Workbook: 2018 FDOT-FRP Industry 2nd Winter Workshop

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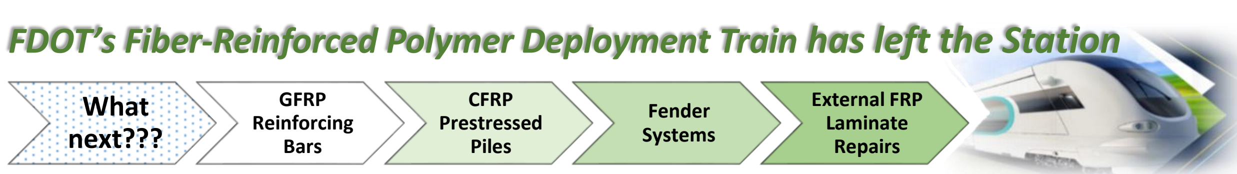

Version 18.2

FDOT FRP-RC Strategic Workplan Summary

Priority #	Goal #'s [(1)]	Topic	Responsible Team	Timeline	Justification
1	1, 2, 3	**Endurance Characteristic Curves Testing** a. Need time/cycles to rupture curves; b. What is the test method or surrogate measure for supplier product acceptance?	FRP Industry (Dave Hartman-OC) in consultation with SMO (Chase Knight)	ASAP	a. Reliably extending service-life beyond 50-75 years; b. Simple, timely, low cost verification tests.
2	1, 5	**Endurance Limits** - on FRP for design (is 20% the best we can do?)			Directly proportional to area of rebar required. Perhaps we should consider a strain-limit approach (Benmokrane)
3	1, 4, 5	**Increasing Material Property Qualification Thresholds and Design Limits** - desirably 20% above *ASTM D7957*.	FDOT with industry concurrence	Decision by 8/1/2018 for ***SM*** publication	>20% reduction in rebar area possible for SLS controlled designs
4	3, 4	**Establishing Consistency** (in what? - manufacturer approval, design, bidding, construction)			
5	1, 3	**Cost Estimating** - Need for published cost estimates for GFRP rebar in-place.	ACMA	Decision by 8/1/2018 for ***SM*** publication	Consistency in ***Bridge Development Reports*** evaluation and ***Bid Estimate*** preparation
5a	-	- Follow up from OC discussion with FDOT at CAMX 2017 - Where is OC and ACMA- FRP RMC on this?	OC/ACMA	Need generic data for Chapter 9 of ***SDG*** for BDR cost estimating by 8/1/2018	

5b	-	- FDOT needs to add this to SDG Chapter 9 for designer's guidance during BDR evaluation - can be added in Nov. 2018 update if a consensus proposal ready by August 30th.	FDOT-SDO	***Structures Manual (SM)*** publication: Nov 1, 2018	
6	4	**Bar Bends** – Improve quality, and Guidance for complex shapes and shear stirrups. Index D21310 or SDM? Can be implement in Nov. 2018.	FDOT/Industry	***Standard Plans*** FY 2019-2020: Nov 1, 2018 publication	Improve efficiency for: 1. Plans Production: Standard callouts and Rebar program automation. 2. Design efficiency: reducing overlapping bar lengths.
7	1	**Minimum Bar Sizes for Design Elements** - allow use of #3 bars in slabs and walls. Historical prohibition due to fear of yielding from workers walking/climbing.			Smaller bars are more efficient for Ultimate/Strength Limit State. GFRP #3 is twice yield strength of Gr60 & 10% > #4
8	1, 3	**Life-Cycle Cost (LCC) Guidance** - 100 or 75 years? Should substructure be more (100+) than superstructure (75 current)?	FDOT-UM (SEACON)	Add ***FDM*** guidance for Nov. 2018 release.	
9	1, 4, 5	**Minimum Concrete Class/Strength** - for non-corrosive reinforcing (FRP not SS): - Class II: 3,400 psi (min. W/C=<0.53, =<470#/CY) - vs. Class IV: 5,500 psi (min. W/C=<0.41, =<658#/CY).	Need parametric study.		Concrete is relatively cheap so is it beneficial *(when sustainability is not currently a required consideration)* Lower strength reduces efficiency (*d*), lower stiffness for deflection, and higher service stresses?

(1) Goals for FRP Deployment:

1. **Stewardship**
2. **Confidence**
3. **Competency**
4. **Consistency**
5. **Codification**

1. Endurance Characteristic Curves and Testing

a. Draft White Paper - ***Developing New Endurance Characterization Curves for GFRP Reinforcing Bars***

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b. AASHTO SCOBS Needs Statement: ***Developing Endurance Characterization Curves for GFRP Reinforcing Bars***

Developing
endurance limits for

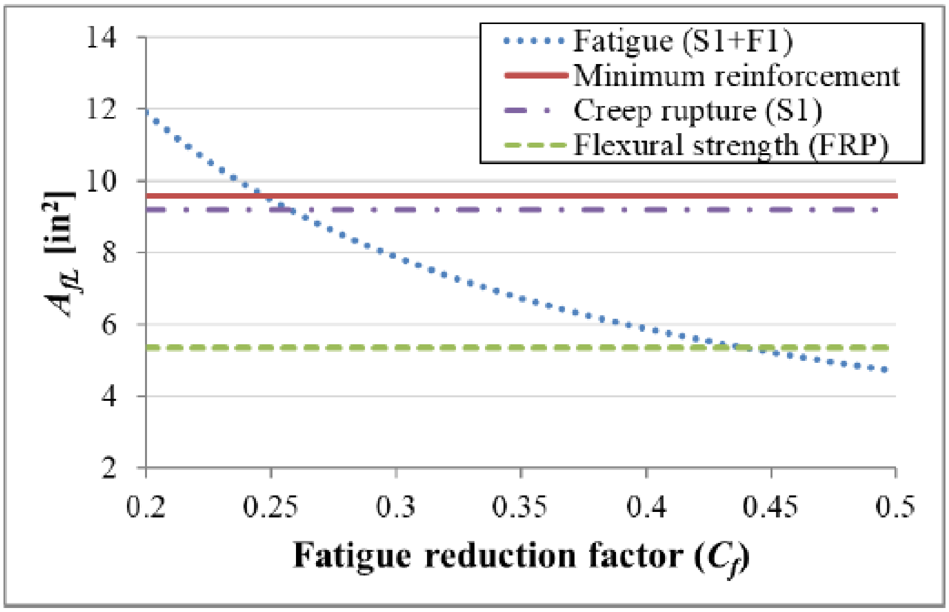
2. Endurance Limits

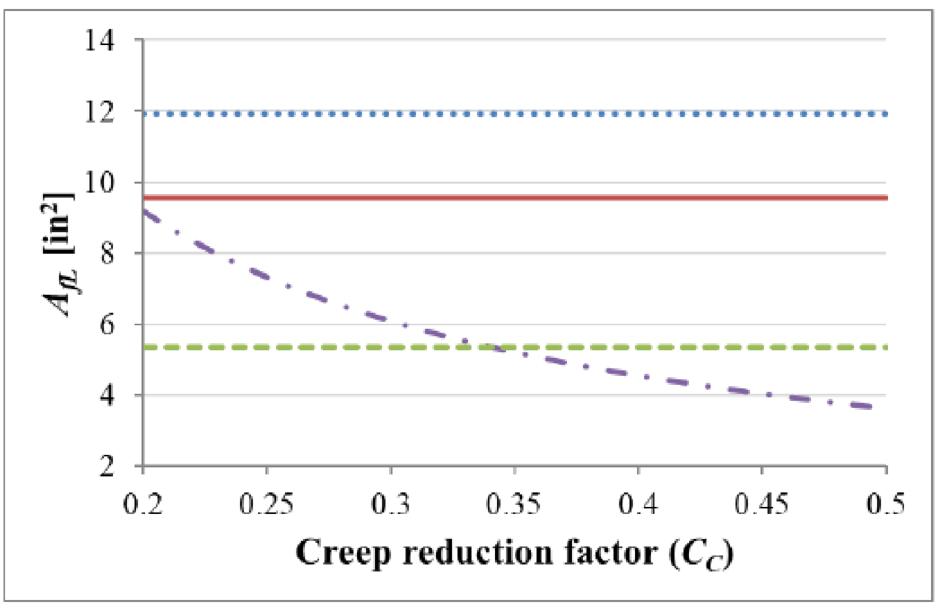
Is 20% the best we can do for Creep-Rupture and Cyclic Fatigue.

Table 1 - Creep rupture stress limits, ACI 440.1R-15 (Table 7.4.1)

Fiber type	GFRP	AFRP	CFRP
Creep rupture stress limit $f_{fs,sus}$	$0.20f_{fu}$	$0.30f_{fu}$	$0.55f_{fu}$

$$f_{fc} = C_c\, f_{fu} = C_c\, C_E\, f^*_{fu} = 0.14\, f^*_{fu}$$ Adapted from ACI 440.1R-15





3. Increasing Material Property Qualification Thresholds and Design Limits

a. 20% increase proposed above ASTM D7957/FDOT 932-2 values

Table 2 –Varied parameters and their effect in terms of reinforcement savings.

Parameters		Range		Flexural Strength	Minimum Reinf.	Creep Rupture	Cyclic Fatigue	Crack Width Limit	A_{fL} Potential Savings (%)
Φ	-	0.55	0.75	x					27%
C_E	-	0.70	0.95	x	x	x	x		27%
f_{fu}^*	Ksi	85	125	x	x	x	x		32%
C_C	-	0.2	0.5			x			61%
C_f	-	0.2	0.5				x		61%
C_b	-	0.7	1.1					x	30%
w	in.	0.02	0.05					x	49%
c_c	in.	3.0	1.0	(x)	(x)	(x)	(x)	x	35%

b. Need to add Elastic Modulus to the parametric study by UM/CICI (Nanni, Rossini)

References:

Rossini, Bruschi, Matta, Poggi, Nanni (2017). *Case-Specific Parametric Analysis as Research-Directing Tool for Analysis and Design of GFRP-RC Structures*, SP-45.

Rossini, Bruschi, Matta, Nolan, Nanni (2018). *Extended abstract: Overview of Proposed AAHTO Design Specifications for GFRP-RC Bridges 2nd Edition using Case-Specific Parametric Analysis*.

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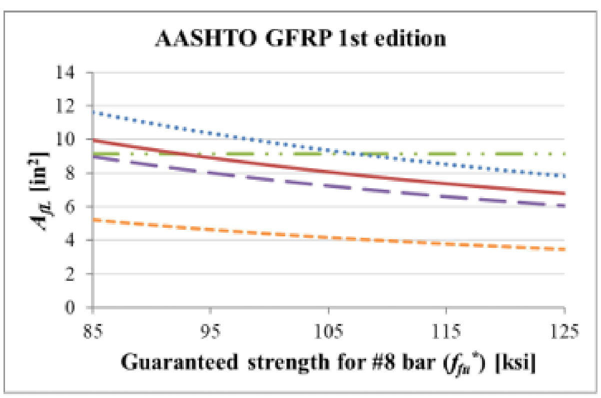
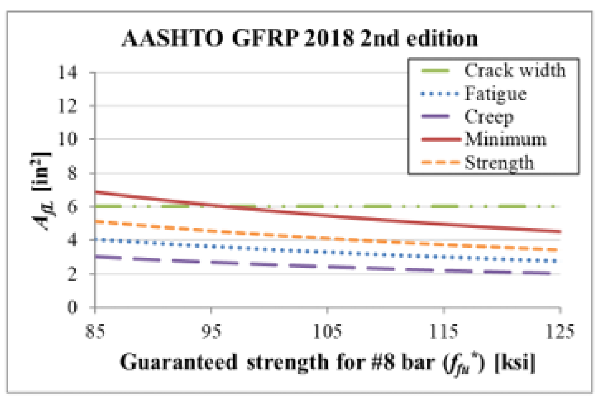
Rossini et al. - Extended Abstract (





4. Establishing Consistency

a. Manufacturer/Product Approval
    i. NIST FRP Roadmapping Workshop Report is available free of charge at: https://doi.org/10.6028/NIST.SP.1218
b. Design
c. Bidding
d. Construction
e. Inspection
f. Maintenance

5. Cost Estimating

a. OC initiative for ACMA FRP-RMC - follow up from OC discussion with FDOT at CAMX Dec, 2017 – What is the status?

b. ***FDOT SDG* Chapter 9** update - for designer's guidance during BDR evaluation - can be added in Nov. 2018 update if a consensus proposal ready by August 30th.

Structures Design Guidelines
9 - BDR Cost Estimating

Topic No. 625-020-018
January 2018

D. Cofferdam Footing (cofferdam and seal concrete*)

Prorate the cost provided herein based on area and depth of water. A cofferdam footing having the following attributes will cost $600,000.

Area: 63 ft x 37.25 ft. Depth of seal; 5 ft. Depth of water over the footing; 16 ft.

* Cost of seal concrete included in pay item 400-3-20 or 400-4-200.

E. Substructure Concrete: cost per cubic yard.

Concrete:	$850
Mass concrete:	$625
Seal concrete:	$375

Bulkhead Concrete:	$900
Shell fill:	$30

For calcium nitrite, add $40 per cubic yard. (@ 4.5 gal per cubic yard)
For silica fume, metakaolin or ultrafine fly ash, add $40 per cubic yard. (@ 60 lbs. per cubic yard)

F. Reinforcing and Post-tensioning Steel

1. Carbon Reinforcing Steel; cost per pound: $0.90.
   Low-Carbon Chromium Reinforcing Steel; cost per pound: $1.25
   Stainless Reinforcing Steel; cost per pound: $4.00

2. Post-tensioning Steel; cost per pound.

Strand	$4.00
Bars	$6.00

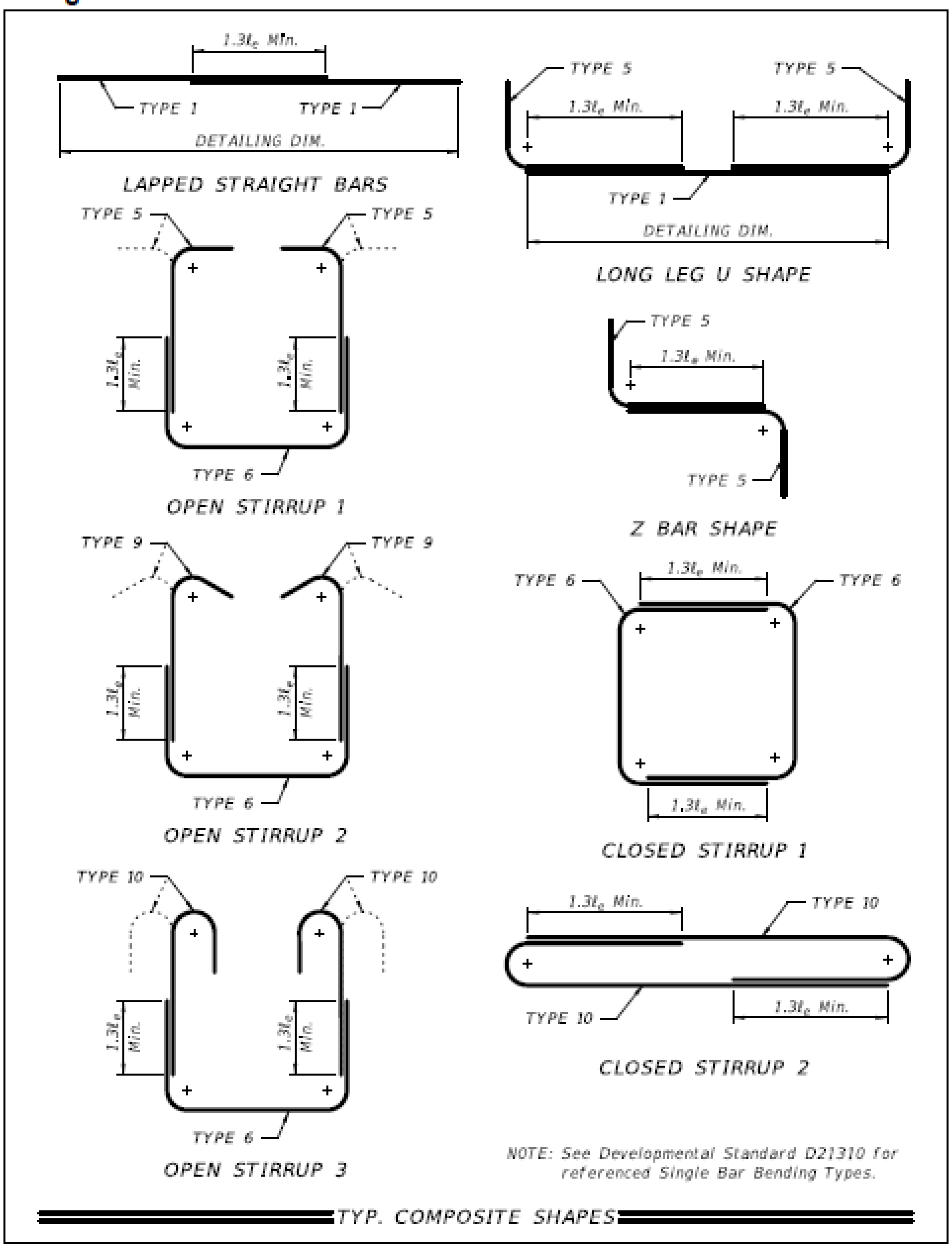
6. Bar Bends

a. FDOT Index D21310 update suggestions
http://www.fdot.gov/roadway/DS/Dev/D21310.pdf

D21310.pdf

b. Complex Shapes, see IDDS-21310
http://www.fdot.gov/roadway/DS/Dev/IDDS/IDDS-D21310.pdf

Design Aids



7. Minimum Bar Sizes for Design Elements

a. Consider allowing use of #3 bars in slabs and walls.
b. Historical prohibition due to fear of yielding from workers walking/climbing
c. Smaller bars are more efficient for Ultimate/Strength Limit State. GFRP #3 is twice yield strength of Grade 60 & 10% greater than #4 Grade 60. (See ***FDOT Spec 932-3.2)***

932-3.2 Bar Sizes and Loads: The sizes and loads of FRP reinforcing bars shall meet the requirements in Table 3-1. The measured cross-sectional area, including any bond enhancing surface treatments, shall be determined according to Table 3-2.

Table 3-1
Sizes and Tensile Loads of FRP Reinforcing Bars

Bar Size Designation	Nominal Bar Diameter (in)	Nominal Cross Sectional Area (in²)	Measured Cross-Sectional Area (in²)		Minimum Guaranteed Tensile Load (kips)	
			Minimum	Maximum	GFRP Bars	CFRP Bars
2	0.250	0.049	0.046	0.085	6.1	10.3
3	0.375	0.11	0.104	0.161	13.2	20.9
4	0.500	0.20	0.185	0.263	21.6	33.3
5	0.625	0.31	0.288	0.388	29.1	49.1
6	0.750	0.44	0.415	0.539	40.9	70.7
7	0.875	0.60	0.565	0.713	54.1	-
8	1.000	0.79	0.738	0.913	66.8	-
9	1.128	1.00	0.934	1.137	82.0	-
10	1.270	1.27	1.154	1.385	98.2	-

8. Life-Cycle Cost

a. What is the goal 100 years or 75?
b. Should substructure be more (100+ years) for future rehab/widening, compared to superstructure (75 years current)?
c. Consider that concrete is relatively cheap so is it beneficial (when sustainability is not a consideration) to use lower strength considering reduce efficiency "d", lower stiffness for deflection, and higher service stresses (creep, fatigue, and crack width)?

9. Minimum Concrete Class

a. Consider for non-corrosive reinforcing (FRP not SS: still needs pozzolans and/or high pH):
    i. Class II: 3,400 psi (min. W/C=<0.53, =<470#/CY)
    ii. vs. Class IV: 5,500 psi (min. W/C=<0.41, =<658#/CY).
b. Beneficial sustainability credits (currently not a FDOT/FHWA requirement)