

# GFRP Rebar Workshop

2016



Design Training

Post-Expo

6/15/2016, 1:00pm - 4:00pm

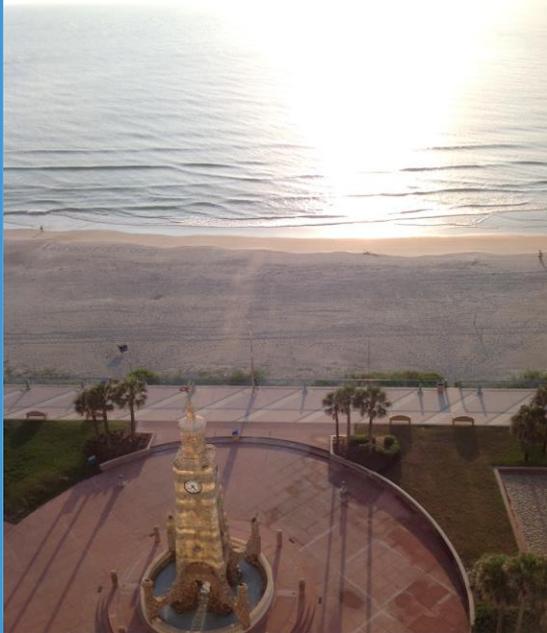
Hilton Daytona Beach Oceanfront Resort

St Johns Room

100 North Atlantic Avenue

Daytona Beach, Florida 32118, USA

Tel: 1-386-254-8200



# Part 1 - Presentations

1. GFRP Industry perspective
  - i. ACMA-TSC (John Busel)
  - ii. Owens Corning (Skinner/Vorobiev)
2. ACI Committee 440 perspective (Antonio Nanni)
3. AASHTO-T6 perspective (Will Potter – FDOT rep.)
4. FDOT perspective
  - i. Design (Vallier/Nolan)
  - ii. Materials (Knight/Lasa)
  - iii. Construction (future workshops)
  - iv. Maintenance (future workshops)

# GFRP Rebar Workshop

## Perspectives

### Table of contents

- Activities in ACI (ACI 440 Committee)
- Activities in ICC-ES (AC454)
- Activities in ASTM (Subcommittee D30.10)

# ACI 440 documents on FRP as internal reinforcement to concrete

## Active Committee Documents:

[440.1R-15: Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer \(FRP\) Ba](#)

[440.3R-12: Guide Test Methods for Fiber-Reinforced Polymer \(FRP\) Composites for Reinforcing or Strengthening Concrete and Masonry Structures](#)

[440.4R-04: Prestressing Concrete Structures with FRP Tendons](#)

[440.5-08: Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars](#)

[440.6-08 Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement](#)

[440.9R-15 Guide to Accelerated Conditioning Protocols for Durability Assessment of Internal and External Fiber-Reinforce](#)

# ACI 440.1R-15

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

Reported by ACI Committee 440

# ACI 440 documents on FRP as internal reinforcement to concrete

## Documents Under Development:

440: Building Code Requirements for Structural Concrete Reinforced Internally with Fiber Reinforced Polymer (FRP) Bars

Document	Doc Ballot by Sub	Doc Ballot by 440 Main	Resolve Negative 440 Main Ballot	Doc to ACI for TAC Review	TAC Review	440 Reply to TAC Comments Ballot	Return to ACI for Layout	In Print
440-H CODE	PI-F15 PII-Su16	PI-S16 PII-S17	PI-S16 PII-F17	Sp18				
440.4R Prestress	1 <sup>st</sup> done, next ?							

# 318 Chapters (Green = Phase 1 Toolbox; Blue = Phase 2; Red = Out this Version)

- Ch 1 – General
- Ch 2 – Notation/Terminology
- Ch 3 – Referenced Standards
- Ch 4 – Structural System Reqmts
- Ch 5 – Loads
- Ch 6 – Structural Analysis
- Ch 7 – One-way Slabs
- Ch 8 – Two-way Slabs
- Ch 9 – Beams
- Ch 10 – Columns
- Ch 11 – Walls
- Ch 12 – Diaphragms
- Ch 13 – Foundations
- Ch 14 – Plain Concrete
- Ch 15 – Beam/Slab-Column Joints
- Ch 16 – Connection btwn Members
- Ch 17 – Anchoring to Concrete
- Ch 18 – Earthquake-Resistant Strcts
- Ch 19 – Concrete: Design & Durbly
- Ch 20 – Rebar Properties, Durbly
- Ch 21 – Strength Reduction Factors
- Ch 22 – Sectional Strength
- Ch 23 – Strut & Tie Models
- Ch 24 – Serviceability Reqmts
- Ch 25 – Reinforcement Details
- Ch 26 – Construction Docs & Inspectn
- Ch 27 – Strgth Eval of Existing Structures
- 318.2 – Thin Shells

# 440: Building Code Requirements for Structural Concrete Reinforced Internally with Fiber Reinforced Polymer (FRP) Bars

## Main Challenges:

- Compression members
- Framed structures

## Limitations:

### Material level

- GFRP solid round

### Structures Level

- No moment redistribution
- No seismic provisions

# **Provisions for the FRP ACI 440 Code**

**ACI 440 FRP Reinforcement - ACI Spring Convention 2016 – Milwaukee , April 17-21 2016**

## **P-M Interaction Diagram of RC Columns Reinforced with Deformed and/or Sand Coated GFRP Bars and Ties**

**Prepared by**

**Prof. Brahim Benmokrane in collaboration with:**

**Michael Guérin, PhD Student, University of Sherbrooke**

**Dr. Hamdy Mohamed, PDF, University of Sherbrooke**

**Prof. Antonio Nanni, University of Miami**

**Prof. Carol Shield, University of Minnesota**



# Fabrication of the Cages

## 24 Square FRP-RC Columns



**Type A  
(Pultrall-V-ROD)**



# Fabrication of the Cages

## 24 Square FRP-RC Columns



**Type B**  
**(Hughes Brothers Aslan)**

# GFRP Rebar Workshop

## Perspectives

### Table of contents

- Activities in ACI (ACI 440 Committee)
- **Activities in ICC-ES (AC454)**
- Activities in ASTM (Subcommittee D30.10)

# How innovation is handled by ICC



The International Building Code (IBC) is the predominant model building code, has been adopted in all 50 states, DC, Puerto Rico and the U.S. Virgin Islands.

What happens if there is a new material or system not covered (or referenced) in the model codes (I-Codes)?

Sections 104.11 and 104.11.1 of IBC (and equivalent ones in the other I-Codes) allow alternative materials when a “research report” is available for building official’s approval.

**104.11 Alternative materials, design and methods of construction and equipment;** The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been *approved*.....

**104.11.1 Research reports:** Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in this code, shall consist of valid research reports from *approved* sources.

- ICC Evaluation Service (**ICC-ES**) develops with proposers of new technology specific documents called “Acceptance Criteria (AC)” for the purpose of issuing “Evaluation (Research) Reports (ESR)”
- ICC-ES issues an ESR when manufacturer demonstrates an approved QC program and the research program outlined in the AC is successfully conducted by a certified independent laboratory.



# **PROPOSED REVISIONS TO THE ACCEPTANCE CRITERIA FOR FIBER-REINFORCED POLYMER (FRP) BARS FOR INTERNAL REINFORCEMENT OF CONCRETE MEMBERS**

**AC454**

**Proposed April 2016**

Previously approved May 2015 and June 2014

**1.2 Scope:** This acceptance criteria applies to glass or basalt fiber-reinforced polymer (FRP) bars, in cut lengths, and bent shapes and continuous closed stirrups and ties (hoops), that are used to reinforce concrete structural members. Items evaluated include material properties; performance under accelerated environmental exposures; performance under exposure to fire conditions; and structural design procedures. This criteria is applicable to FRP bars that are solid and have circular cross sections, or solid but have a cross sections other than circular, or hollow and have circular cross sections. FRP bars under this criteria are in use as flexural reinforcement in tension to reinforce structural concrete members such as beams, shallow foundations and one-way or two-way slabs, and as shear reinforcement for flexural members. Use of FRP bars for other structural considerations such as longitudinal reinforcement in columns or walls, or as compression reinforcement in flexural members, is outside the scope of this criteria. Application of FRP bars under this criteria is limited to structures to be used in seismic design category ~~a or b~~ A or B, and constructed using normal-weight concrete.

## **2.7.5 FRP Bar Shapes:**

**2.7.5.1** FRP Bent shape: an FRP reinforcing bar bent to a prescribed shape.

**2.7.5.2** FRP Closed continuous stirrup/tie: an FRP bent shape fabricated as a continuous loop without end-joints.

**2.7.5.3** FRP spirals: continuously wound FRP reinforcement in the form of a cylindrical or polygonal helix.

**TABLE 1—NOMINAL PROPERTIES AS A FUNCTION OF MEASURED BAR AREA RANGE AND  
MINIMUM GUARANTEED TENSILE LOAD FOR FRP BARS**

MEASURED		NOMINAL			
Bar Area Range in <sup>2</sup> .	Minimum Guaranteed Tensile Load (kips)	Bar Designation	Bar Diameter (in.)	Bar Area in <sup>2</sup> .	Tensile Strength* (ksi)
0.046 to 0.085	6.4	2	1/4	0.05	130.6
0.104 to 0.161	13.2	3	3/8	0.11	120.0
0.185 to 0.263	21.6	4	1/2	0.20	110.2
0.288 to 0.388	32.2	5	5/8	0.31	104.9
0.415 to 0.539	44.2	6	3/4	0.44	100.0
0.565 to 0.713	57.1	7	7/8	0.60	95.0
0.738 to 0.913	70.6	8	1	0.79	89.9
0.934 to 1.137	84.5	9	1 1/8	1.00	85.0
1.154 to 1.385	98.2	10	1 1/4	1.27	80.0

For SI: 1.0 sq.in. = 645 mm<sup>2</sup>; 1.0 in = 25.4 mm, 1.0 kip = 4.45 kN

\* Based on Nominal bar area

# GFRP Rebar Workshop

## Perspectives

### Table of contents

- Activities in ACI (ACI 440 Committee)
- Activities in ICC-ES (AC454)
- **Activities in ASTM (Subcommittee D30.10)**

# Efforts in ASTM

## Existing standards related to FRP in Civil structures

**D570** Standard Test Method for Water Absorption of Plastics

**D792** Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

**D2584** Standard Test Method for Ignition Loss of Cured Reinforced Resins

**D3171** Standard Test Method for Constituent Content of Composite Materials.

**D5229/D5229M** Standard Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer matrix Composite Materials

**E1356** Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry

**E1640** Standard Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis

# Efforts in ASTM within Subcommittee D30.10:

## Existing standards

**D7205/D7205M** Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars

**D7617/D7617M** Standard Test Method for Transverse Shear Strength of Fiber Reinforced Polymer Matrix Composite Bars

**D7705/D7705M** Standard Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction

**D7913/D7913M** Standard Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing

**D7914/D7914M** Standard Test Method for Strength of Fiber-Reinforced Polymer (FRP) Bent Bars in Bend Locations

- **Development of a new Spec to replace ACI 440.6 (last draft March 16, 2016)**

# Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement<sup>1</sup>

## 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 must meet the requirements for geometric, material, and physical properties described herein.

1.2 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.

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

1.3.1 Bars made of more than one load bearing fiber type (that is, hybrid FRP), and

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

1.3.3 Bars with geometries other than solid, substantially round cross sections.

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

1.4 This specification is applicable for either SI (as Specification DXXYYM) or inch-pound units (as Specification DXXYY).

Bar Designation No.	Nominal Dimensions		Measured Cross-Sectional Area Limits mm <sup>2</sup> [in. <sup>2</sup> ]		Minimum Guaranteed Ultimate Tensile Force kN [kip]
	Diameter mm [in.]	Cross-Sectional Area mm <sup>2</sup> [in. <sup>2</sup> ]	Minimum	Maximum	
M6 [2]	6.3 [0.250]	32 [0.049]	30 [0.046]	55 [0.085]	27.3 [6.1]
M10 [3]	9.5 [0.375]	71 [0.11]	67 [0.104]	104 [0.161]	59.0 [13.2]
M13 [4]	12.7 [0.500]	129 [0.20]	119 [0.185]	169 [0.263]	96.1 [21.6]
M16 [5]	15.9 [0.625]	199 [0.31]	186 [0.288]	251 [0.388]	130 [29.1]
M19 [6]	19.1 [0.750]	284 [0.44]	268 [0.415]	347 [0.539]	182 [40.9]
M22 [7]	22.2 [0.875]	387 [0.60]	365 [0.565]	460 [0.713]	241 [54.1]
M25 [8]	25.4 [1.000]	510 [0.79]	476 [0.738]	589 [0.913]	297 [66.8]
M29 [9]	28.7 [1.128]	645 [1.00]	603 [0.934]	733 [1.137]	365 [82.0]
M32 [10]	32.3 [1.270]	819 [1.27]	744 [1.154]	894 [1.385]	437 [98.2]

Note that min and max dimensions are same as AC454 but capacity is given in force and lower than AC454

Thanks

Questions/Comments?