 ports)



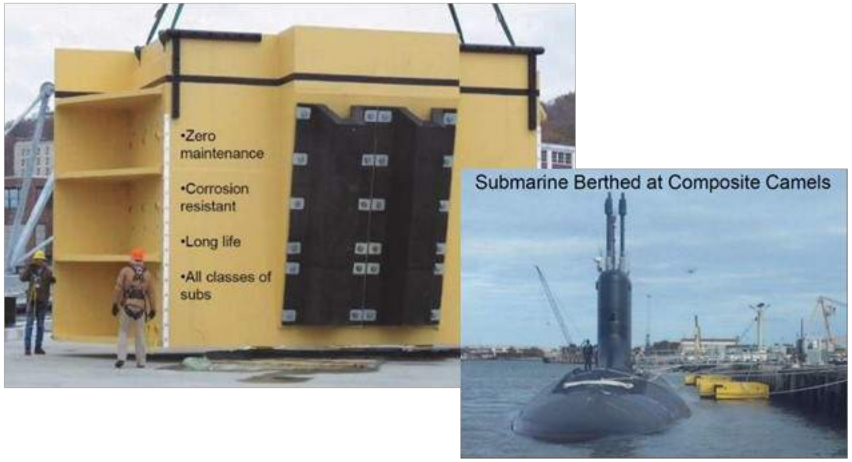


FRP Filler Panels

Willow Island L&D – Huntington District

- Steel panels significantly corroded.
- FRP panels fabricated with pultruded shapes and housed in steel frames.
- Initial Savings = $48k (12 panels)
- 50 Year Savings = $580k

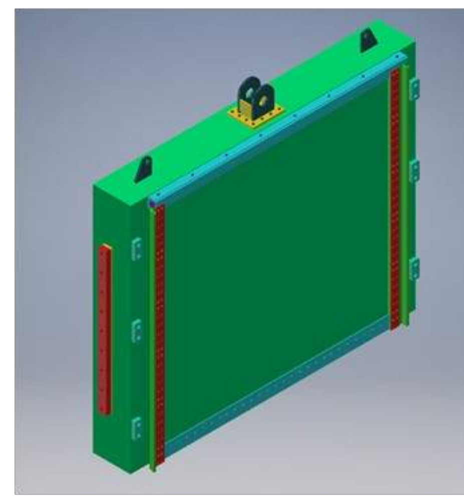
Navy FRP composite submarine berthing camels (Composite Advantage).



Navy FRP composite aircraft carrier berthing camels (Composite Advantage).

FRP composite wicket gates for IWW.

FRP composite culvert valves for IWW.



What are we doing?

- Structural composites for infrastructure
- Structural thermoplastics
- Thermoplastic rebar
- Advanced polymers and fibers
- Repair and rehabilitation
- Guidance modernization

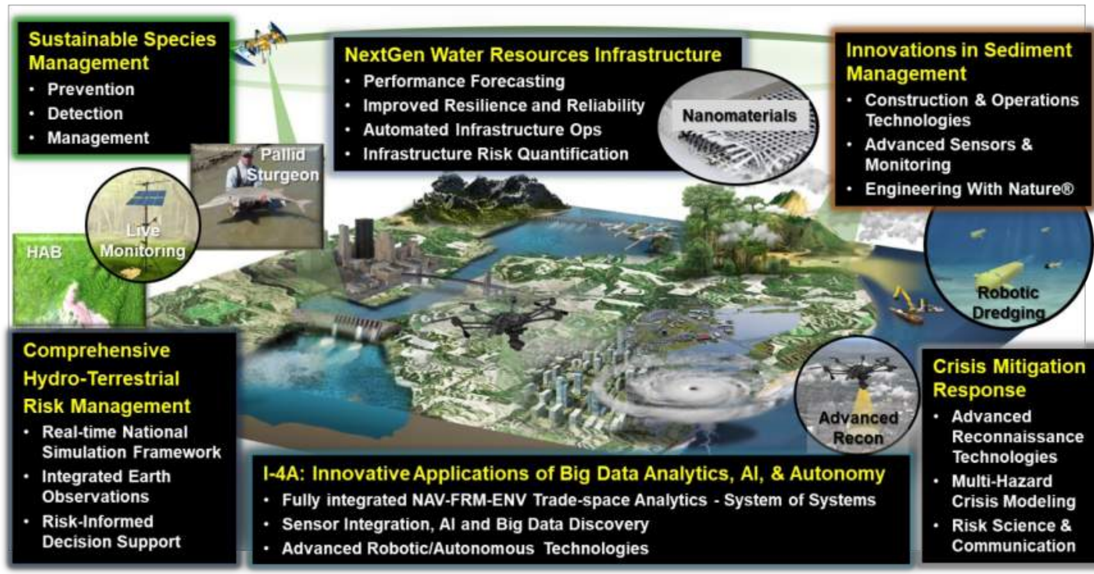
Where are we going?

- Infrastructure bill
- Advanced materials (WRDA, IMAGINE)
- R&D expansion and transition

What are the challenges?

- Tech transition
- AGING INFRASTRUCTURE
- Resilient infrastructure
- Specialized vs. commodity

Civil Works R&D Strategic Focus Areas



Example Extramural R&D Partnerships

STATE
AIT Advanced Infrastructure Technologies
1865 THE UNIVERSITY OF MAINE
UNIVERSITY OF MISSISSIPPI 1848
THE UNIVERSITY OF SOUTHERN MISSISSIPPI
EATON Powering Business Worldwide

THIRD INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURS

"Advances in concrete reinforcement"

August 3-4, 2021 - Virtual

Standards & Specifications Perspective on the use of FRP Rebar, AFGC French working group

Emmanuel FERRIER, University LYON 1, FRANCE

USE of GFRP in France for RC concrete structures

Soft-eye opening for the Bangkok Metro (http://aslanfrp.com)

Tunnels, basement

COROSION FREE

Grand Paris construction site

(https://www.sireggeotech.it)

Building (Precast concrete wall)

Thermal conductivity

Schöck
Solutions constructives innovantes

FDOT

Use of GFRP in « Grand Paris » underground

www.solscope.fr

Association Française de Génie Civil

Working group

Use of GFRP bars for RC structures

Coordinateurs:

Sylvain Chataigner *(Université Gustave Eiffel)*

Laurent Michel (*Université Lyon* I)

Animateurs:

Karim Benzarti (*Université Gustave Eiffel*), ***Emmanuel Ferrier*** (*Université Lyon* I), ***Elhem Ghorbel*** (*Université Cergy* Pontoise), ***Philippe Jandin*** (CEREMA), ***Anthony Pruvost*** (CEREMA), ***Marc Quiertant*** (*Université Gustave Eiffel*), ***Arnaud Rolland*** (*CEREMA*)

THIRD INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURS

"Advances in concrete reinforcement"

"The working group focuses on the use of internal "composite" reinforcements (long fibers and organic matrix) for the reinforcement of reinforced concrete in the case of new structures. These structures can be of various nature (structures, building, foundations, tunnels, ...). Its objective is to propose recommendations adapted to the national situation, in accordance with international work on the subject.

Université, Grandes Ecoles

Ferrier	Emmanuel	LMC²
Michel	Laurent	LMC²
Ghorbel	Elhem	IUT Cergy Pontoise
Benmokrane	Brahim	Université Sherbrooke

Centres de recherche et d'études techniques

Rolland	Arnaud	CEREMA
Benzarti	Karim	IFSTTAR
Quiertant	Marc	IFSTTAR
Chataigner	Sylvain	IFSTTAR
Bouteille	Sebastien	CETU
Roth	Jeremy	CEREMA
Pineau	François	ANDRA
Meyer	Caroline	CEREMA
Tessier	Christian	IFSTTAR
Junes	Angel	CSTB
Deme	Baila	Société du Grand Paris
Nedjar	Boumediene	IFSTTAR
Zghondi	Jad	ANDRA

Entreprises du Bâtiment et des Travaux Publics

Simon	Alain	Eiffage
Degeorge	Reynald	Soletanche Bachy
Romagon	Mathieu	Soletanche Bachy
Champlon	Jordan	TES TECHNIFOR

Entreprises productrices d'armatures

Gaufillet	Faustin	Schoeck
Mathelet	Benoit	Schoeck
Weber	andre	Schoeck
Drouin	Bernard	Pultrall
Mandelli	Claudio	Sireg
Valkai	Dorian	Epsilon Composites
Millet	Leonard	DEXTRA
Barragan	Bryan	OWENS CORNING
Hofmann	Pierre	DEXTRA
Seynave	Xavier	Pultrall
Spitz	Christoph	H-Bau
Goubin	Tristant	SIKA
Arduini	Marco	CoForce
Balconi	Gabriele	Sireg
Seynave	Xavier	Pultrall
Saade	Julien	Pultron Composites
Crofts	Nick	Mateenbar
Wirth	Remi	Schoeck
Gerard	Pierre	Arkema
Thalmann	Cédric	Basalt Fibertec
Patrascu	Bogdan	Pultron Composites
Willems	Steve	Epsilon Composites
Alexander	Zoller	Arkema
Casadei	Paolo	sireg

Bureaux d'étude, de contrôle

Jandin	Philippe	CEREMA
Pruvost	Anthony	CEREMA
Caniac	Eric	AFCAB
Lanza	Matthias	NGE Fondations
Martigny	Benoit	NGE Fondations
Babahouari	Zineb	SEFI-INTRAFOR
Tchombou	Guy	APAVE
Heisel	Pascal	MAREAL

50 members with at least 30 participants at each meeting 2018-2021

GUIDELINE OUTLINE

AFGC

Chapitre 1 :
Caractérisati
Armatures cor

AFGC

Chapitre 2 :
Durabi
Comporte
Températ
Armatures c

AFGC

Chapitre 3 :
Conceptior
structures en
armé avec
Armatures com

AFGC

Chapitre 4 :
Exemple
Dimension

AFGC

Chapitre 5 :
Contrôles Qua
procédures de
œuvre

AFGC

ANNEXE 1 :
Etudes de

AFGC

ANNEXE 2 :
Exemple d'obtention des caractéristiques mécaniques à long terme

ANNEXE 3 :
Détails des hypothèses de calcul à l'ELU

ANNEXE 4 :
Application au dimensionnement d'un hourdis de pont mixte

AFGC

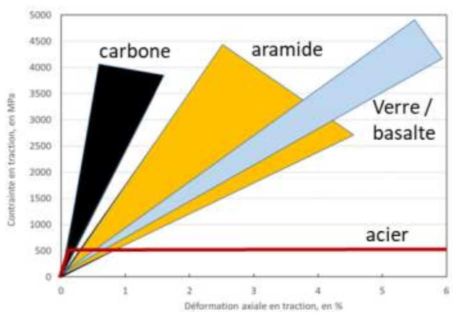
Chapitre 1 :

Caractérisation des Armatures composites

CHAPTER 1 : MATERIAL PROPERTIES

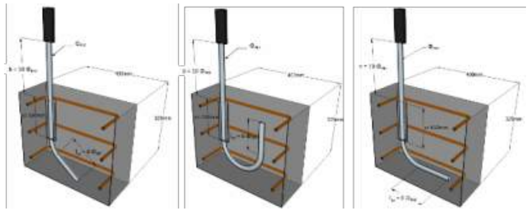
- ***Intoduction to GFRP***

Kind of fibers, surface properties



- ***Geometrical, physical and mechanical properties1***

  - Geometrical properties;
  - Glass temperature Tg ;
  - coefficient of thermal expansion ;
  - Degree of crosslinking ;
  - Density.



Diamètre nominal $\emptyset_{PRF}$, en mm	*Section nominale, A_{PRF} en mm²*	*Section minimale mesurée, en mm²*	*Section maximale mesurée, en mm²*
5	19,6	18	25
6	28,3	26	35
7	38,5	36	45
8	50,3	47	57
9	63,6	59	71
10	78,5	73	102
12	113	106	124
13	132	124	144
14	154	144	165
15	176	165	188
16	201	188	246
19	283	266	295
20	314	295	370
25	491	461	565
29	660	620	750
32	804	755	909
36	1018	956	1021
38	1134	1065	1131
40	1257	1181	1407

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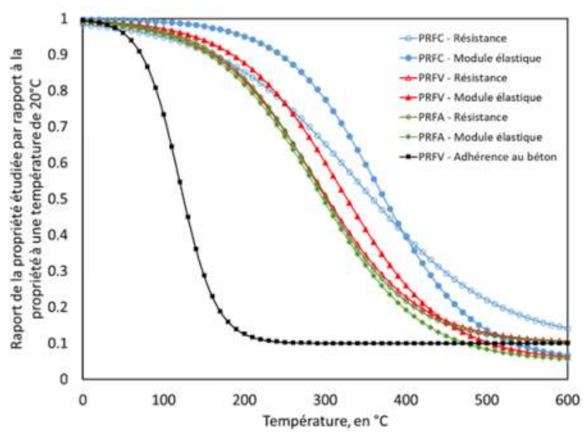
CHAPTER 2 : DURABILITY

AFGC

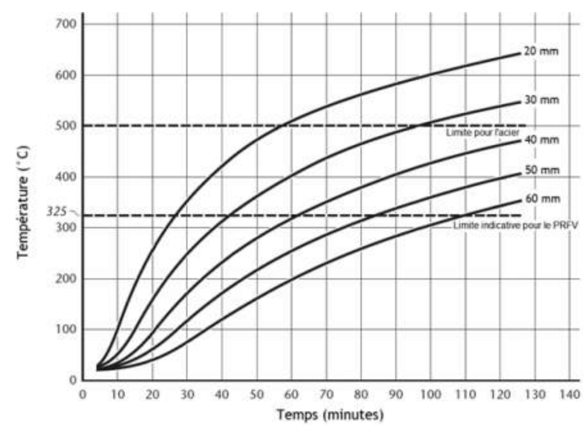
Chapitre 2 :

Durabilité et Comportement en Température des Armatures composites

- ***Fatigue and creep strength***
- ***Alkali sensitivity ;***
- ***Serviciability Temperature ;***
- ***Fire behaviour***



Evolution en fonction de la température des résistances et modules élastiques des PRFC, PRFA et PRFV ainsi que l'adhérence entre PRFV et béton (Bisby, 2003)



Exemple d'abaque permettant de déterminer l'épaisseur d'enrobage nécessaire à partir de la méthode de la température critique

- ***Review of 25 years of background***

CHAPTER 3 : DESIGN PROVISIONS

AFGC

Chapitre 3 :

Conception de structures en béton armé avec des Armatures composites

Based on
NF EN 1992-1

- ***Covering ;***
- ***Design material properties;***
  Safety factors
- ***Calculus of beams under flexural and normal loading;***
  - Calculation for ULS
  - Calculation for SLS ;
  - Minimal ratio ;
  - Detailing
- ***Calculus for shear ;***
  - Minimal ratio ;
  - Detailing
- ***Calculus for T beams ;***
- ***Calculus for punching ;***
- ***Calculus of columns under compression and flexural loading ;***
- ***Detailing;***
- ***Fatigue calculation***

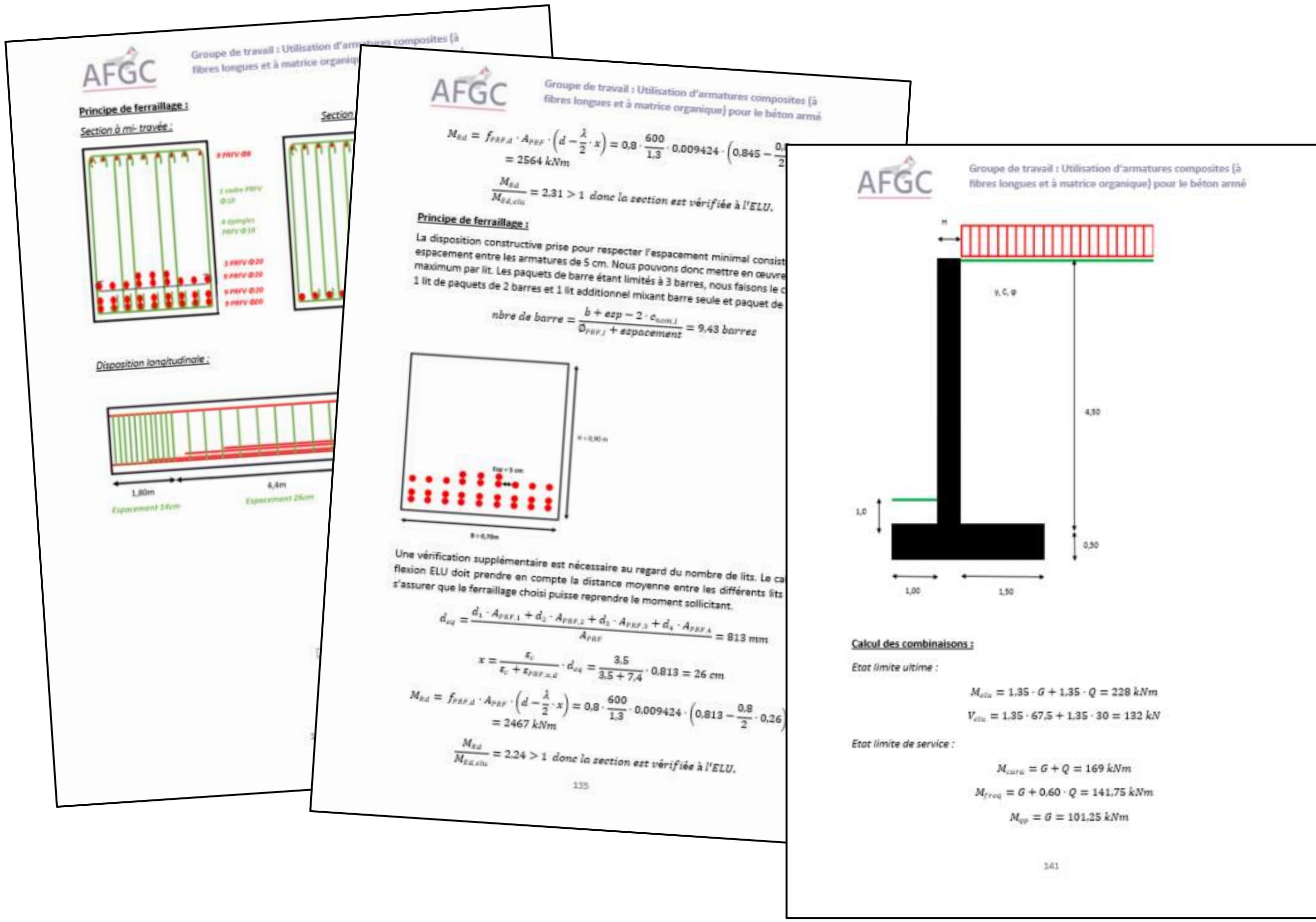
CHAPTER 4 : DESIGN EXEMPLES

AFGC

Chapitre 4 :

Exemples de Dimensionnement

Based on
NF EN 1992-1



- ***Beams ;***
- ***Sustaining RC wall ;***
- ***columns***

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Chapitre 5 :

Contrôles Qualité et procédures de mise en œuvre

CHAPTER 5 : QUALITY CONTROL

- ***List of initial evaluation tests on reinforcements;***
- ***List of internal factory production controls;***
- ***On-site implementation procedures;***
- ***On-site storage procedures;***
- ***Rules of transport;***
- ***Rules for setting up reinforcements ...***

THIRD INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURS

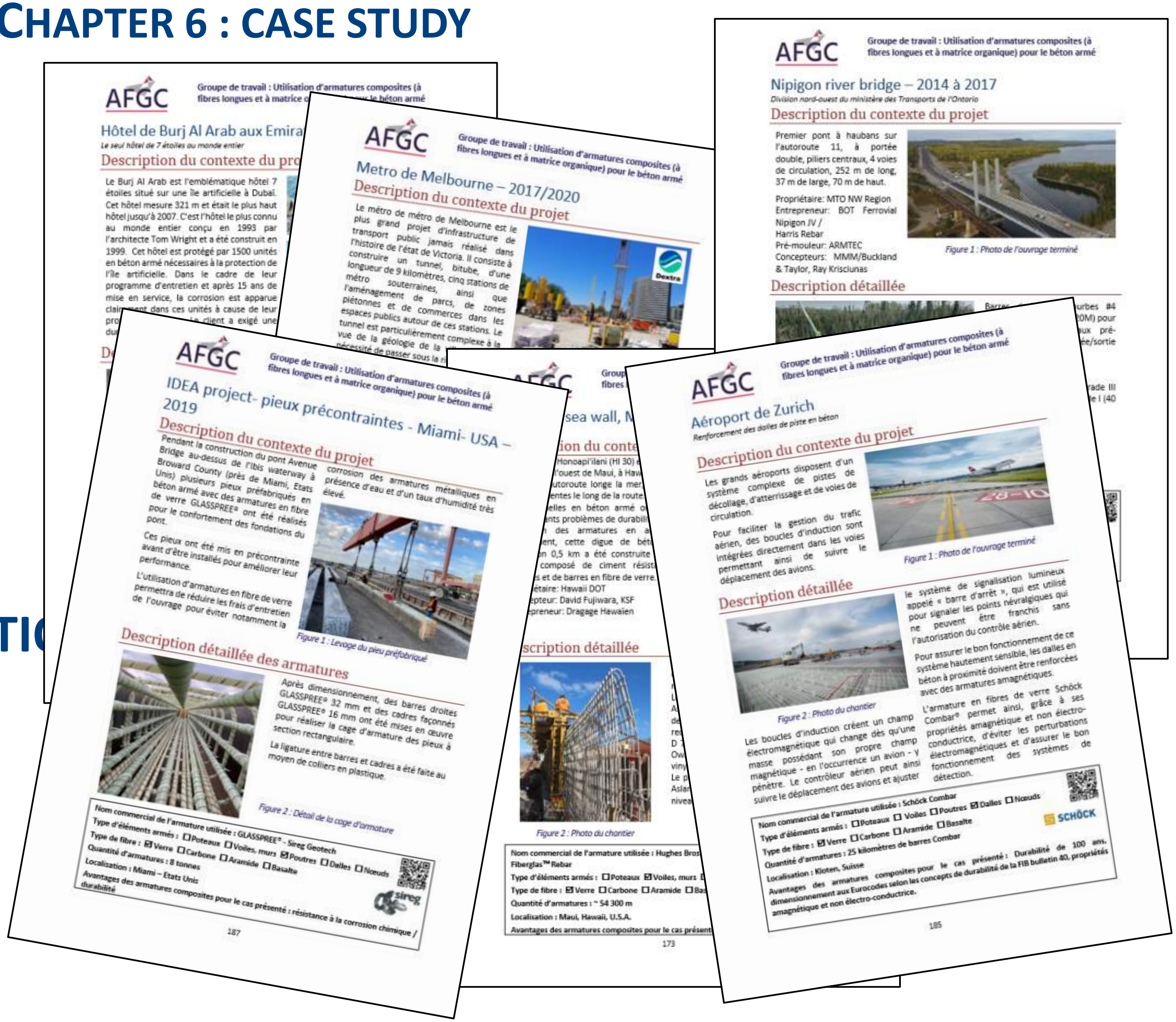
"Advances in concrete reinforcement"

AFGC

ANNEXE 1 :

Etudes de cas

CHAPTER 6 : CASE STUDY



- ***Dextra ;***
- ***Mateenbar ;***
- ***Owens Corning ;***
- ***Pultrall ;***
- ***Schöck ;***
- ***Sireg***

PRÉSENTATIO

CONCLUSION

Open working group (approx. 50 participants)

10 meetings for 3 years. (+ group meetings)

GFRP bars world wide used

Need to move forward on the French standard (strong industrial demand and some project owners) to allow a wider diffusion of composite reinforcements,

Final proofreading phase in progress.

=> Objective: finalization of the draft at the end of 2021!

Thank you for your attention

sylvain.chataigner@ifsttar.fr

laurent.michel@univ-lyon1.fr

THIRD INTERNATIONAL WORKSHOP ON FRP BARS FOR CONCRETE STRUCTURS

"Advances in concrete reinforcement"

August 3-4, 2021 - Virtual

Standards & Specifications on the Use of FRP Rebar: *Perspective in Australia*

Allan Manalo, University of Southern Queensland, Australia

Current Australian market

- Between 2012 and 2017, there are more than ***1.5 million meters*** of GFRP bars installed in actual construction projects.
- Mostly used as ***reinforcement in concrete structures in harsh environmental conditions*** with 20% of market are for electrical and magnetic non-conductive applications.
- Market value for GFRP bars is around AU$8.0 million in 2021 and ***increases by 13% per year***.

https://www.tuf-bar.com/

https://www.buildaustralia.com.au/products/mateenbar-concrete-reinforcement/

https://www.bandbfrp.com/

https://basaltfrp.com.au/basalt-products-reinforcement-bar-mesh-fabric/fibreglass-rebar/

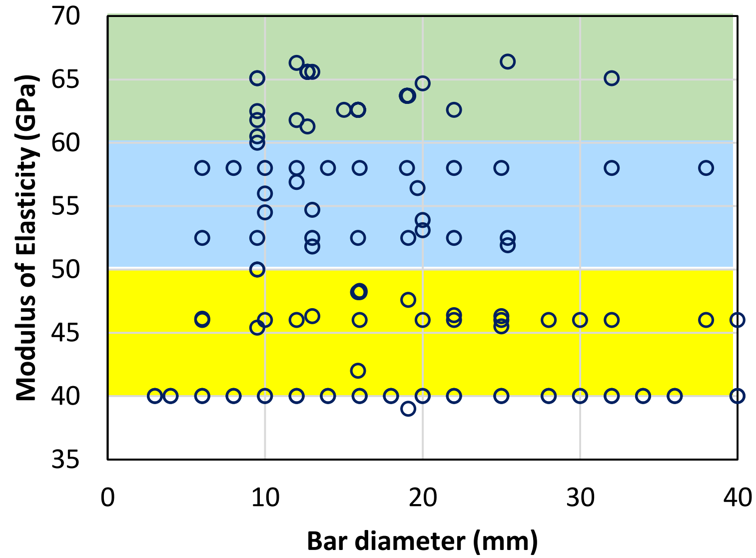
http://galencomposite.com/products/composite-reinforcement-rockbar/

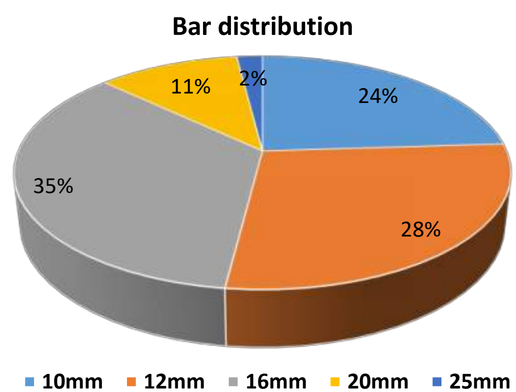
Current Australian market

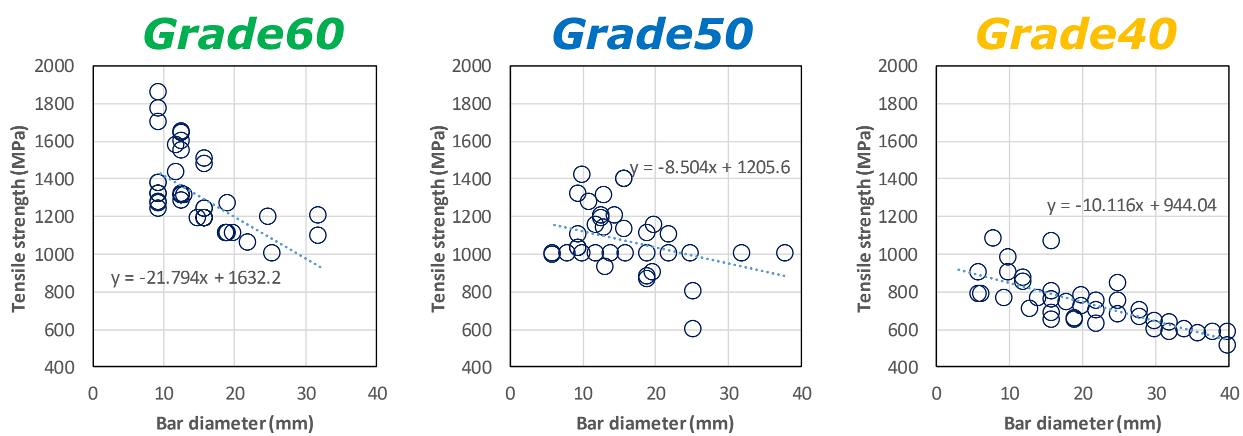
- **3 grades of FRP bars**

Grade40: 40 GPa ≤ E < 50 GPa
Grade50: 50 GPa ≤ E < 60 GPa
Grade60: E ≥ 60 GPa

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







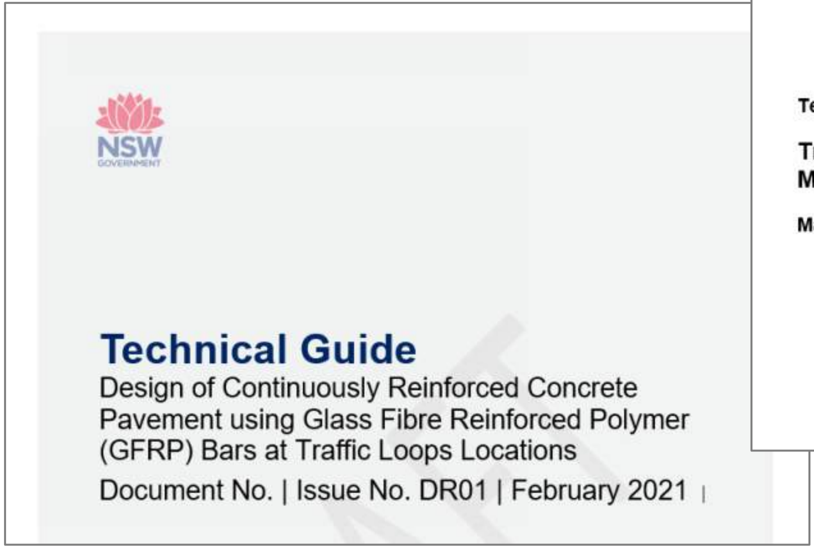
Tensile strength of FRP bars based on MOE

Design codes and specifications

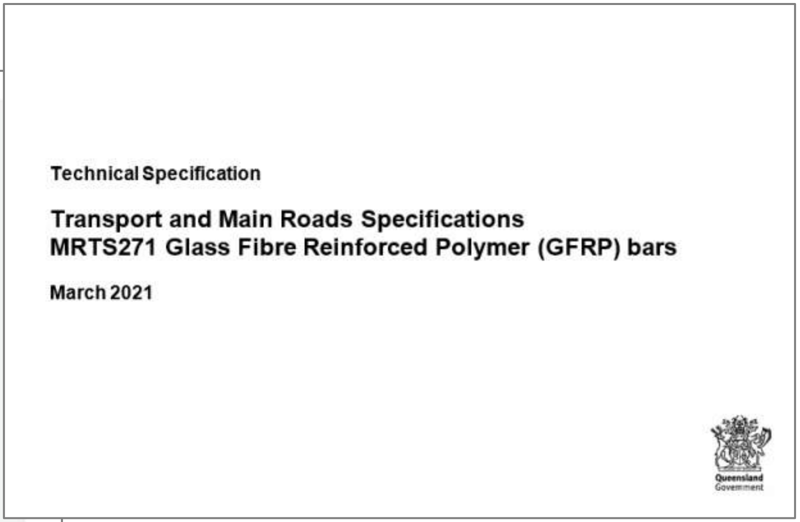
STANDARDS Australia

BD-108 Fibre-Reinforced Polymer (FRP) Bars

AS 5204: Material Standards for Fibre-Reinforced Polymer (FRP) Composite Bars as Internal Reinforcement for Concrete Structures
(proposal under stakeholders and public consultation)


NSW GOVERNMENT

Technical Guide
Design of Continuously Reinforced Concrete Pavement using Glass Fibre Reinforced Polymer (GFRP) Bars at Traffic Loops Locations
Document No. | Issue No. DR01 | February 2021


Technical Specification

Transport and Main Roads Specifications
MRTS271 Glass Fibre Reinforced Polymer (GFRP) bars

March 2021

Queensland Government

Advanced Queensland Industry Research Fellowship

GFRP-reinforced precast concrete in boating and marine infrastructure

Precast concrete pontoons

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

Testing of GFRP-reinforced precast planks under torsion

Rehabilitation of marine infrastructure

Precast concrete marine piles
https://lockesolutions.com/wp-content/uploads/2017/08/4.jpg

Summary

- GFRP bar is now an accepted alternative reinforcement in concrete structures exposed to aggressive environment and in electrical and magnetic non-conductive applications.
- The properties of GFRP bars available in Australia are in alignment with the property limits suggested by CSA S807 and ASTM D7957.
- The complete acceptance of the GFRP bars for concrete structures can be achieved by the development of materials and design standards.

Case Study

Check for updates

ASCE

Fiber-Reinforced Polymer Bars for Concrete Structures: State-of-the-Practice in Australia

A. C. Manalo[1]; P. Mendis[2]; Y. Bai[3]; B. Jachmann[4]; and C. D. Sorbello[5]

FDOT