Structures Manual Guidance: Implementing AASHTO 2nd Edition and Procurement Process

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Structures Manual Guidance: Implementing AASHTO 2nd Edition and Procurement Process

Speaker Bio: Steven Nolan, P.E.

Professional Engineer in Florida since 2003, current technical lead coordinator for Florida DOT for implementation of Fiber-Reinforced Polymer reinforcing and prestressing, stainless-steel prestressing, and UHPC for structural applications. 9-years' experience with development of design guidance for FRP, 25-years' experience with prestressed concrete design and bridge design specification development. Member of TRB committee AKB10-Innovative Highway Structures and Appurtenances, ACI, ASCE-Structural Engineering Institute, and Bridge Engineering Institute.

Structures Manual Guidance: Implementing AASHTO 2nd Edition and Procurement Process

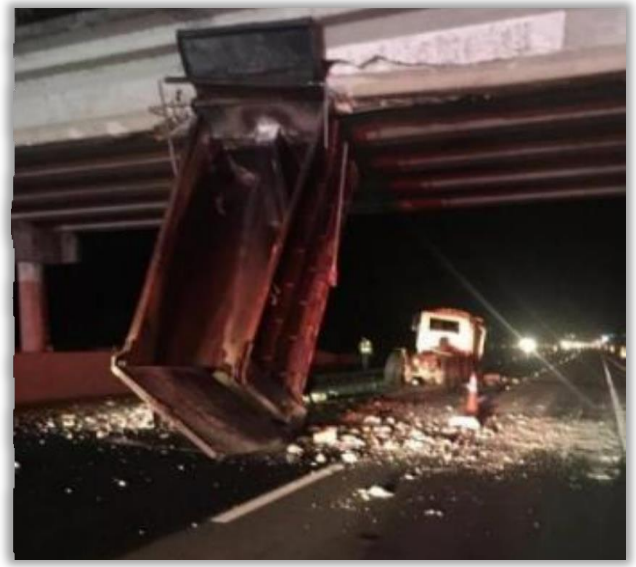
Abstract

FDOT currently specifies the use of ***ACI PRC-440.2-17 Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures*** with a few exceptions as noted in ***Structures Manual-Volume 4 (FRPG), Section 4***. The EOR is instructed to develop Technical Special Provisions for construction and quality control that conform to *Attachment A* of the ***NCHRP Report 609 "Recommended Construction Specifications and Process Control Manual for Repair and Retrofit of Concrete Structures Using Bonded FRP Composites"***, with a few exceptions as noted in the ***FRPG***. Technical Special Provisions must be non-proprietary, multi-vendor solutions, reviewed and approved by the State Specifications and Estimates Office and the State Structures Design Office, or District Structures Maintenance Office.

With the 2023 updates to the ***AASHTO Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements, 2nd Edition***, FDOT plans to transition to this specification for project repair and strengthening design soon. The incorporation of FDOT model Technical Special Provision for construction, example Contract Document layout, and recently completed and ongoing research on externally-bonded FRP, will also be presented.

Structures Manual Guidance: Implementing AASHTO 2nd Edition and Procurement Process

1. **Policy & Practice for FDOT projects**
2. **Future Adoption of AASHTO 2nd Ed.**
3. **Recently completed Research**
4. **Current and Future Research Needs**
5. **Example Projects**



Policy & Practice for FDOT projects

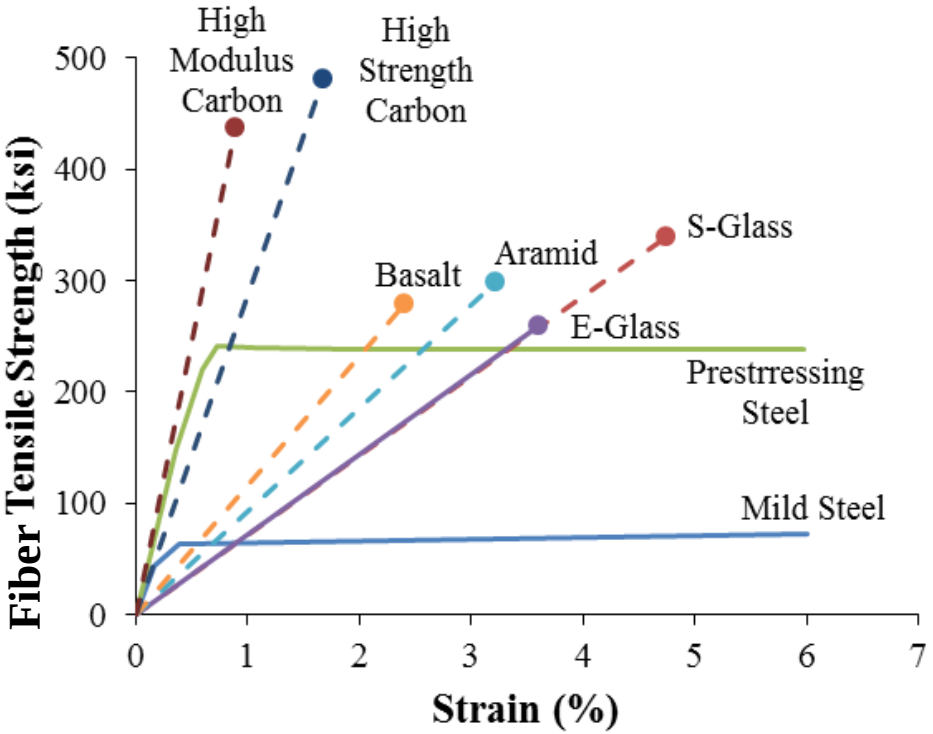
1. Why we use CFRP for Repair & Strengthening
    1. Low Unit Weight
    2. High Durability (corrosion-free)
    3. Moderate Stiffness
2. Innovative Technology Development

Research and installations performed since the early 1990s

FDOT in-house installations until early 2000s (research staff)

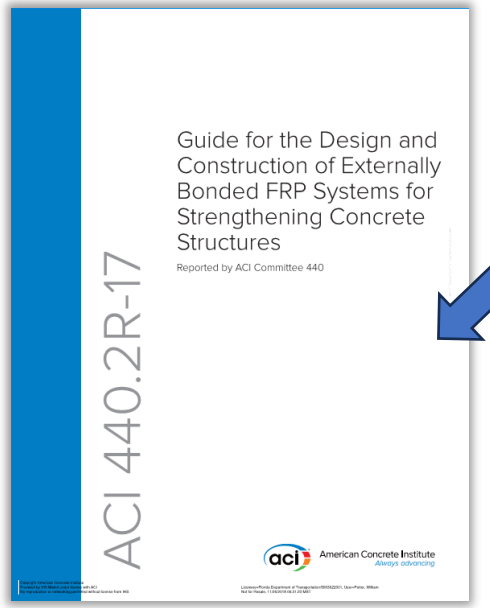
Primary installations:

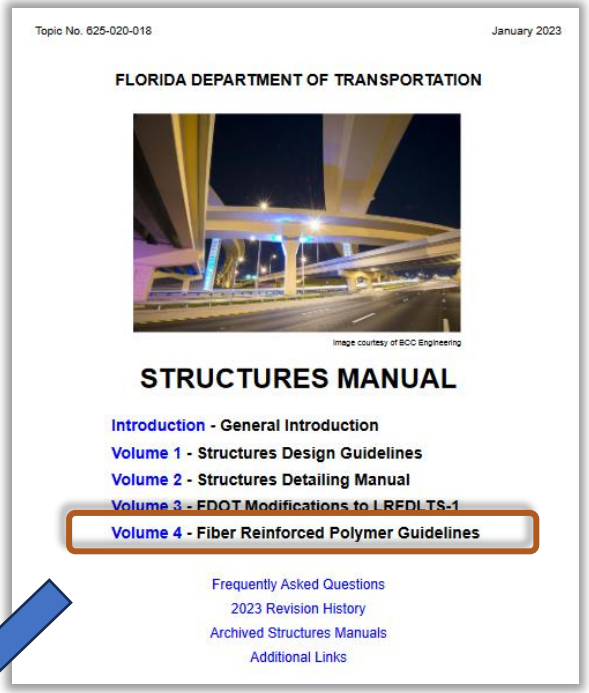
- Over-height vehicle damage
- Corrosion deterioration
- Considered routine practice for certain applications
- Flexural strengthening/repairs
- Confinement
- Some shear strengthening…



Current Policy & Practice for FDOT projects

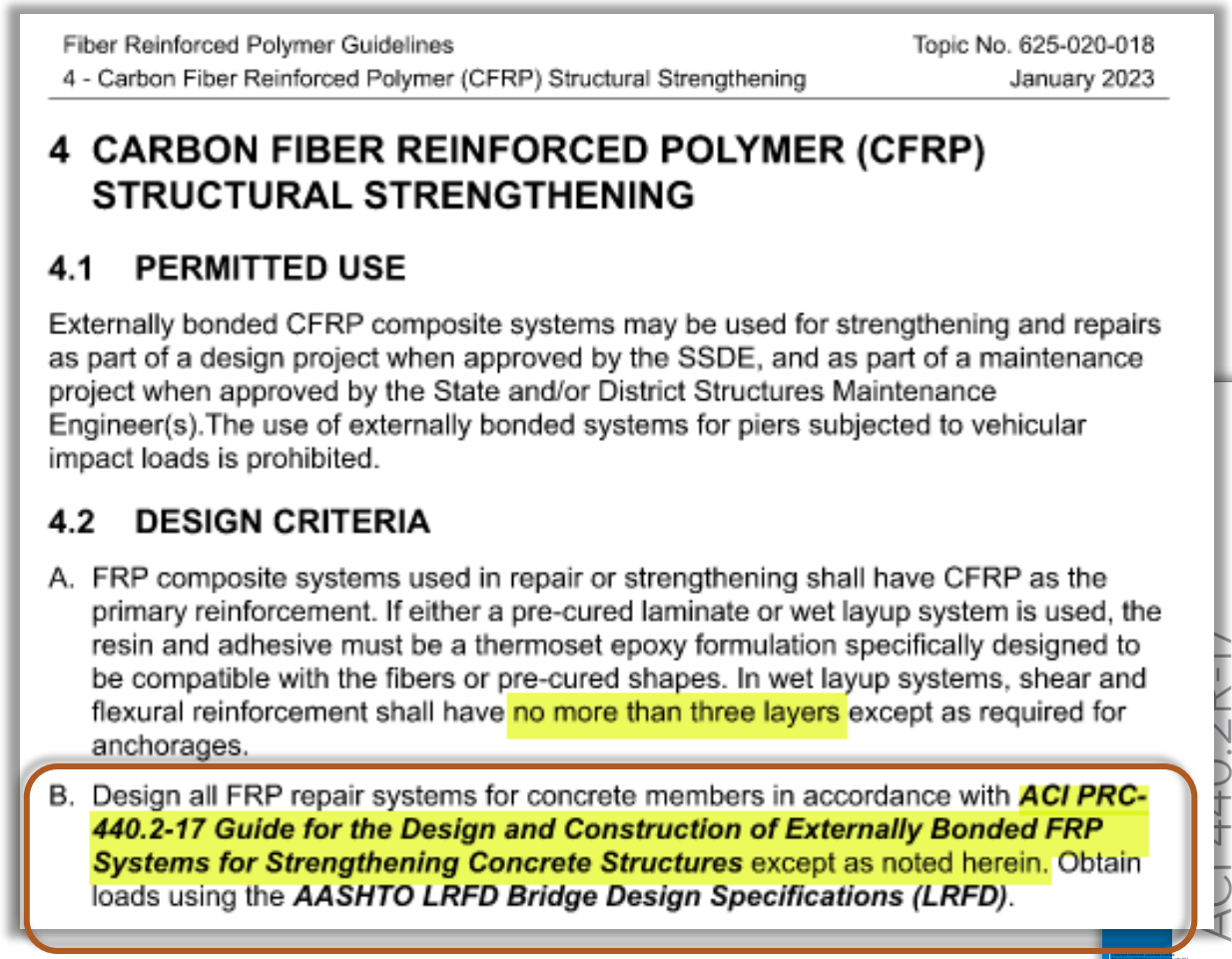
1. ***Structures Manual-Volume 4 (FRPG)***
2. ***ACI 440.2R*** *(2017)* with exceptions
   - Complete or 3-sided anchored u-wraps for shear strengthening
   - U-wraps for end anchorage for flexure
3. Technical Special Provisions
   - ***NCHRP 609 Appendix A*** with adjustments per project
4. Do we need an innovation webpage?





Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.1 and 4.2 A&B)***



Fiber Reinforced Polymer Guidelines
4 - Carbon Fiber Reinforced Polymer (CFRP) Structural Strengthening

Topic No. 625-020-018
January 2023

4 CARBON FIBER REINFORCED POLYMER (CFRP) STRUCTURAL STRENGTHENING

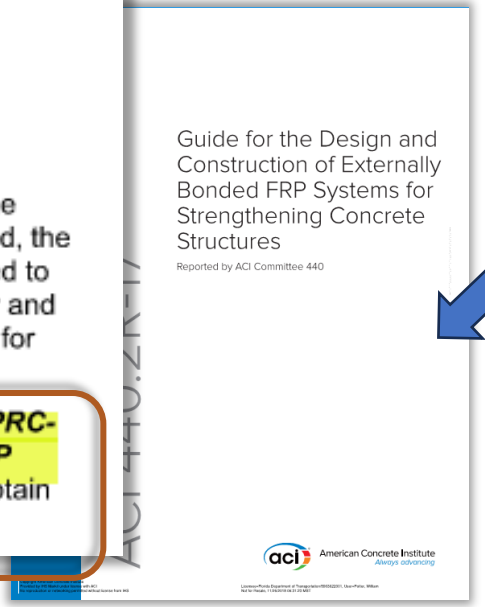
4.1 PERMITTED USE

Externally bonded CFRP composite systems may be used for strengthening and repairs as part of a design project when approved by the SSDE, and as part of a maintenance project when approved by the State and/or District Structures Maintenance Engineer(s).The use of externally bonded systems for piers subjected to vehicular impact loads is prohibited.

4.2 DESIGN CRITERIA

A. FRP composite systems used in repair or strengthening shall have CFRP as the primary reinforcement. If either a pre-cured laminate or wet layup system is used, the resin and adhesive must be a thermoset epoxy formulation specifically designed to be compatible with the fibers or pre-cured shapes. In wet layup systems, shear and flexural reinforcement shall have no more than three layers except as required for anchorages.

B. Design all FRP repair systems for concrete members in accordance with ***ACI PRC-440.2-17 Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures*** except as noted herein. Obtain loads using the ***AASHTO LRFD Bridge Design Specifications (LRFD)***.



Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures

Reported by ACI Committee 440

ACI 440.2R-17

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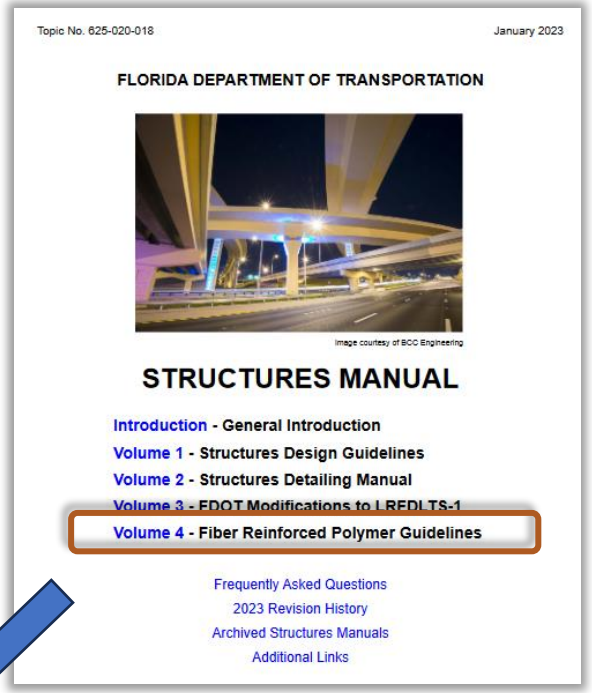

Topic No. 625-020-018 January 2023

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STRUCTURES MANUAL

Introduction - General Introduction
Volume 1 - Structures Design Guidelines
Volume 2 - Structures Detailing Manual
Volume 3 - FDOT Modifications to LRFDLTS-1
Volume 4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.2.C)*** ***modifications – existing/remaining capacity before strengthening:***

C. Modify Section 9.2 as follows:

When strengthening a single girder in a span containing at least four similar girders, the following limit shall control:

$$(\phi R_n)_{Existing} \geq (1.1S_{DL} + 0.75S_{LL})$$

Where:

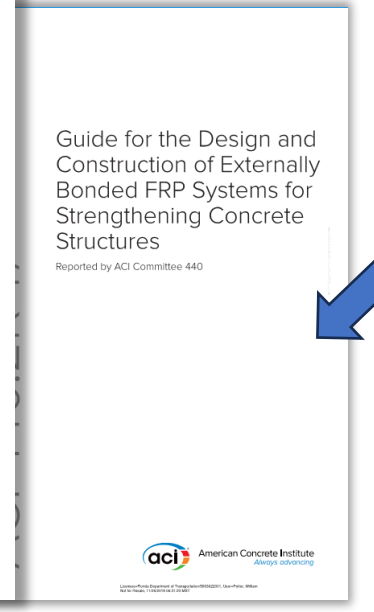
$(\Phi R_n)_{Existing}$ = the capacity of the existing member considering ONLY the existing reinforcement

S_{DL} and S_{LL} = the unfactored dead load and live load effects, respectively, that occur after the member has been strengthened.

When multiple girders in a single span are strengthened then the following limit shall control:

$$(\phi R_n)_{Existing} \geq (1.1S_{DL} + 1.0S_{LL})$$

If the existing reinforcement is insufficient to satisfy this equation, then implement alternative means of strengthening or replacement of the structure. Use load factors and capacity reduction factors from the ***LRFD*** for this check.


Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures

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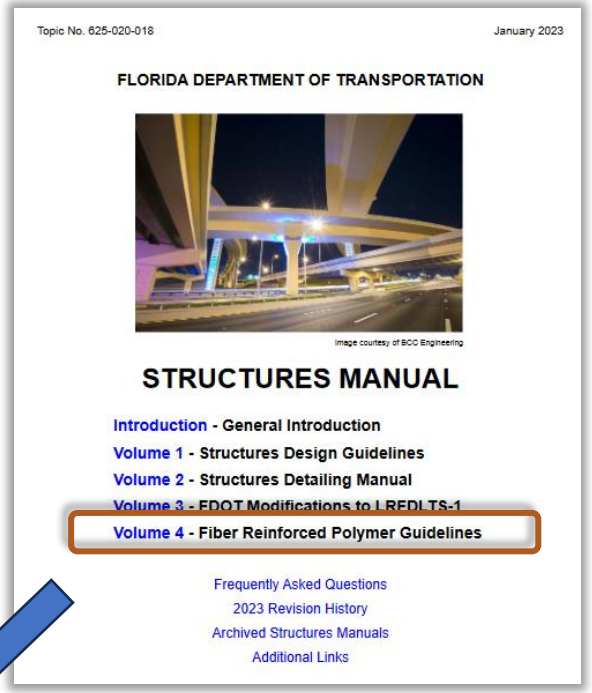
Topic No. 625-020-018 January 2023

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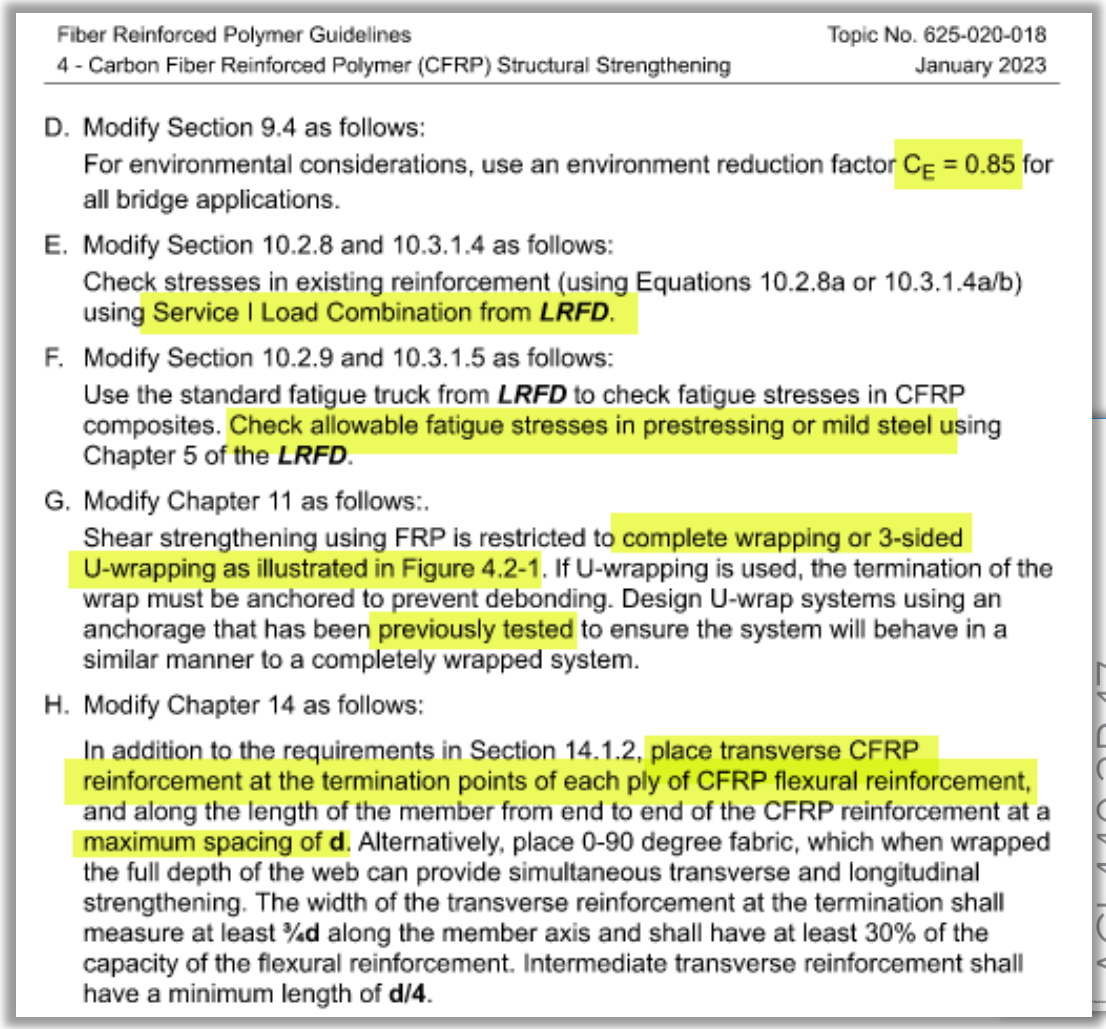
STRUCTURES MANUAL

Introduction - General Introduction
Volume 1 - Structures Design Guidelines
Volume 2 - Structures Detailing Manual
Volume 3 - FDOT Modifications to LRFD LTS-1
Volume 4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.2.D - H)*** ***modifications***



Fiber Reinforced Polymer Guidelines — Topic No. 625-020-018
4 - Carbon Fiber Reinforced Polymer (CFRP) Structural Strengthening — January 2023

D. Modify Section 9.4 as follows:

For environmental considerations, use an environment reduction factor $C_E = 0.85$ for all bridge applications.

E. Modify Section 10.2.8 and 10.3.1.4 as follows:

Check stresses in existing reinforcement (using Equations 10.2.8a or 10.3.1.4a/b) using Service I Load Combination from ***LRFD***.

F. Modify Section 10.2.9 and 10.3.1.5 as follows:

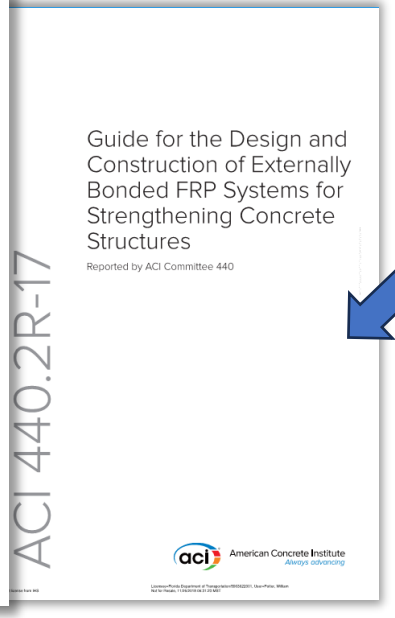
Use the standard fatigue truck from ***LRFD*** to check fatigue stresses in CFRP composites. Check allowable fatigue stresses in prestressing or mild steel using Chapter 5 of the ***LRFD***.

G. Modify Chapter 11 as follows:.

Shear strengthening using FRP is restricted to complete wrapping or 3-sided U-wrapping as illustrated in Figure 4.2-1. If U-wrapping is used, the termination of the wrap must be anchored to prevent debonding. Design U-wrap systems using an anchorage that has been previously tested to ensure the system will behave in a similar manner to a completely wrapped system.

H. Modify Chapter 14 as follows:

In addition to the requirements in Section 14.1.2, place transverse CFRP reinforcement at the termination points of each ply of CFRP flexural reinforcement, and along the length of the member from end to end of the CFRP reinforcement at a maximum spacing of **d**. Alternatively, place 0-90 degree fabric, which when wrapped the full depth of the web can provide simultaneous transverse and longitudinal strengthening. The width of the transverse reinforcement at the termination shall measure at least ¾**d** along the member axis and shall have at least 30% of the capacity of the flexural reinforcement. Intermediate transverse reinforcement shall have a minimum length of **d/4**.

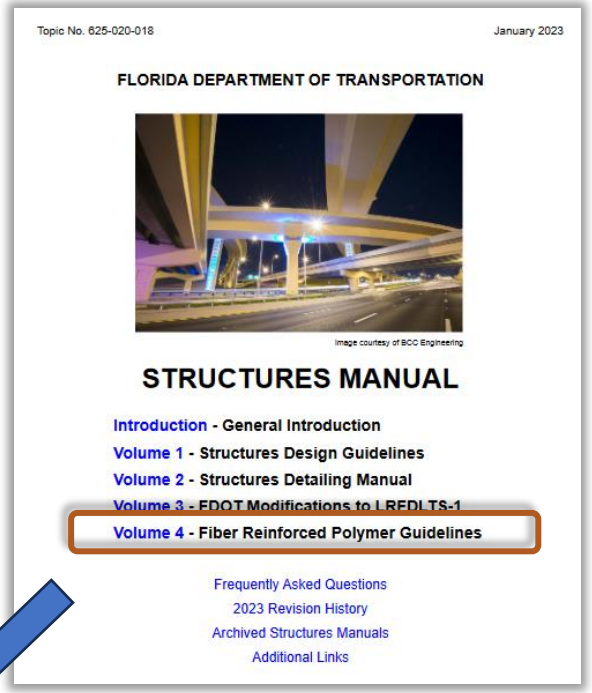


ACI 440.2R-17

Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures

Reported by ACI Committee 440

American Concrete Institute



Topic No. 625-020-018 — January 2023

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STRUCTURES MANUAL

Introduction - General Introduction
Volume 1 - Structures Design Guidelines
Volume 2 - Structures Detailing Manual
Volume 3 - FDOT Modifications to LRFD LTS-1
Volume 4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

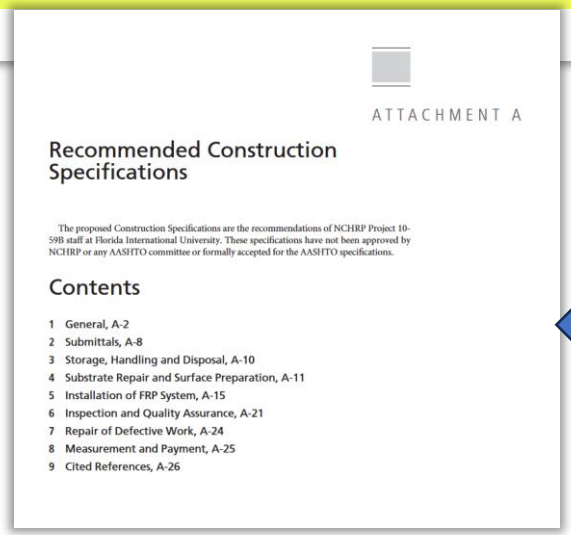
Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.3): Specs***

4.3 PREPARATION OF SPECIFICATIONS PACKAGE

The Engineer of Record shall develop Technical Special Provisions for construction and quality control that conform to the specifications given in Attachment A of ***National Cooperative Highway Research Program (NCHRP) Report 609*** "Recommended Construction Specifications and Process Control Manual for Repair and Retrofit of Concrete Structures Using Bonded FRP Composites", except as noted herein.

Technical Special Provisions should be non-proprietary, multi-vendor solutions (2 minimum), reviewed and approved by the State Specifications and Estimates Office and the State Structures Design Office, or District Structures Maintenance Office as applicable per ***FRPG*** Section 4.1.

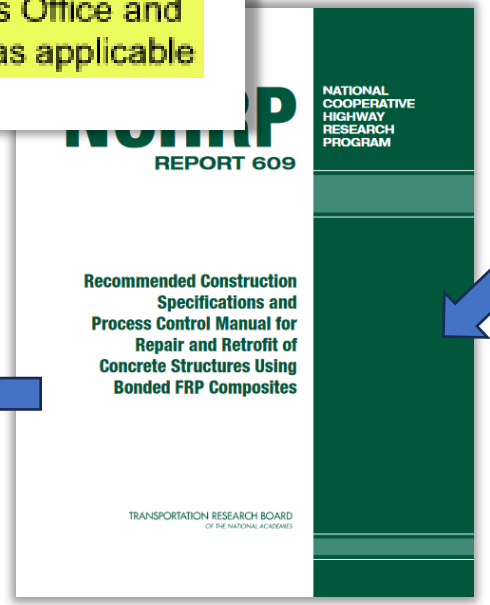

ATTACHMENT A

Recommended Construction Specifications

The proposed Construction Specifications are the recommendations of NCHRP Project 10-59B staff at Florida International University. These specifications have not been approved by NCHRP or any AASHTO committee or formally accepted for the AASHTO specifications.

Contents

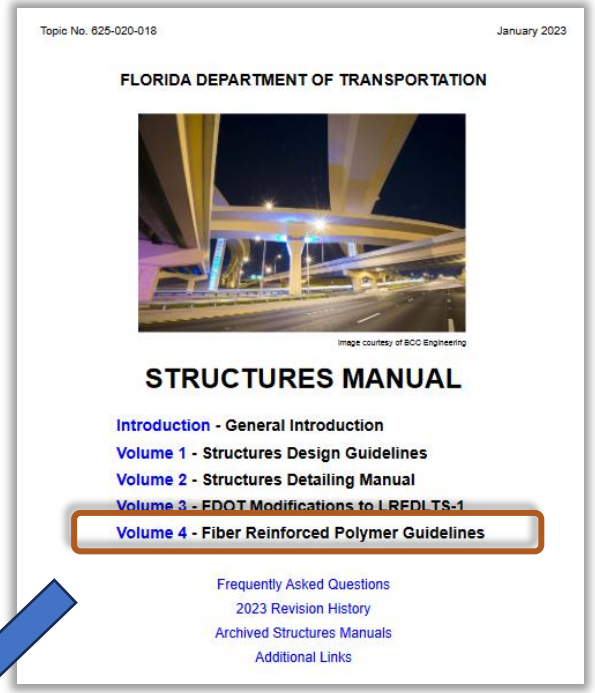
1 General, A-2
2 Submittals, A-8
3 Storage, Handling and Disposal, A-10
4 Substrate Repair and Surface Preparation, A-11
5 Installation of FRP System, A-15
6 Inspection and Quality Assurance, A-21
7 Repair of Defective Work, A-24
8 Measurement and Payment, A-25
9 Cited References, A-26


NCHRP REPORT 609

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Recommended Construction Specifications and Process Control Manual for Repair and Retrofit of Concrete Structures Using Bonded FRP Composites

TRANSPORTATION RESEARCH BOARD OF THE NATIONAL ACADEMIES


Topic No. 625-020-018 January 2023

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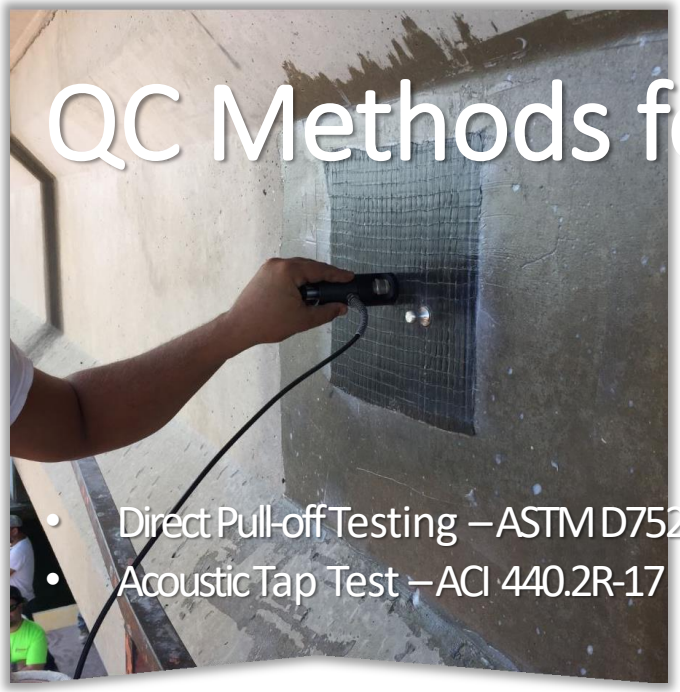
STRUCTURES MANUAL

Introduction - General Introduction
Volume 1 - Structures Design Guidelines
Volume 2 - Structures Detailing Manual
Volume 3 - FDOT Modifications to LRFD LTS-1
Volume 4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

Current Policy & Practice for FDOT projects

1. Technical Special Provisions:
   - ***NCHRP Report 609 - Appendix A*** with adjustments per project
2. No Approved/Innovative Product Listing requirements:
   - ***AASHTO NTPEP/PEAS*** considering future approval & audit program for FRP.



Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.3): Technical Special Provisions***

T102: CFRP Testing

SECTION T102
CARBON FIBER REINFORCED POLYMER TESTING REQUIREMENTS

T102-1 GENERAL

THE ENGINEER SHALL OBSERVE ALL ASPECTS OF ON-SITE FIELD-TESTING

T102-2 QUALITY ASSURANCE

ALL TESTS SHALL COMPLY WITH REQUIREMENTS OF ASTM A370, ASTM C802, ASTM C1021, ASTM D3039, ASTM D4541, ASTM E329, ASTM E543, ASTM E548, ASTM E699, AND ACI 440.2R-17.

CALIBRATE TESTING EQUIPMENT BEFORE PROCEEDING WITH EACH SET OF TESTS USING DEVICES OF ACCURACY TRACEABLE TO EITHER NATIONAL BUREAU OF STANDARDS OR ACCEPTED VALUES OF NATURAL PHYSICAL CONSTANTS.

T102-3 CONTRACTOR SUBMITTALS

PRIOR TO STARTING WORK, SUBMIT TO THE ENGINEER FOR APPROVAL, A PROPOSED QUALITY ASSURANCE AND TESTING PLAN AND WORK SCHEDULE.

T102-4 CARBON WRAP TESTING REQUIREMENTS

T102-4.1 INSPECTION FOR VOIDS/DELAMINATIONS

AFTER ALLOWING AT LEAST 24 HOURS FOR INITIAL RESIN CURE TO OCCUR, PERFORM A VISUAL AND ACOUSTIC TAP TEST OF THE LAYERED SURFACE, IN ACCORDANCE WITH ACI 440.2R-17 (CHAPTER 7 (7.2.3)). THE ACOUSTIC TAP TEST SHALL BE PERFORMED TO DETECT DELAMINATIONS OF 2 IN² OR LARGER IN THE CARBON FIBER REINFORCED POLYMER (CFRP). ADDITIONAL TESTING SHALL BE PERFORMED IF AN AREA IS DEEMED TO BE SUSPECT.

OTHER METHODS FOR DETECTING VOIDS MUST BE SUBMITTED AND APPROVED BY THE ENGINEER PRIOR TO PROCEEDING.

T102-4.2 BOND TESTING (CFRP FABRIC)

ALL TESTS UNDER THIS SECTION ARE TO BE PERFORMED IN THE PRESENCE OF THE ENGINEER.

CONDUCT DIRECT PULL-OFF TESTING PER ASTM D 4541-17, OR APPROVED EQUAL. DOCUMENTATION - ASTM, ACI, LOGBOOKS, AND MANUFACTURER'S DATA SHOULD BE READILY AVAILABLE. CONDUCT DIRECT PULL-OFF TESTS UNDER THE FOLLOWING TEST CONDITIONS:

PRIOR TO THE FIRST CFRP INSTALLATION, CONDUCT PULL-OFF TESTS ON INSTALLED SAMPLES OF THE CFRP (12 INCHES BY 12 INCHES) TO VERIFY THE TENSILE BOND BETWEEN THE CFRP AND THE EXISTING CONCRETE SUBSTRATE. THIS SAMPLE SHALL CONFORM TO THE NUMBER OF CFRP LAYERS TO BE USED IN THE REPAIR. THE LOCATION OF THE PULL-OFF TESTS SHALL BE REPRESENTATIVE OF THE GENERAL CONDITIONS AND PERFORMED ON A FLAT SURFACE. ALLOW THE CFRP SYSTEM TO CURE A MINIMUM OF 24 HOURS BEFORE EXECUTION OF THE DIRECT PULL-OFF TEST. AFTER TESTING, INSPECT THE FAILURE SURFACE OF THE COUPON SPECIMEN. FAILURE AT THE BOND LINE AT TENSILE STRESSES BELOW 200 PSI IS UNACCEPTABLE. IF THE RESULTS ARE UNACCEPTABLE, CONSULT THE MANUFACTURER, MAKE NECESSARY MODIFICATIONS, AND REPEAT THE TESTS UNTIL ACCEPTABLE RESULTS ARE OBTAINED. IF THE RESULTS FROM THE REPEATED TESTS PROVE UNACCEPTABLE, THE ENGINEER HAS THE DISCRETION TO ORDER THE CONTRACTOR TO SUBSTITUTE A DIFFERENT CARBON WRAP SYSTEM.

T102-4.3 TESTING FREQUENCY

CONDUCT DIRECT PULL-OFF TESTING AT THE FOLLOWING FREQUENCY: ONE INITIAL CFRP PULL-OFF TEST SAMPLE (12"X12") ON PREPARED SUBSTRATE IS REQUIRED. THE ENGINEER WILL SELECT THE LOCATION WHERE THIS INITIAL TESTING WILL BE PERFORMED.

TEST THE INSTALLED CFRP PRIOR TO THE APPLICATION OF THE PROTECTIVE COATING. PERFORM A MINIMUM OF 2 DIRECT PULL-OFF TEST AT EACH STRUCTURE WHERE LESS THAN 500 SQUARE FEET OF CFRP IS INSTALLED. FOR STRUCTURES WHERE MORE THAN 500 SQUARE FEET OF CFRP IS INSTALLED, PERFORM 1 ADDITIONAL DIRECT PULL-OFF TEST FOR EACH 500 SQUARE FOOT INCREMENT. ALLOW THE CFRP SYSTEM TO CURE A MINIMUM OF 24 HOURS BEFORE EXECUTION OF THE DIRECT PULL-OFF TEST. THE ENGINEER WILL SELECT THE LOCATIONS WHERE THE TESTING WILL BE PERFORMED. PATCH ALL TEST AREAS WITH AN EQUIVALENT CFRP MATERIAL PRIOR TO THE APPLICATION OF THE PROTECTIVE COATING.

T102-4.4 CONDITIONS OF ACCEPTANCE (CFRP FABRIC)

THE TENSILE BOND STRENGTH MUST BE IN EXCESS OF 200 PSI. IF REQUIRED, REPAIR THE TESTED AREA IN ACCORDANCE WITH SECTION T104 OF THESE PLAN NOTES.

VERIFY COMPLIANCE OF MATERIALS AND MIXES WITH REQUIREMENTS OF THE CONTRACT DOCUMENTS. PROMPTLY NOTIFY THE ENGINEER OF OBSERVED IRREGULARITIES OR NON-CONFORMANCE OF WORK AND/OR PRODUCTS.

PERFORM ADDITIONAL TESTS REQUIRED BY THE ENGINEER. IF RETESTING IS REQUIRED DUE TO NONCONFORMANCE TO SPECIFIED CONTRACT REQUIREMENTS, INCLUDING THE REQUIREMENTS INCORPORATED INTO THES PLAN NOTES, PERFORM THE REQUIRED REPAIR, AS WELL AS THE NEW TESTING, AT NO ADDITIONAL COST TO THE DEPARTMENT.

TAKE A MINIMUM OF FIVE SAMPLES FOR QUALITY CONTROL TESTING OF EACH OF THE FOLLOWING: CFRP SHEETS, BONDING RESINS, AND TOPPING PRODUCTS. PROVIDE THESE SAMPLES AT NO ADDITIONAL COST TO THE DEPARTMENT.

T102-5 TEST REPORT

AFTER EACH TEST, PROMPTLY SUBMIT ONE COPY OF THE TEST REPORT TO THE ENGINEER. INCLUDE WITH EACH TEST REPORT AT A MINIMUM:

- DATE ISSUED;
- PROJECT TITLE;
- NAME OF INSPECTOR;
- DATE AND TIME OF INSPECTION AND TESTING;
- IDENTIFICATION OF PRODUCT AND SPECIFICATIONS SECTION (INCLUDING BATCH NUMBERS);
- LOCATION OF TESTS WITHIN THE PROJECT;
- TYPE OF INSPECTION OR TEST;
- RESULTS OF TESTS;
- CONFORMANCE WITH CONTRACT DOCUMENTS AND SPECIFICATIONS.

Example

Topic No. 625-020-018 January 2023

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STRUCTURES MANUAL

Introduction - General Introduction
Volume 1 - Structures Design Guidelines
Volume 2 - Structures Detailing Manual
Volume 3 - FDOT Modifications to LRFD LTS-1
Volume 4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.3): TSP T104 – CFRP Strengthening***

SECTION T104
CFRP STRENGTHENING

T104-1 GENERAL

T104-1.1 SUBMITTALS

SUBMIT PRODUCT DATA INDICATING PRODUCT STANDARDS, PHYSICAL AND CHEMICAL CHARACTERISTICS, TECHNICAL SPECIFICATIONS, LIMITATIONS, INSTALLATION INSTRUCTIONS, MAINTENANCE INSTRUCTIONS, AND GENERAL RECOMMENDATIONS REGARDING EACH MATERIAL IN ACCORDANCE WITH THE SPECIFICATIONS.

THE EPOXY/COMPOSITE SUPPLIER SHALL PROVIDE A FIVE-YEAR PROVEN RECORD OF PERFORMANCE OF CONCRETE MEMBER STRENGTHENING WITH CARBON FIBER MATERIALS, CONFIRMED BY ACTUAL FIELD TESTS, AND A MINIMUM OF 25 SUCCESSFUL FIELD INSTALLATIONS.

SUBMIT FOR RECORD A QUALIFICATION STATEMENT LISTING COMPLETED CFRP PROJECTS SIMILAR IN SIZE AND SCOPE, INCLUDING: LOCATION, OWNER, ENGINEER/ARCHITECT, AND CONTACT NUMBERS. INCLUDE A CERTIFIED LETTER STATING THAT THE CONTRACTOR IS CURRENTLY QUALIFIED TO INSTALL THE MANUFACTURER'S CFRP.

SUBMIT HEALTH AND SAFETY SHEETS AND MATERIAL SAFETY DATA SHEETS (MSDS) OF EACH PRODUCT USED ON SITE AND CERTIFICATION THAT THE MATERIALS CONFORM TO LOCAL, STATE, AND FEDERAL ENVIRONMENTAL AND WORKERS' SAFETY LAWS AND REGULATIONS.

PREPARE AND SUBMIT, FOR APPROVAL, THE QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PLAN, INCLUDING THE SHOP DRAWINGS AND THE WORK PLAN FOR THE INSTALLATION OF THE CFRP SYSTEM IN ACCORDANCE WITH THE SPECIFICATIONS. THE SHOP DRAWINGS AND WORK PLAN SHALL CONTAIN ALL THE DETAILS OF THE CFRP WRAP, CFRP ANCHOR, SURFACE PREPARATION, CRACK AND CONCRETE REPAIR MATERIALS, JOINT AND END DETAILS, LAP DETAILS, AND ALL OTHER INFORMATION REQUIRED FOR THE PROPER INSTALLATION OF THE SYSTEM. THE WORK PLAN WILL DESCRIBE THE TESTING AND INSPECTION REQUIREMENTS AND TESTING EQUIPMENT TO BE USED.

T104-1.2 QUALITY ASSURANCE

T104-1.2.1 CARBON WRAP MANUFACTURER/SUPPLIER QUALIFICATION

THE CFRP SYSTEM MANUFACTURER/SUPPLIER SHALL SPECIALIZE IN THE MANUFACTURING OF THE PRODUCTS SPECIFIED IN THESE SPECIFICATIONS, WITH DOCUMENTED EXPERIENCE. THE CFRP MANUFACTURER SHALL HAVE BEEN IN EXISTENCE FOR A MINIMUM OF 5 YEARS, WITH AN ESTABLISHED PROGRAM FOR CERTIFYING CONTRACTORS FOR PROPER INSTALLATION OF THE SYSTEM. THE CARBON MANUFACTURER/SUPPLIER SHALL HAVE A MINIMUM OF 25 DOCUMENTED SUCCESSFUL FIELD INSTALLATIONS.

T104-1.2.2 CARBON FIBER CONTRACTOR QUALIFICATIONS

THE CONTRACTOR SHALL HAVE SUCCESSFULLY COMPLETED A MINIMUM OF FIVE PROJECTS OF SIMILAR SIZE AND SCOPE. IN ADDITION, THE CONTRACTOR SHALL BE EXPERIENCED IN THE INSTALLATION OF THE SPECIFIED CARBON WRAP PRODUCT AND PROVIDE A NOTARIZED CERTIFICATION LETTER FROM THE CARBON MANUFACTURER, ATTESTING THE CONTRACTOR IS CURRENTLY QUALIFIED TO INSTALL THE MATERIALS.

T104-1.2.3 INSPECTION

INSPECT ALL MATERIALS PRIOR TO APPLICATION TO ASSURE THAT THEY MEET SPECIFICATIONS AND HAVE ARRIVED AT THE JOB SITE UNDAMAGED. THE CFRP REINFORCEMENT SHALL BE COMPLETELY INSPECTED BY THE CONTRACTOR DURING, AND IMMEDIATELY FOLLOWING, APPLICATION OF THE COMPOSITE MATERIALS. THE CONTRACTOR SHALL ASSURE CONFORMANCE WITH THE DESIGN DRAWINGS, PROPER ALIGNMENT OF FIBERS, AND QUALITY WORKMANSHIP. ENTRAPPED AIR SHALL BE RELEASED OR ROLLED OUT BEFORE THE EPOXY SETS. DEFECTS SHALL BE NOTED IN THE DAILY CONSTRUCTION LOG, KEPT BY THE FIELD REPRESENTATIVE. AFTER CFRP REINFORCEMENT HAS CURED, INSPECT ALL THE WORK TO CHECK FOR VOIDS AND/OR DEBONDING. REPAIRS SHALL BE MADE AND NOTED IN THE DAILY CONSTRUCTION LOG.

T104-1.3 JOB SITE CONDITIONS

ENVIRONMENTAL CONDITIONS SHALL BE EXAMINED BEFORE AND DURING INSTALLATION OF THE CFRP SYSTEM TO ENSURE CONFORMITY TO THE CONTRACT DOCUMENTS AND MANUFACTURER'S RECOMMENDATIONS. DO NOT APPLY PRIMERS, PUTTY, SATURATING RESINS OR ADHESIVES TO DAMP, OR WET SURFACES.

AMBIENT AND CONCRETE SURFACE TEMPERATURES SHALL BE WITHIN 50°-95°F, UNLESS SPECIFIED BY THE MANUFACTURER. MOISTURE LEVEL ON ALL THE CONTACT SURFACES SHALL BE LESS THAN 4.3% AT THE TIME OF INSTALLATION OF THE CFRP SYSTEM, AS EVALUATED ACCORDING TO ACI 503R-93. MOISTURE RESTRICTIONS MAY BE WAIVED FOR RESINS THAT HAVE BEEN FORMULATED FOR WET APPLICATIONS. CONTACT SURFACE MOISTURE LEVEL MAY EXCEED IF THE MANUFACTURER PROVIDES WRITTEN CONFIRMATION THAT THE RESIN IS FORMULATED FOR THAT HIGHER CONTENT SURFACE MOISTURE LEVEL, AND TEST RESULTS ARE PROVIDED THAT DEMONSTRATE THE REQUIRED PERFORMANCE AND BOND CAPACITIES.

DO NOT APPLY CFRP REINFORCEMENT MATERIALS IF RAIN OR DEW CONDENSATION IS EXPECTED. THE AMBIENT TEMPERATURE AND TEMPERATURE OF THE EPOXY COMPONENTS SHALL BE BETWEEN 50° AND 80°F AT THE TIME OF MIXING.

T104-1.4 STORAGE, HANDLING AND DISPOSAL

T104-1.4.1 STORAGE REQUIREMENTS

ALL COMPONENTS OF THE CFRP SYSTEM SHALL BE DELIVERED AND STORED IN THE ORIGINAL FACTORY-SEALED UNOPENED PACKAGING OR CONTAINERS, WITH PROPER LABELS IDENTIFYING THE MANUFACTURER, BRAND NAME, SYSTEM IDENTIFICATION NUMBER, AND DATE. STORE CATALYSTS AND INITIATORS SEPARATELY. ALL COMPONENTS SHALL BE PROTECTED FROM DUST, MOISTURE, CHEMICALS, DIRECT SUNLIGHT, PHYSICAL DAMAGE, FIRE, AND TEMPERATURES OUTSIDE THE RANGE SPECIFIED IN THE SYSTEM DATA SHEETS. ANY COMPONENT THAT HAS BEEN STORED IN A CONDITION DIFFERENT FROM THAT STATED ABOVE SHALL BE DISPOSED OF AS SPECIFIED IN T104-1.4.4. COMPONENTS OF THE CFRP SYSTEM, ESPECIALLY RESINS AND ADHESIVES, THAT HAVE BEEN STORED LONGER THAN THE SHELF LIFE SPECIFIED ON THE SYSTEM DATA SHEET, SHALL NOT BE USED, AND SHALL BE DISPOSED OF, AS SPECIFIED IN T104-1.4.4.

T104-1.4.2 HANDLING

ALL COMPONENTS OF THE CFRP SYSTEM, ESPECIALLY FIBER SHEETS AND ANCHORS, SHALL BE HANDLED WITH CARE ACCORDING TO THE MANUFACTURER'S RECOMMENDATIONS TO PROTECT THEM FROM DAMAGE, AND TO AVOID MISALIGNMENT OR BREAKAGE OF THE FIBERS BY PULLING, SEPARATING, OR WRINKLING THEM, OR BY FOLDING THE SHEETS. AFTER CUTTING, SHEETS SHALL BE EITHER STACKED DRY WITH SEPARATORS, OR ROLLED GENTLY AT A RADIUS NO TIGHTER THAN 12 INCHES OR AS RECOMMENDED BY THE MANUFACTURER.

T104-1.4.3 SAFETY HAZARDS

ALL COMPONENTS OF THE CFRP SYSTEM, ESPECIALLY RESINS AND ADHESIVES, SHALL BE HANDLED WITH CARE TO AVOID SAFETY HAZARDS, INCLUDING BUT NOT LIMITED TO, SKIN IRRITATION AND SENSITIZATION, BREATHING VAPORS, AND DUSTS. MIXING RESINS SHALL BE MONITORED TO AVOID FUMING AND INFLAMMABLE VAPORS, FIRE HAZARDS, OR VIOLENT BOILING. THE CONTRACTOR IS RESPONSIBLE TO ENSURE THAT ALL COMPONENTS OF THE CFRP SYSTEM AT ALL STAGES OF WORK, CONFORM TO LOCAL, STATE, AND FEDERAL ENVIRONMENTAL AND WORKER'S SAFETY LAWS AND REGULATIONS.

MSDS FOR ALL COMPONENTS OF THE CFRP SYSTEM SHALL BE ACCESSIBLE TO ALL AT THE PROJECT SITE. SPECIFIC HANDLING HAZARDS AND DISPOSAL INSTRUCTIONS SHALL BE SPECIFIED IN THE MSDS.

THE CONTRACTOR IS RESPONSIBLE FOR PROVIDING PROPER MEANS OF PROTECTION FOR SAFETY OF THE PERSONNEL AND THE WORKPLACE, INFORMING THE PERSONNEL OF THE DANGERS OF INHALING FUMES OF PRIMER, PUTTY OR RESIN, AND TAKING ALL NECESSARY PRECAUTIONS AGAINST INJURY TO PERSONNEL. THE RESIN MIXING AREA SHALL BE WELL VENTED TO THE OUTSIDE.

THE CONTRACTOR IS RESPONSIBLE FOR THE CLEAN-UP OF THE EQUIPMENT AND THE PROJECT SITE FROM HAZARDOUS AND AESTHETICALLY UNDESIRABLE CFRP COMPONENTS USING APPROPRIATE SOLVENTS, AS RECOMMENDED IN THE MSDS.

T104-1.4.4 DISPOSAL

ANY COMPONENT OF THE CFRP SYSTEM THAT HAS EXCEEDED ITS SHELF LIFE OR POT LIFE, OR HAS NOT BEEN PROPERLY STORED OR HANDLED, AND ANY UNUSED OR EXCESS MATERIAL THAT IS DEEMED WASTE, SHALL BE DISPOSED OF IN A MANNER AMIABLE TO THE PROTECTION OF THE ENVIRONMENT AND CONSISTENT WITH THE MSDS.

T104-2 CFRP SYSTEM PROPERTIES

CFRP SYSTEM AND ALL COMPONENTS MUST BE ICC-ES APPROVED/LISTED PRODUCTS PER AC125. A VALID ICC-ES REPORT SHALL BE SUBMITTED.

T104-2.1 FIBER PROPERTIES AND DATA

CFRP FABRIC PROPERTIES VARY DEPENDING ON THE MANUFACTURER.

THE NUMBER OF LAYERS UTILIZED IN THE APPLICATION SHOULD BE DETERMINED TO SATISFY THE REQUIREMENTS SPECIFIED IN THE FOLLOWING TABLES. THE MAXIMUM NUMBER OF LAYERS UTILIZED SHALL NOT EXCEED THREE LAYERS, NOT INCLUDING ANCHORS AND ANCHOR PATCHES.

Example

January 2023

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ction - General Introduction
1 - Structures Design Guidelines
2 - Structures Detailing Manual
3 - FDOT Modifications to LRFD LTS-1
4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

FDOT Structures Manual Guidance: Implementing AASHTO 2nd Edition and Procurement Process

Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.3): TSP T104 – CFRP Strengthening***

SECTION T104
CFRP STRENGTHENING (CONTINUED)

CARBON DRY FIBER PROPERTIES	
PROPERTY	MINIMUM REQUIREMENT
ULTIMATE TENSILE STRENGTH	550,000 PSI
TENSILE MODULUS	36 X 10⁶ PSI
ELONGATION	1.67%
PRIMARY FIBER DIRECTION	UNIDIRECTIONAL

CURED LAMINATE PROPERTIES	
PROPERTY	MINIMUM REQUIREMENT
TENSILE STRENGTH	139,000 PSI
MODULUS OF ELASTICITY	12.0 X 10⁶ PSI
ELONGATION AT BREAK	1.00%
THICKNESS	0.040 IN.
0° TENSILE STRENGTH PER INCH WIDTH	5,560 LBS/INCH
0° TENSILE STIFFNESS PER INCH WIDTH	480,000 LBS

T104-2.2 FIBER ANCHOR PROPERTIES

CFRP ANCHOR FIBER PROPERTIES SHALL BE MADE OF THE SAME MATERIAL USED FOR THE CFRP WRAP SYSTEM. THE FIBER AREA OF CFRP ANCHOR SHALL BE EQUAL TO THE AREA OF THE CFRP WRAP OR TESTING DATA SHALL BE PROVIDED, SHOWING THAT THE ANCHORAGE SYSTEM IS DESIGNED TO TAKE 100% OF THE TENSILE STRESS AT FAILURE OF THE CFRP STRIP. ALTERNATE ANCHORAGE SYSTEMS COMPATIBLE WITH THE CFRP WRAP SYSTEM MAY BE SUBMITTED TO THE ENGINEER FOR APPROVAL. ANCHOR SUBMITTALS SHALL MEET THE REQUIREMENTS OF SECTION T104-1.1 OF THESE PLAN NOTES.

T104-2.3 SURFACE PRIMER

SURFACE PRIMER SHALL BE A TWO COMPONENT, 100% SOLIDS, MOISTURE TOLERANT EPOXY. SURFACE PRIMER SHALL MEET THE FOLLOWING MINIMUM REQUIREMENTS:

PROPERTY	REQUIREMENT	ASTM TEST
TENSILE STRENGTH, 7 DAY	2,500 PSI	D638
TENSILE MODULUS, 7 DAY	105 KSI	D638
ELONGATION AT BREAK, 7 DAY	1.0%	D638
FLEXURAL STRENGTH, 14 DAY	3,500 PSI	D790
HEAT DEFLECTION TEMP (HDT)	118° F	D648

T104-2.4 SATURANT

SATURANT RESIN SHALL BE A TWO COMPONENT, 100% SOLIDS, MOISTURE TOLERANT, HIGH STRENGTH, HIGH-MODULUS EPOXY. SATURANT SHALL MEET THE FOLLOWING MINIMUM REQUIREMENTS:

PROPERTY	REQUIREMENT	ASTM TEST
TENSILE STRENGTH	8,000 PSI	D638
TENSILE MODULUS	440 KSI	D638
ELONGATION AT BREAK	3.5%	D638
FLEXURAL STRENGTH	17,900 PSI	D732
FLEXURAL MODULUS	450KSI	D790
HEAT DEFLECTION TEMP (HDT)	160° F	D648

T104-3 PROCEDURE FOR CFRP APPLICATION

T104-3.1 CONCRETE SECTION PREPARATION

THE WORK UNDER THIS SECTION CONSISTS OF RESTORING DELAMINATED CONCRETE ON SELECTED BRIDGE COMPONENTS USING POLYMER/LATEX MODIFIED CONCRETE. SURFACES WHERE THE CFRP SYSTEM IS TO BE APPLIED SHALL BE SOUND. CONCRETE SPALLS AND DELAMINATIONS SHALL BE REPAIRED ACCORDING TO PROCEDURES ACI 546R-96 AND ICRI NO. 03730, AS FOLLOWS:

CONCRETE RESTORATION SHALL INCLUDE THE REMOVAL OF ALL DELAMINATED CONCRETE FROM THE AREA TO BE RESTORED. ANY LOOSE CONCRETE REMAINING IN THE DAMAGED REGION SHALL BE REMOVED, LEAVING THE MEMBER WITH SOUND CONCRETE. THE PERIMETER OF THE SPALL SHALL BE IDENTIFIED AND SAW CUT TO A MINIMUM DEPTH OF ¾ INCH TO PREVENT FEATHERED EDGES. THE RESULTING SHAPE SHALL BE UNIFORM WITH NO POINTED CORNERS. NO CONCRETE REMOVAL SHALL BE PERFORMED WITHOUT CONSULTATION AND APPROVAL OF THE ENGINEER.

DISPOSITION AND TREATMENT OF CRACKS WITHIN SOLID CONCRETE SHALL FOLLOW SECTION 411 OF THE SPECIFICATIONS. CFRP SYSTEM SHALL BE INSTALLED NO EARLIER THAN 24 HOURS AFTER CRACK TREATMENT. ANY SURFACE ROUGHNESS CAUSED BY CRACK TREATMENT SHALL BE REMOVED.

ANY EXISTING CHIPS OR SPALLS SHALL BE ABRASIVE OR WATER (HIGH PRESSURE WATER > 10,000-18,000 PSI) BLASTED CLEAN IN ACCORDANCE WITH THE REPAIR MATERIAL MANUFACTURER'S RECOMMENDATIONS BEFORE PATCHING. ONCE THE CONCRETE SURFACE IS PREPARED TO RECEIVE THE REPAIR MATERIAL IN ACCORDANCE WITH THE REPAIR MATERIAL MANUFACTURER'S RECOMMENDATIONS, CONCRETE RESTORATION SHALL BE PERFORMED USING AN APPROVED POLYMER/LATEX-MODIFIED MORTAR/CONCRETE. THE SELECTED MATERIAL SHALL ACHIEVE A MINIMUM COMPRESSIVE STRENGTH OF 4,500/5,500 PSI IN 7/28 DAYS, RESPECTIVELY. PROPOSED MATERIAL AND METHOD OF APPLICATION INCLUDING MANUFACTURER'S TECHNICAL SPECIFICATIONS AND FORMULATION, IF APPLICABLE, SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO COMMENCING WORK.

THE RESTORED CONCRETE SURFACE SHALL BE SMOOTH, UNIFORM AND SHALL MATCH THE CONCRETE COMPONENT'S ORIGINAL PROFILE. REMOVE FORM LINES AND SHARP ROUGH EDGES BY GRINDING OR FILLING WITH PUTTY. RIDGES > 0.2 INCH MAY MAY BE GROUND DOWN PER THE ENGINEER'S DIRECTION.

ALL INSIDE AND OUTSIDE CORNERS AND SHARP EDGES SHALL BE ROUNDED OR CHAMFERED TO A MINIMUM RADIUS OF ½ INCH. RIDGES, FORM LINES, AND SHARP OR ROUGHENED EDGES GREATER THAN ¼ INCH SHALL BE GROUND DOWN OR FILLED WITH PUTTY. FILLER MATERIAL, WHERE REQUIRED, SHALL BE AS APPROVED BY THE ENGINEER. OBSTRUCTIONS AND EMBEDDED OBJECTS SHALL BE REMOVED BEFORE INSTALLING THE CFRP SYSTEM IF REQUIRED BY THE ENGINEER.

SUBSTRATE CONCRETE AND FINISHED SURFACE OF CONCRETE SHALL BE CLEANED TO THE APPROVAL OF THE ENGINEER. ALL CONCRETE SURFACES SHALL TO RECEIVE THE CARBON WRAP SYSTEM SHALL MEET THE SURFACE MOISTURE REQUIREMENTS OF T104-1.3.

FINAL APPROVAL OF THE SURFACE PRIOR TO ABRASIVE OR WATER BLASTING SHALL BE RECEIVED FROM THE ENGINEER PRIOR TO PROCEEDING WITH THE WORK.

T104-3.2 CONCRETE SURFACE PREPARATION

WORK PERFORMED UNDER THIS SECTION CONSISTS OF ROUGHENING AND CLEANING THE CONCRETE SURFACE PRIOR TO THE APPLICATION OF CFRP. WORK TO BE PERFORMED INCLUDE ABRASIVE OR WATER (HIGH PRESSURE WATER > 10,000-18,000 BLASTING, AIR BLOWING, VACUUMING, AND ANY OTHER TECHNIQUE REQUIRED TO REMOVE DUST. GRIT, COATINGS, CHALK MARKS, PAINTS, CURING COMPOUNDS, LAITANCE, AND OTHER SUBSTANCES WHICH WOULD INHIBIT BONDING OF THE CFRP TO THE CONCRETE SURFACE. ALL CONCRETE SURFACES TO RECEIVE THE CARBON WRAP SYSTEM SHALL MEET THE SURFACE MOISTURE REQUIREMENTS OF T104-1.3.

THE SURFACE PREPARATION TECHNICIANS AND SUPERVISORS SHALL BE CERTIFIED BEFORE ABRASIVE BLASTING IS STARTED.

BLASTING AT EACH LOCATION SHALL NOT BEGIN BEFORE NECESSARY CONCRETE REPAIRS AT THAT LOCATION ARE COMPLETED, AND THE ENVIRONMENTAL MEASURES ARE IN PLACE.

BEFORE BLASTING COMMENCES AT EACH LOCATION, THE CONCRETE PATCH MATERIAL SHALL BE ALLOWED TO CURE AS RECOMMENDED BY THE MANUFACTURER OR OTHERWISE SPECIFIED IN THE CONTRACT DOCUMENTS. NOTIFY THE ENGINEER IF THE MANUFACTURER'S RECOMMENDATIONS CONFLICT WITH THE REQUIREMENTS IN THESE PLAN NOTES.

PERFORM NO WORK ON THIS ITEM UNTIL WRITTEN APPROVAL IS RECEIVED FROM THE ENGINEER AND ALL SUPERVISORS AND TECHNICIANS HAVE BEEN CERTIFIED FOR WORK.

T104-3.3 EQUIPMENT AND MATERIALS REQUIREMENTS

THE FOLLOWING ARE EQUIPMENT AND MATERIAL REQUIREMENTS FOR THIS ITEM OF WORK.

ABRASIVE BLASTING EQUIPMENT - ABRASIVE BLASTING EQUIPMENT SHALL BE CONVENTIONAL, AIR PRESSURE-TYPE BLASTERS. A MINIMUM PRESSURE OF 100 PSI SHALL BE MAINTAINED AT THE BLAST NOZZLE.

ABRASIVES - THE ABRASIVE MATERIAL SHALL BE CLEAN AND DRY SILICA SAND OR OTHER SUITABLE MATERIAL. THE BLAST MATERIAL SHALL BE PLANT PACKAGED AND MAINTAINED IN A CLEAN AND DRY CONDITION AT ALL TIMES. MATERIAL STORED IN THE BLASTER POT OVERNIGHT SHALL NOT BE USED. A COPY OF THE MSDS SHALL BE PROVIDED TO THE ENGINEER PRIOR TO BLASTING. SPENT ABRASIVES SHALL NOT BE REUSED.

COMPRESSED AIR - COMPRESSED AIR USED FOR ABRASIVE BLASTING SHALL BE CLEAN, OIL FREE, AND DRY, PER ASTM D4285. AIR LINE FILTERS AND MOISTURE SEPARATORS SHALL BE INSTALLED UPSTREAM FROM THE BLASTING EQUIPMENT. THESE SHALL BE INSPECTED DAILY FOR CLEANLINESS AND CORRECT OPERATION. ANY INDICATION OF MALFUNCTIONING EQUIPMENT SHALL BE CORRECTED IMMEDIATELY.

SUBMIT DETAILED DESCRIPTIONS OF ALL MATERIALS TO BE USED TO THE ENGINEER FOR APPROVAL. THIS INFORMATION SHALL PROVIDE ALL RELEVANT CONSTITUENTS AND PROPERTIES OF EACH MATERIAL AND THE SPECIFICATIONS TO WHICH EACH COMPLIES. DATA PUBLISHED BY THE MANUFACTURERS WILL BE ACCEPTABLE EXCEPT WHERE CERTIFICATIONS OF MATERIALS CHARACTERISTICS ARE REQUIRED.

Example

625-020-018 January 2023

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STRUCTURES MANUAL

Introduction - General Introduction
Volume 1 - Structures Design Guidelines
Volume 2 - Structures Detailing Manual
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Volume 4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

Current Policy & Practice for FDOT projects

1. ***Structures Manual-Volume 4 (FRPG 4.3): TSP T104 – CFRP Strengthening***

SECTION T104
CFRP STRENGTHENING (CONTINUED)

T104-4 REPAIR OF DEFECTS

UPON COMPLETION OF THE CURING PROCESS, THE INSTALLED SYSTEM SHALL BE CHECKED FOR AREAS WHERE SATURANT HAS NOT PENETRATED OR WHERE SATURANT HAS NOT COMPLETELY CURED. SUCH AREAS SHALL BE EPOXY INJECTED TO REESTABLISH BOND, SUBJECT TO THE APPROVAL OF THE ENGINEER.

REPAIR PROCEDURES SHALL BE PERFORMED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS AND AS SPECIFIED BY THE ENGINEER. ALL REPAIRS SHALL BE SUBJECT TO THE SAME APPLICATION, CURING, AND QUALITY CONTROL SPECIFICATIONS AS THE ORIGINAL WORK.

SMALL DELAMINATIONS, LESS THAN 2 SQUARE INCHES EACH, DO NOT REQUIRE CORRECTIVE ACTION, AS LONG AS THE TOTAL DELAMINATED AREA IS LESS THAN 5% OF THE APPLIED SURFACE AREA.

LARGE DELAMINATIONS, GREATER THAN 25 SQUARE INCHES EACH, SHALL BE REPAIRED BY SELECTIVELY CUTTING AWAY THE AFFECTED SHEET, REAPPLYING PRIMER AND RESIN LAYERS, AND APPLYING AN OVERLAPPING CFRP PATCH OF EQUIVALENT PLIES AND FIBER ORIENTATION. ALLOW FOR 6 INCHES OVERLAP IN ALL DIRECTIONS.

MODERATE DELAMINATIONS, LESS THAN 25 SQUARE INCHES EACH, SHALL BE REPAIRED BY FILLING THE DELAMINATIONS USING LOW-PRESSURE INJECTION OF THE SATURANT, OR BY THE PREVIOUS PROCEDURE SPECIFIED FOR LARGE DELAMINATIONS.

REPAIR PROCEDURES FOR CONDITIONS THAT ARE NOT SPECIFICALLY ADDRESSED IN THESE NOTES SHALL BE SUBMITTED AND APPROVED BY THE ENGINEER PRIOR TO PROCEEDING WITH THE WORK.

T104-5 PROTECTIVE COATING

T104-5.1 GENERAL

THIS SPECIFICATION DESCRIBES THE COATING OF THE WRAP SYSTEM, INCLUDING ADJACENT CONCRETE SURFACES, WITH A NON-VAPOR-BARRIER, FLEXIBLE, PROTECTIVE, WATERPROOFING COATING. MATERIAL SHALL BE A POLYMER BASED LATEX COATING. FINAL APPEARANCE IS TO MATCH, WITHIN REASON, THE COLOR AND TEXTURE OF THE ADJACENT CONCRETE.

INSTALL MATERIALS IN ACCORDANCE WITH ALL SAFETY AND WEATHER CONDITIONS REQUIRED BY THE MANUFACTURER, OR AS MODIFIED BY APPLICABLE RULES AND REGULATIONS OF LOCAL, STATE, AND FEDERAL AUTHORITIES HAVING JURISDICTION. CONSULT MSDS FOR COMPLETE HANDLING RECOMMENDATIONS.

DO NOT APPLY COATING MATERIAL IF IT IS RAINING, OR IF SUCH CONDITIONS APPEAR TO BE IMMINENT.

T104-5.2 SUBMITTALS

SUBMIT THREE COPIES OF MANUFACTURER'S LITERATURE, TO INCLUDE:
PRODUCT DATA SHEET, SYSTEM DATA SHEET, APPLICATION GUIDE, AND APPROPRIATE MSDS.

SAMPLE MOCK-UP (MINIMUM 12 INCHES BY 12 INCHES) OF THE COATING PRODUCT TO BE INSPECTED FOR COLOR MATCHING AND APPROVED BY THE ENGINEER PRIOR TO APPLICATION.

T104-5.3 PRODUCTS

UV PROTECTIVE EPOXY-BASED POLYMER COATINGS. THE POLYMER COATING SHALL SATISFY THE FOLLOWING CONDITIONS:

MATERIAL SHALL BE GRAY-COLORED, ACRYLIC, PROTECTIVE COATING;
MATERIAL SHALL PREVENT MOISTURE INGRESS;
MATERIAL SHALL BE WATER VAPOR PERMEABLE AND PROVIDE CARBONATION BARRIER;
MINIMUM DRY FILM THICKNESS SHALL BE 4-6 MILS;
PROVIDE UV PROTECTION.

T104-5.4 SURFACE PREPARATION AND APPLICATION REQUIREMENTS

ALL SURFACES TO BE COATED SHALL BE CLEAN AND DRY. SURFACE PREPARATION SHALL BE AS RECOMMENDED BY THE MANUFACTURER. SOLVENT-WIPES SHALL NOT BE USED TO CLEAN THE CFRP SURFACE, UNLESS APPROVED BY THE CFRP MANUFACTURER. IF ABRASIVE CLEANING IS NECESSARY, AIR PRESSURE SHALL BE LIMITED TO AVOID ANY DAMAGE TO FIBERS. INCLUDE THE PREPARATION TECHNIQUE AS PART OF THE DETAILED WORK PLAN SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO STARTING THE WORK.

THE RECOMMENDED APPLICATION TEMPERATURE (AMBIENT AND SUBSTRATE) IS 50°-95°F. MATERIAL CAN BE APPLIED BY BRUSH, ROLLER, OR SPRAY OVER ENTIRE AREA MOVING IN ONE DIRECTION. ALLOW A MINIMUM OF 20-90 MINUTES PRIOR TO RECOATING. AT HIGHER TEMPERATURES, WORK CAREFULLY TO MAINTAIN WET EDGE. TO ACHIEVE A DRY FILM THICKNESS OF 4-6 MILS, TWO [illegible] COATS SHOULD BE ANTICIPATED. ON POROUS SUBSTRATES, A THIRD COAT MAY BE NECESSARY.

ADHERE TO ALL LIMITATIONS AND CAUTIONS [illegible] MATERIAL IN THE MANUFACTURER'S PRINTED LITERATURE.

T104-6 INSPECTION, TESTING AND [illegible]

ALL INSPECTION IN THESE NOTES SHALL BE PERFORMED BY A TRAINED INSPECTOR ACTING ON BEHALF OF THE DEPARTMENT FOR QUALITY ASSURANCE OF THE PROJECT, IN THE PRESENCE OF THE CONTRACTOR AND THE ENGINEER. THE CONTRACTOR MAY HAVE ITS OWN INSPECTOR FOR QUALITY CONTROL.

T104-6.1 INSPECTION AND QUALITY ASSURANCE

MANUFACTURER'S CERTIFICATIONS FOR ALL DELIVERED AND STORED CFRP COMPONENTS WILL BE INSPECTED FOR CONFORMITY TO THESE PLAN NOTES BEFORE STARTING THE CFRP REPAIR.

MATERIALS TESTING SHALL BE CONDUCTED ON SAMPLES OF PRE-CURED WITNESS PANELS. ANY MATERIAL THAT DOES NOT MEET THE REQUIREMENTS OF THE CONTRACT DOCUMENTS WILL BE REJECTED.

DAILY INSPECTION WILL INCLUDE:

- DATE AND TIME OF REPAIR;
- AMBIENT AND CONCRETE SURFACE TEMPERATURES;
- RELATIVE HUMIDITY AND GENERAL WEATHER CONDITIONS;
- SURFACE DRYNESS PER ACI 503.4;
- SURFACE PREPARATION AND SURFACE PROFILE USING ICRI SURFACE-PROFILE-CHIPS;
- QUALITATIVE DESCRIPTION OF SURFACE CLEANLINESS;
- WIDTHS OF CRACKS NOT INJECTED WITH EPOXY;
- FIBER LAMINATE BATCH NUMBERS AND THEIR LOCATIONS IN STRUCTURE BATCH NUMBERS, MIXTURE RATIOS, MIXING TIMES, AND QUALITATIVE DESCRIPTIONS OF THE APPEARANCE OF ALL MIXED RESINS, PRIMERS, PUTTIES, SATURANTS, ADHESIVES, AND COATINGS;
- OBSERVATIONS OF PROGRESS OF CURE OF RESINS;
- CONFORMANCE WITH INSTALLATION PROCEDURES;
- ADHESION TEST RESULT INCLUDING BOND STRENGTH, FAILURE MODE, AND LOCATION;
- CFRP PROPERTIES FROM TESTS OF FIELD SAMPLE PANELS;
- LOCATION AND SIZE OF ANY DELAMINATIONS OR AIR VOIDS;
- GENERAL PROGRESS OF WORK.

FIBER [illegible] PLY ORIENTATION, FIBER KINKS, AND WAVINESS WILL BE EXAMINED BY VISUAL INSPECTION FOR CONFORMITY TO THE CONDITIONS SPECIFIED IN THE PLAN NOTES. NON-CONFORMING CFRP AREA WILL BE REMOVED, AND REPAIRED AS PER SECTION T104-4, AT THE CONTRACTOR'S EXPENSE.

AFTER AT LEAST 24 HOURS FOR THE INITIAL CURE OF THE RESIN, A VISUAL INSPECTION OF THE SURFACE WILL BE PERFORMED FOR ANY SWELLING, BUBBLES, VOIDS, OR DELAMINATIONS. IF AN AIR POCKET IS SUSPECTED, AN ACOUSTIC TAP TEST WILL BE CARRIED OUT IN ACCORDANCE WITH "SECTION T102 - CARBON FIBER REINFORCED POLYMER TESTING REQUIREMENTS."

T104-6.2 TESTING

FOR TESTING REQUIREMENTS, SEE "SECTION T102 - CARBON FIBER REINFORCED POLYMER TESTING REQUIREMENTS."

Example

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TRUCTURES MANUAL

ction - General Introduction
1 - Structures Design Guidelines
2 - Structures Detailing Manual
3 - FDOT Modifications to LRFD LTS-1
4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

Current Policy & Practice for FDOT projects

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SECTION T104
CFRP STRENGTHENING (CONTINUED)

T104-6.3 SAMPLING

RECORD LOT NUMBER OF FIBER USED FOR WRAPPING. TWO SAMPLES SHALL BE PREPARED RANDOMLY THROUGHOUT THE DURATION OF THE PROJECT. THE ENGINEER SHALL SELECT THE TIME AND LOCATION OF THESE SAMPLES. SAMPLES SHALL CONSIST OF TWO 12 INCH BY 12 INCH LAYERS OF FIBER (FLAT).

MIX SAMPLES OF EPOXY RESIN ACCORDING TO MANUFACTURER'S RECOMMENDATIONS. ALL MATERIALS USED FOR THE SAMPLES SHALL BE FROM THE SAME PRODUCTS (LOT NUMBER) BEING USED AT THE SITE ON A DAILY BASIS. ON A SMOOTH, FLAT, LEVEL SURFACE COVERED WITH POLY ETHYLENE SHEETS, PREPARE A SAMPLE BY PLACING TWO LAYERS OF THE COMPOSITE ORIENTED IN THE SAME DIRECTION. COVER WITH POLY ETHYLENE SHEETS AND SQUEEZE OUT ALL BUBBLES. THE PREPARED, IDENTIFIED SAMPLES SHALL BE TESTED. ALL TESTING SHALL BE AT THE CONTRACTOR'S EXPENSE, BY AN INDEPENDENT LABORATORY, AND IN ACCORDANCE WITH ASTM 3039. TWO COPIES OF THE TEST RESULTS ARE TO BE SUBMITTED TO THE ENGINEER WITHIN FIVE DAYS OF TESTING. AS A MINIMUM, THE TESTING SHALL CONSIST OF:

- ULTIMATE TENSILE STRENGTH;
- TENSILE MODULUS;
- PERCENT ELONGATION.

FOR PULL-OUT TESTING REQUIREMENTS, SEE [illegible] 4.3.

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January 2023

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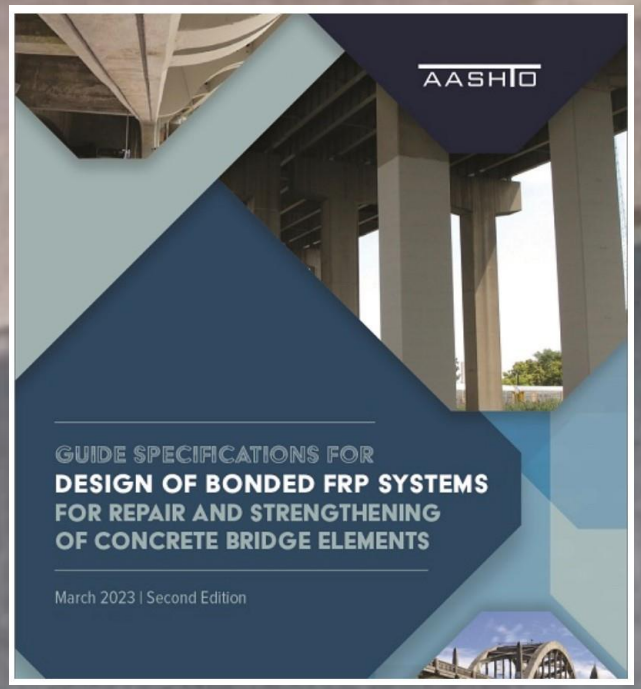
TRUCTURES MANUAL

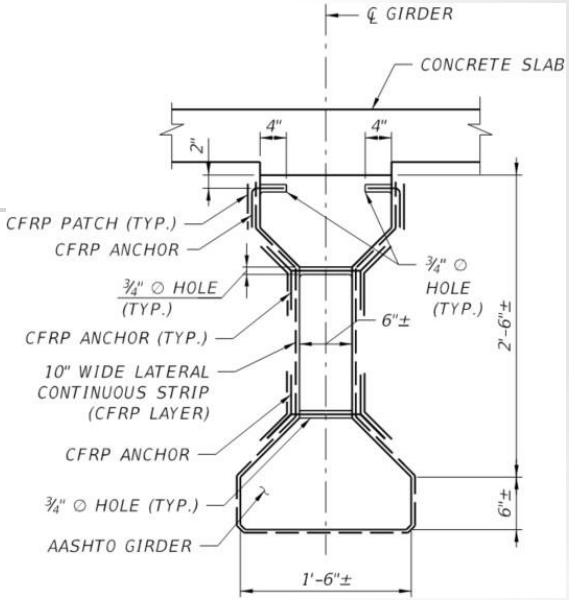
ction - General Introduction
e 1 - Structures Design Guidelines
e 2 - Structures Detailing Manual
e 3 - FDOT Modifications to LRFD LTS-1
e 4 - Fiber Reinforced Polymer Guidelines

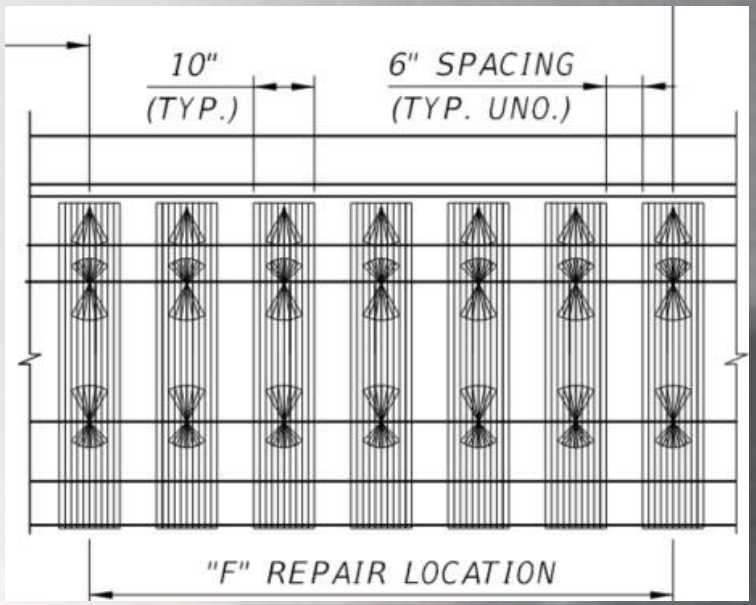
Frequently Asked Questions
2023 Revision History
Archived Structures Manuals
Additional Links

Future Adoption of AASHTO 2nd Ed.



What's the plan?





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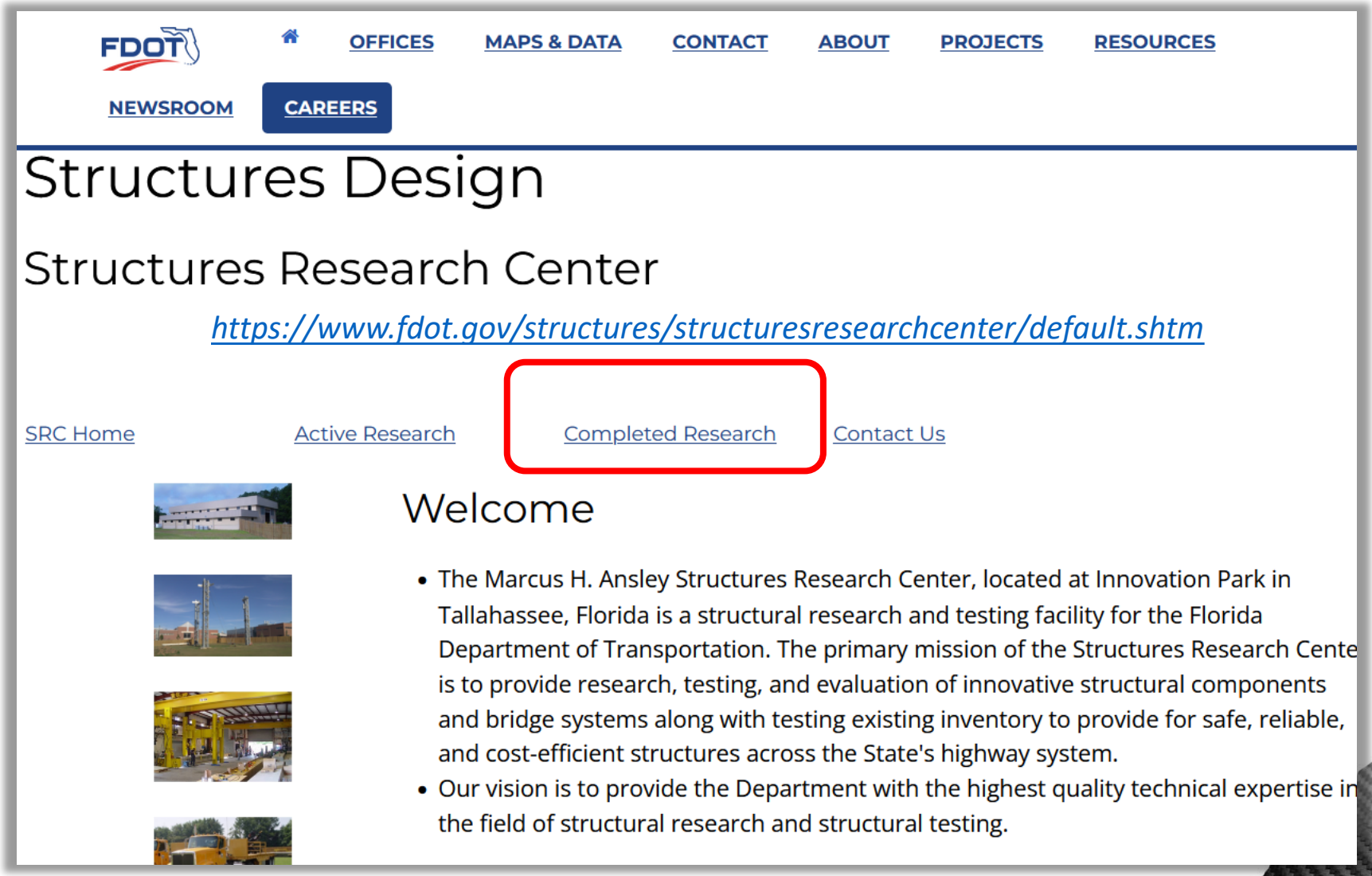
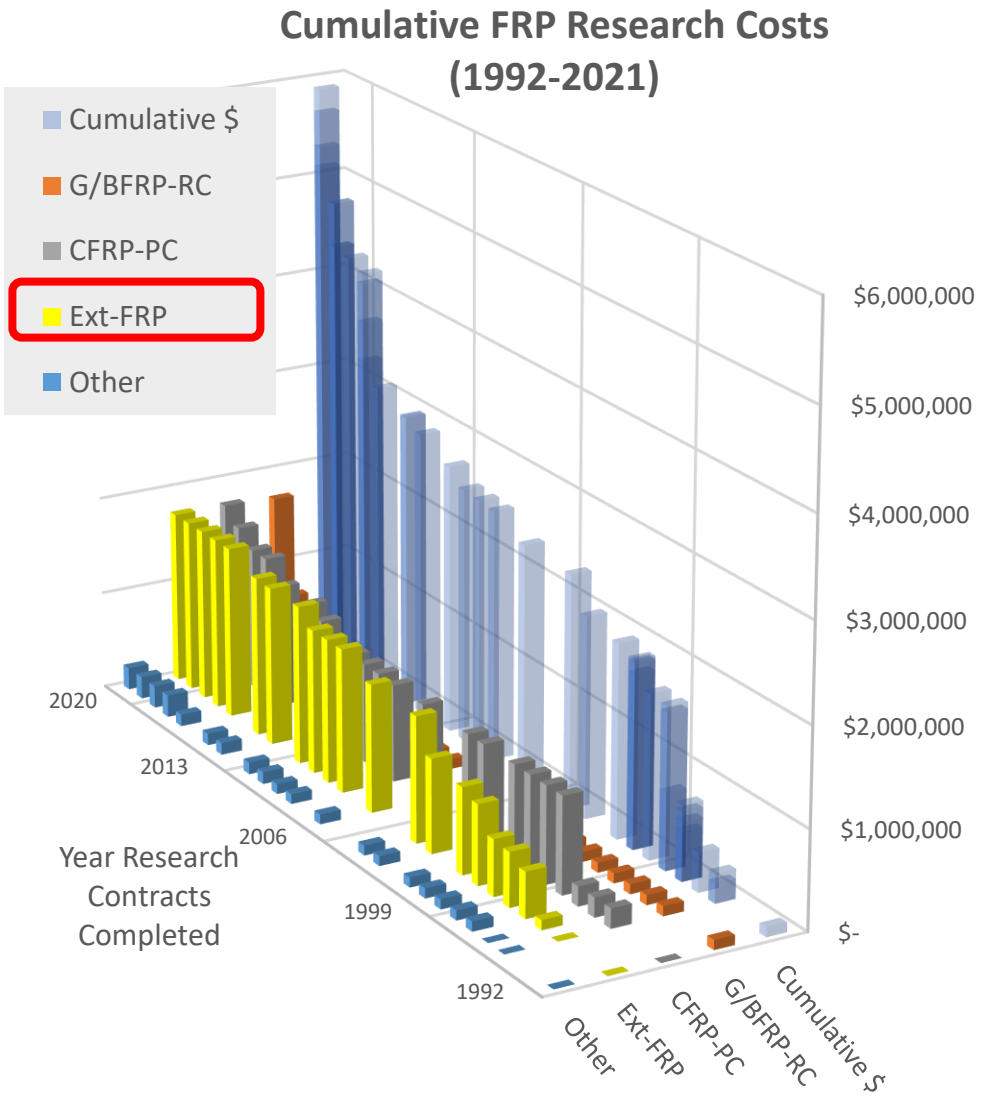
Recently completed Research

1. FDOT SRC



Completed FRP Research

FRP Strengthening & Repair



1992	Feasibility of Fiberglass Pretensioned Piles in a Marine Environment	Sen, R.	USF
1995	Active Deformation Control of Bridges with AFRP Cables	Arockiasamy, M.	FAU
1995	Durability of CFRP Pretensioned Piles in a Marine Environment – Phase II	Sen, R.	USF
1997	Mechanical and Microscopy Analysis of CFRP Matrix Composite Materials	Garmestani, H.	FAMU/FSU
1997	FRP Composite Column and Pile Jacket Splicing	Mirmiran, A.	UCF
1997	An Analytical and Experimental Investigation of Concrete Filled FRP Tubes	Mirmiran, A.	UCF
1997	Flexural Reliability of RC Bridge Girders Strengthened with CFRP Laminates	Okeil, A.	UCF
1998	Studies of CFRP Prestressed Concrete Bridge Columns and Piles in Marine Environment	Arockiasamy, M.	FAU
1998	Analysis and Modeling of Fiber-Wrapped Columns and Concrete-Filled Tubes	Shahawy, M.	FDOT
1999	LRFD Flexural Provisions for PSC Bridge Girders Strengthened with CFRP Laminates	El-Tawil, S.	UCF

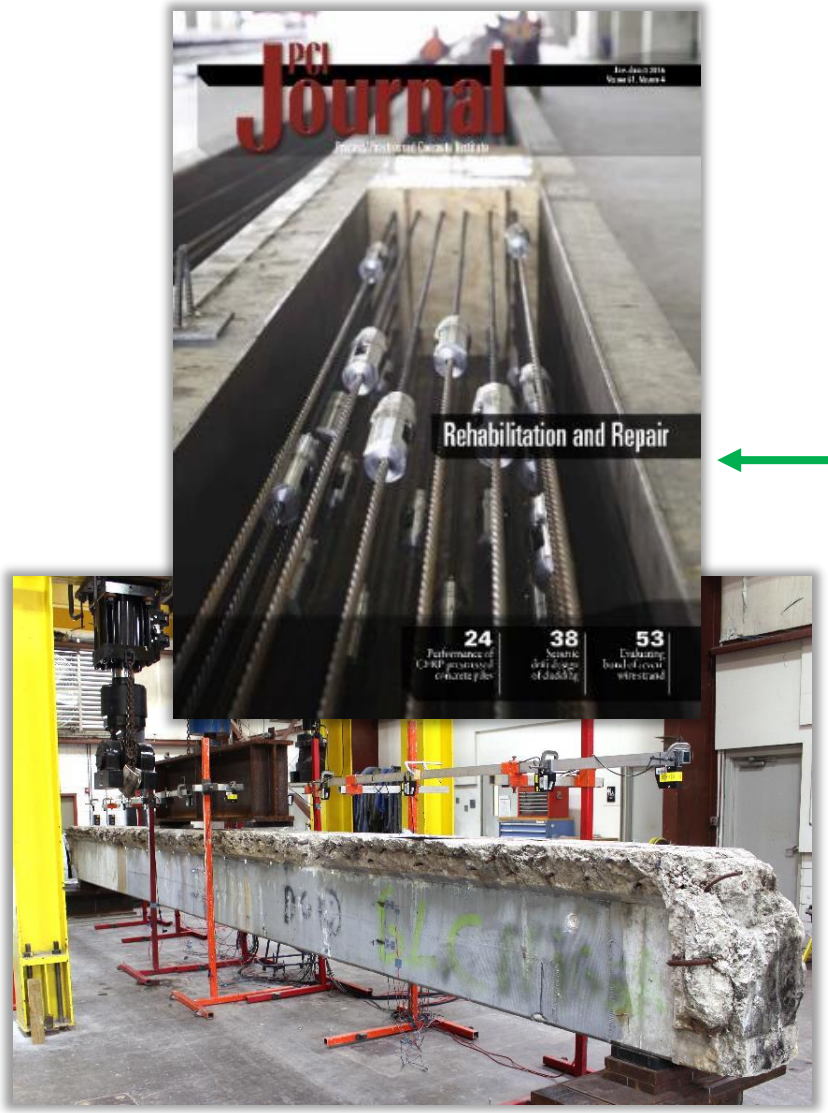
Completed FRP Research

FRP Strengthening & Repair

1999	Behavior of Reinforced Concrete Beam-Column Retrofitted with Composite Wrapping Systems	Chaallal, O.	FDOT
2000	Effect of Concrete Strength on the Performance of FRP Wrapped RC Column Under Combined Axial-Flexure Loading	Chaallal, O.	FDOT
2000	Behavior of Axially Loaded Short Rectangular Columns Strengthened with CFRP Composite Wrapping	Chaallal, O.	FDOT
2000	Investigation of Fender Systems for Vessel Impact	Yazdani, N.	FAMU/FSU
2000	Short-Term Tensile Strength of CFRP Laminates for Flexural Strengthening of Concrete Girders	Okeil, A.	UCF
2001	Design of Concrete Bridge Girders Strengthened with CFRP Laminates	El-Tawil, S.	UCF
2003	Hybrid FRP-Concrete Column	Mirmiran, A.	NC State
2004	CFRP Repair of Impact Damaged Bridge Girders	Hamilton, T	UF
2007	Testing Bridge Decks with Near-Surface mounted FRP Bars Embedded in Cement Based Grout	Hamilton, T	UF
2009	Thermo-Mechanical Durability of CFRP Strengthened RC Beams	Mackie, K	UCF

Completed FRP Research

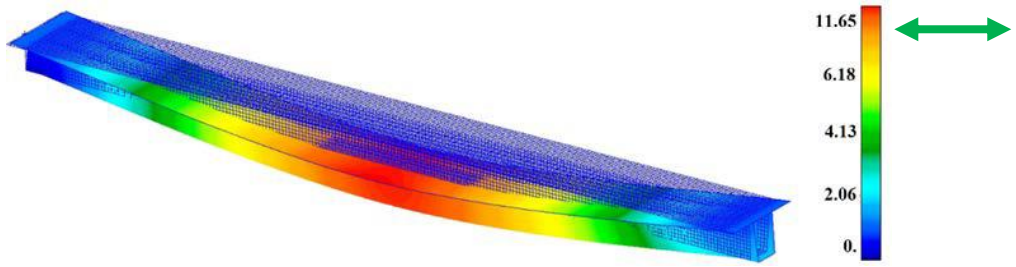
FRP Strengthening & Repair



2010	Testing Precast Piles with Carbon Fiber Reinforced Polymer Mesh	Abalo, V.	FDOT
2011	Testing of Trelleborg Structural Plastics	Wagner, D.	FDOT
2011	Testing of Trelleborg Structural Plastics	Wagner, D.	FDOT
2012	The Repair of Damaged Bridge Girders with CFRP Laminates	El-Safty, A.	UNF
2014	Investigation of CFCC in Prestressed Concrete Piles	Roddenberry, M.	FAMU/FSU
2015	Use of CFRP Cable for Post-Tensioning Applications	Mirmiran, A.	FIU
2015	Repair of Impact Damaged Utility Poles with FRP, Phase II	Mackie, K.	UCF
2017	Durability Evaluation of Florida's FRP Composite Reinforcement for Concrete Structures	Hamilton, T.	UF
2018	Testing, Evaluation, and Specification for Polymeric Materials used for Transportation Structures	El-Safty, A.	UNF
2018	Degradation Mechanisms and Service Life Estimation of FRP Concrete Reinforcements	El-Safty, A.	UNF

Completed FRP Research

FRP Strengthening & Repair



2018	Bridge Girder Alternatives for Extremely Aggressive Environments	Brown, J.	ERAU
2018	Performance Evaluation of GFRP Reinforcing Bars Embedded in Concrete Under Aggressive Environments	Kampmann, R.	FAMU/ FSU
2019	Performance Evaluation, Material and Specifications for Basalt FRP Reinforcing Bars Embedded in Concrete	Kampmann, R. Roddenberry, M.	FAMU/ FSU
2020	Basalt FRP-FRC Link-Slab Demonstration Project Monitoring (STIC-Phase 1)	El-Safty, A.	UNF
2020	Inspection and Monitoring of Fabrication and Construction for the Halls River Bridge Replacement	Roddenberry, M.	FAMU/ FSU
2020	HSSS Strands and Lightweight Concrete for Pretensioned Concrete Girders (w/ Shear & Confinement Rebar)	Roddenberry, M.	FAMU/ FSU
2021	Testing Protocol and Material Specifications for Basalt Fiber Reinforced Polymer Bars (Long-term Durability Modelling)	Kampmann, R. Tang, Y	FAMU/ FSU
2021	Evaluation of GFRP Spirals in Corrosion Resistant Concrete Piles	Jung, S.	FAMU/ FSU
2021	Development of GFRP Reinforced Single-Slope Railing	Consolazio, G.	UF
2021	Epoxy Dowelled Pile Splice Evaluation & Testing	Mehrabi, A.	FIU
2022	Detailing of Externally Bonded CFRP for Shear Strengthening	Suksawang, N.	BEA90	FIT

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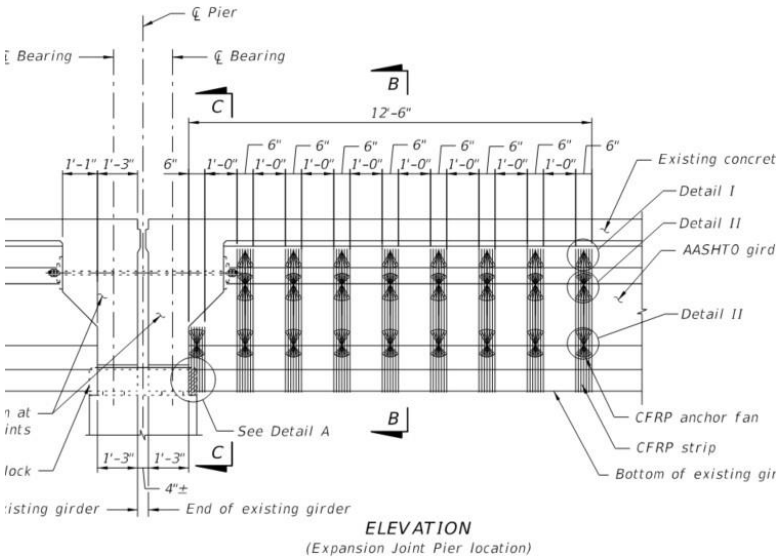
Ongoing FRP Research

FRP Strengthening & Repair

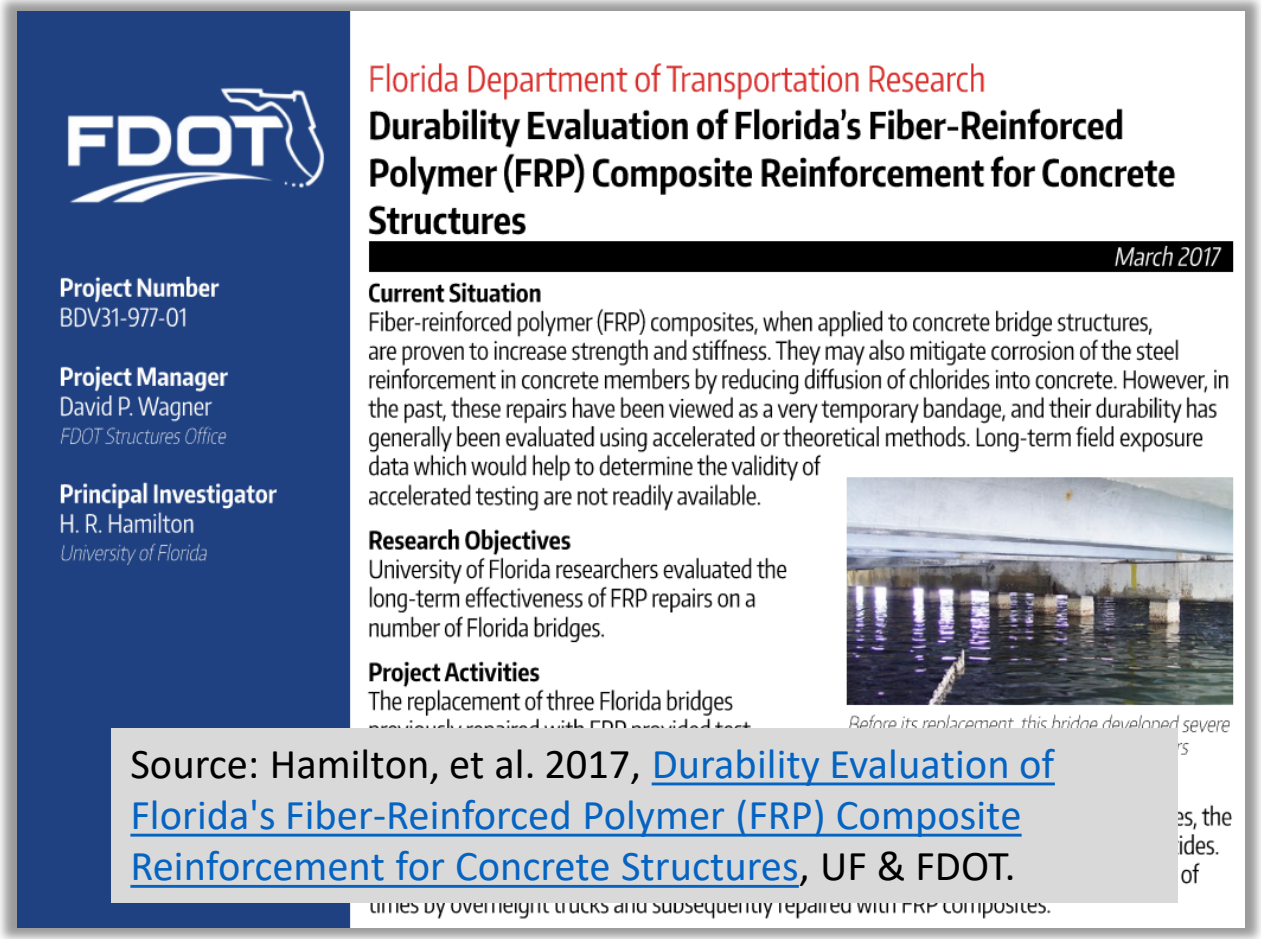
2023	Strengthening Piers to Resist Vehicular Collision (Analytical)	Zhang, Q.	FAMU/FSU
2025?	Experimental Evaluation of Strengthening Methods for Bridge Piers Against Vehicular Collision	TBA	TBA
2025?	Evaluation of Ultra-High Performance Concrete (UHPC) Pile Splices	Garber, D.	TBA



FDOT Structures Manual Guidance: Implementing AASHTO 2nd Edition and Procurement Process

Completed Projects

- Repair & strengthening.



FDOT

Project Number
BDV31-977-01

Project Manager
David P. Wagner
FDOT Structures Office

Principal Investigator
H. R. Hamilton
University of Florida

Florida Department of Transportation Research

Durability Evaluation of Florida's Fiber-Reinforced Polymer (FRP) Composite Reinforcement for Concrete Structures

March 2017

Current Situation
Fiber-reinforced polymer (FRP) composites, when applied to concrete bridge structures, are proven to increase strength and stiffness. They may also mitigate corrosion of the steel reinforcement in concrete members by reducing diffusion of chlorides into concrete. However, in the past, these repairs have been viewed as a very temporary bandage, and their durability has generally been evaluated using accelerated or theoretical methods. Long-term field exposure data which would help to determine the validity of accelerated testing are not readily available.

Research Objectives
University of Florida researchers evaluated the long-term effectiveness of FRP repairs on a number of Florida bridges.

Project Activities
The replacement of three Florida bridges

Before its replacement, this bridge developed severe

Source: Hamilton, et al. 2017, Durability Evaluation of Florida's Fiber-Reinforced Polymer (FRP) Composite Reinforcement for Concrete Structures, UF & FDOT.

Table 7—Summary of survey responses

Bridge No.	Location	Repair Date	FRP	FRP source	Inspection reports?	Load test?
790035	Volusia County	2007	Wet layup CFRP	Unknown	Y	Y
570017	District 3	2015	Wet layup CFRP	Unknown	Y	N
570018	District 3	2015	Wet layup CFRP	Unknown	Y	N
110070	SR 91 NB over CR 561	2009	Wet layup CFRP	TREX Wrap TEC3-10U	Y	N
110074	Bridges Road over SR 91	2005	Wet layup CFRP	MAS-2000	Y	N
920027	CR 530 WB over SR 91	2010	Wet layup CFRP	TREX Wrap TEC3-10U	Y	N
920075	Ramp A over SR 91	2005	Wet layup CFRP	MAS-2000	Y	N
930144	45th Street over SR 91	2007	Wet layup CFRP	TREX Wrap TEC3-20C	Y	N
930144	45th Street over SR 91	2004	Wet layup CFRP	BASF MBrace CF160	Y	Y
930148	PGA Blvd Ramp over SR 91	2004	Wet layup CFRP	BASF MBrace CF160	Y	Y
104320	Phillips Lane, Hillsborough County	2001	Wet layup CFRP	Unknown	Y	Y
104323	Dickman Road, Hillsborough County	2014	Wet layup CFRP	Mapei	Y	N
104422	Durant Road, Hillsborough County	2013	Wet layup CFRP	Mapei MapeWrap C Bi-Ax 230	Y	N

2016-2023 projects pending

Common Example Projects

There are several other reasons FRP repairs and strengthening are necessary:

- Over-height truck impacts.
- In sufficient detailing past practice for shear strength.
- Fire damage rehabilitation
- Beam end/bearing repair (confinement)

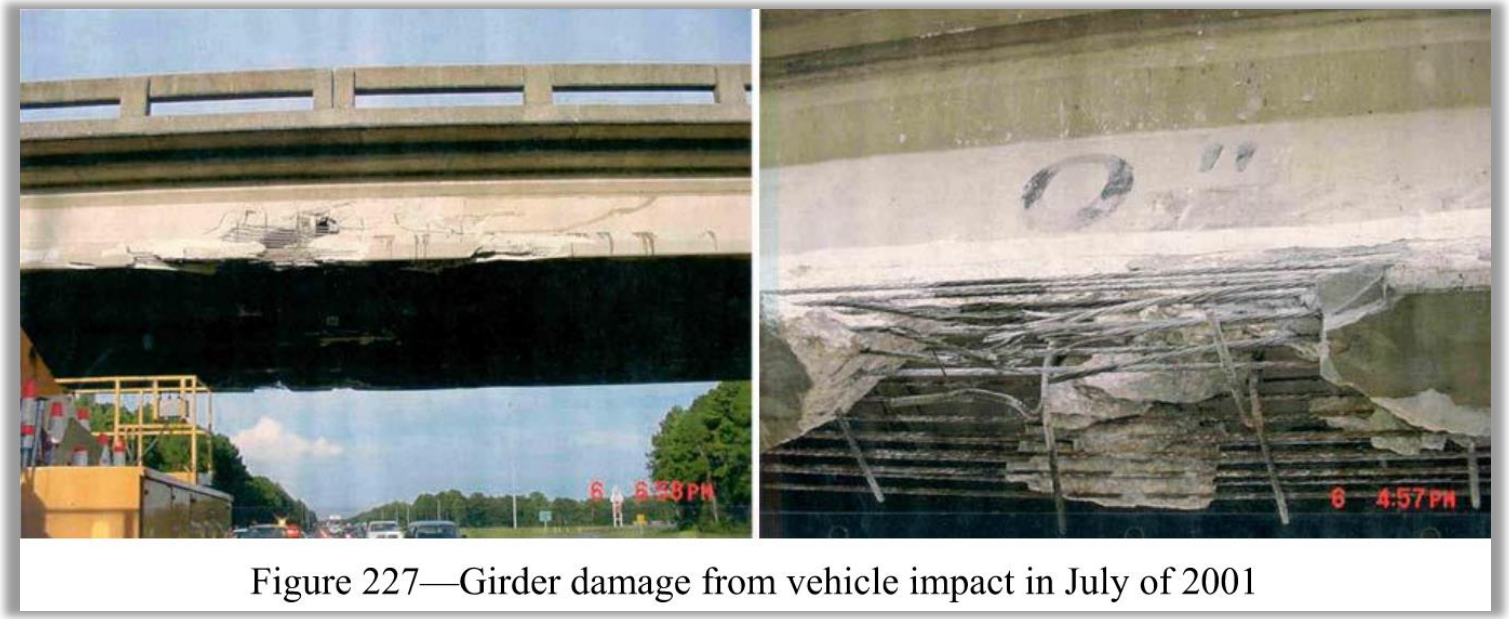


Figure 227—Girder damage from vehicle impact in July of 2001

Novel Degradation Mechanisms in Florida

Aggressive environments also include:

- Areas subject to spray from jet skis.
- Saltwater dripping from boat trailers.
- In northern Florida there has been a move to place salt after winter storms. If this becomes a more common occurrence, consideration may be given to including these.

Example Other Types of FRP Projects

1. **FRP-Prestressed Concrete (PC):**
   - **Prestressed Beams** - CFRP strands, GFRP/BFRP auxiliary
   - **Bearing Piles –** CFRP strands, spirals, & splice dowels, (GFRP/BFRP auxiliary??)
   - **Sheet Piles -** CFRP strands, GFRP (BFRP ? *submerged)* stirrups
2. **FRP-Reinforced Concrete (RC):**
   - **CIP Decks & Flat-Slab Bridges** - GFRP (BFRP *now allowed*)
   - **Seawalls –** GFRP *(submerged)*
   - **Bulkhead Caps –** GFRP/BFRP
   - **Retaining Walls -** GFRP/BFRP
   - **Drainage Structures/Box Culverts** – *(no recent examples)*
3. **FRP Elements (MS):**
   - **Fenders, Piles, HCBs, Pedestrian Structures**

FRP RC/PC material systems used in Florida's Highway Bridges & Structures

Recent Completed Projects

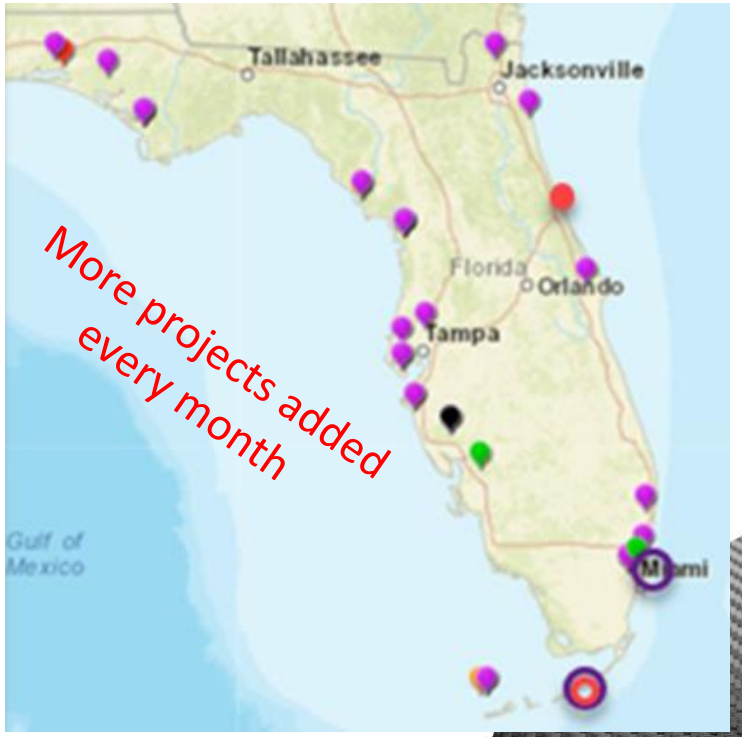
Arthur Drive over Lynn Haven Bayou **
Bakers Haulover Cut Bulkhead Replacement *
Cedar Key Bulkhead Rehab *
Key West Bight Ferry Terminal Extension **
Halls River Bridge ***
PortMiami Tunnel Retaining Walls
South Maydell Dr over Palm River *
SR-A1A Flagler Beach Seawall (Segment 3) *
SR-5 (US-17) over Trout River Rehab **
SR-5 (US 41)/Morning Star and Sunset link-slabs
SR-45 (US 41) over North Creek ***
SR-312 over Matanzas River Rehab **
SR-520 over Indian River Bulkhead Rehab *
Sunshine Skyway Seawall Rehab & Extension*
UM Innovation Bridge ***
UM Fate Bridge superstructure
UM i-Dock ***
US-1 over Cow Key Channel FSB's

Current Projects

4th St at Big Island Gap **
40th Ave NE over Placido Bayou ***
Barracuda Blvd over Canal Bradano **
Bayway Structure-E Seawall Cap *
Bimini Dr over Duck Key Canal *
CR30A over Western Lake ***
Jupiter Federal Observation Platform ***
NE 23rd Ave over Ibis Waterway ***
S. Maydell Dr/Palm River Bulkhead *
SR-A1A over Myrtle Creek and Simpson Creek
SR-A1A N. Bridge Observation Platform ***
SR 404 & 528 Indian & Banana Rivers Rehab *
SR5 over Oyster Creek *
SR 5/US 1 over Earman River Canal ***
SR-30 over St Joe Inlet *
SR-112/I-195 Westshore waterway *
Village of North Bay Seawall *
West Wilson St over Turkey Creek **

https://www.fdot.gov/structures/innovation/FRP.shtm

* *bulkhead/seawall only*
** *piling/substructure only*
*** *complete bridge*



FRP structural member systems used in Florida's Highway Bridges & Structures

Recent Completed Projects

Acosta Bridge fender replacement *
Bayway Structure-E fender *
US-331/Choctawhatchee Bay fender wales
Halls-River Bridge - Hybrid Composite Beams
Howard Frankland Bridge NB fender *
Ocala Water-Recharge Park Boardwalk ***
Skyplex Blvd - Composite Arch Bridge **
SR-A1A/Sisters Creek fender *
SR-A1A/Blue Heron fender replacement *
SR-3 over Barge Canal fender replacement *
SR-44 over Indian River fender replacement *
SR 714/South Fork St Lucie River *

Current & Future Projects

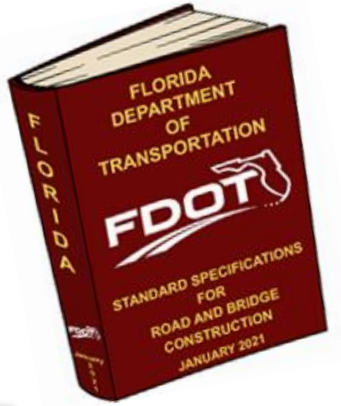
Bimini Dr over Duck Key Canal ? **
CR510 3-Sided Culvert-Bridge ? **
Marco Island Winter Berry Bridge
I-10/Apalachicola River Fender replace *
Jax. Main St Bridge Fender rehab *
SR-40 over Halifax River fender replacement *
SR-292 Perdido Key/ICWW fender replacement *
SR-520 over Indian River fender replacement *
US-192 over Indian River fender replacement *
SR-401 over Barge Canal fender replacement *
SR-518 over Indian River fender replacement *

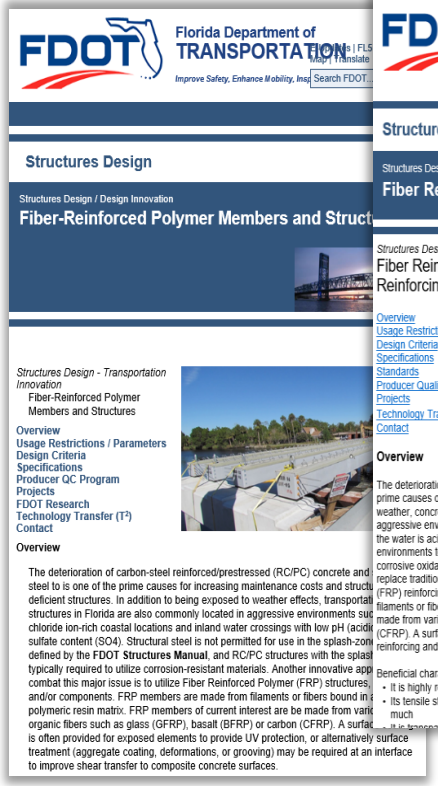
https://www.fdot.gov/structures/innovation/frpms

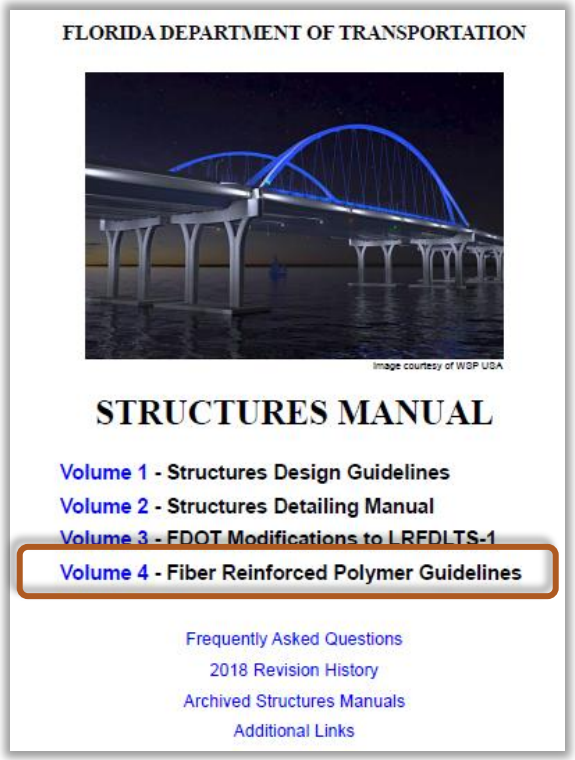
* *complete fender system*
** *FRP concrete filled arch*
*** *FRP pedestrian structure*

FRP Design Guidance, Specs, & Tools: Florida DOT

- **Mandatory Specifications**
- **Uniform Approval Processes**
  - Manufacturer Approval vs. Product Approval
- **Design Tools**







https://www.fdot.gov/structures/innovation/

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Future FRP Bridge Strengthening & Rehabilitation

- **Environmental Reduction Factors** for Ext. Bonded CFRP
- **FRP** rebar NSM (Carbon, Glass, Basalt)
- **Precured laminates -** when to use?
- **Other Strengthening Solutions** will UHPC become more important for some application
- **FRP synergy** with strengthening systems and adaptability

Questions ?

SAFETY IS
EVERYONE'S
RESPONSIBILITY

TARGET ZERO
FATALITIES & SERIOUS INJURIES

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Florida Department of Transportation
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Website: https://www.fdot.gov/design/Innovation/