



2018 STIC Incentive Project (BFRP-RC Standardization) – 30 Month Report

Fed Project No: STIC-004-A; FPID 443377-1

This is the fifth report for the Basalt Fiber-Reinforced Polymer (BFRP) Bar Standardization for Reinforced Concrete (RC) with the FHWA allocation memorandum dated March 1, 2018. This report covers a period from June 2020 to Nov 2020. Underlined text is additional to previous reports.

Description of the proposed work

Develop standard (guide) design specification, and standard material and construction specifications for basalt fiber-reinforced polymer (BFRP) bars for the internal reinforcement of structural concrete. Tasks involve *(highlighted tasks are completed or partially completed in this section of the report):*

- i. Establishing design and durability parameters using current state-of-the-art BFRP test data with *ACI 440.1R* as a design model framework, supplemented with *AASHTO's LRFD Bridge Design Guide Specification for GFRP Reinforced Concrete - 2nd Edition (BDGS-2)* published December 2018; *BDV30 986-01 Final Report* provided recommendations for design and future refinement (*see Appendix A of Report 3*).
- ii. Develop FDOT design modifications to *BDGS-2* for inclusion of BFRP reinforcing - *see BDV30 986-01 Final Report* – Chapter 6 recommendations which have been incorporated into the *2020 Structures Manual* published January 2020. No increase in BFRP design parameters above those currently established for GFRP are proposed at this time, until additional testing is performed to refine the environmental reduction factors for different limit states. Some of the necessary work for this effort is ongoing under FDOT research project *BE694 - Improving Testing Protocol and Material Specifications for BFRP Bars*.
- iii. Develop FDOT material specification for acceptance based on the 2017 *ASTM D7957: Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement* - *see BDV30 986-01 Final Report* – Chapter 6, and FDOT *Materials Manual* – Section 12.1 (*see Appendix B of Report #3*). Incorporated into *FDOT Standard Specification Section 932-3* for July 2021 Workbook.
- iv. Develop FDOT Construction Specifications based on *BDGS-2* and *FDOT Specification Section 415 & 932* GFRP reinforcing specifications – *Specification Section 932* updates (*Section 416* had no updates required) where approved by *FHWA Sept 3, 2019*.
- v. Develop BFRP Reinforcing Database for collection of current and future test results based on FDOT GFRP reinforcing test library developed under *BDV30 977-18* and new research project *BE694 “Testing Protocol and Material Specification for BFRP*

- Rebars*” established under [BE694-Deliverable 2](#). Test data from [BDV30 986-01](#) published in Chapter 3.
- vi. Deliver a designer focus live workshop at the end of the STIC project in central Florida (and national event if funding permits). Post the delivered training material on [FDOT FRP Innovation](#) website for broader access and future updating.
 - (a) BFRP-RC Designer Training schedule for 3 sessions at the FDOT Transportation Symposium (FTS-2019) on June 4th (see [FDOT Transportation Symposium FRP-RC Design - Part 1, Part 2, & Part 3](#));
 - (b) [BEI-2019](#) FRP Composites II (Session B-9) on BFRP-RC for coastal and marine structures was provide as the Bridge Engineering Institute conference July 23-25. Additionally, several papers on BFRP-RC were presented and published in the [Conference Proceedings](#), pp 514-523, 527-531, & 551-562; see [Appendix D of Report #3](#));
 - (c) Peer Exchange BFRP-RC Designer Training was provided to Hawaii DOT Bridge Office on July 22, 2019 (see BFRP-RC Design - [Part 1, Part 2, Part 3, & Part 4](#));
 - vii. Demonstration Project #1 - Plans developed and construction completed for BFRP-RC link-slab on pedestrian bridge in Port Charlotte, FL (along US 41). Construction of BFRP-FRC link slab on Morning Star Waterway bridge completed in April 2020, with embedded strain gages and data loggers installed March 6-7, continuously recording temperature & strain data under Research Contract [BDV29 986-02. Deliverable #1](#) (literature review), and [Deliverable #2](#) (revised instrumentation plan) posted on [FRP Design-Innovation webpage](#). Retrieval of data and installation of surface mounted crack gages has not been conducted due to continued COVID-19 restrictions on travel imposed on the PI by the University of North Florida.
 - viii. Demonstration Project #2 - An additional demonstration project has been proposed for construction in early 2021 using BFRP closed stirrup bars in a seawall-bulkhead cap. One quadrant of the St Joe Bay Inlet bridge replacement seawall-bulkhead will use BFRP closed stirrups as a substitute for GFRP pairs of overlapping U-shaped bars above each sheet pile tongue & groove joint (see [Appendix B](#)).

Project Breakdown and Schedule

The project is broken into several phases with distinct tasks some of which were not completely scoped, pending progress and findings in the early Phases. **Table 1** shows a summary of the project Phases. There will be at least two services contracts with Florida Universities for the various tasks of: Existing information collection and curation (Phase 1a); Development of model specifications and standards (Phase 1b); Provision of supplemental test data and analysis (Phase 2a); Development of Materials Database (Phase 2b); Technology Transfer (Phase 3).

PROJECT PHASE	1	2	3
PROJECT WORK TASKS	Develop Standards: (BDV30 986-01) - Design Spec. - Materials Qualification and Verification Test Procedures - Construction Spec.	- Demo #1: Full-scale Link-Slab and Monitoring; (BDV34 986-02)* <u>Demo #2: Seawall-bulkhead cap with closed BFRP stirrups (FPID 435815-1)</u> - Supplemental Bar Testing - BFRP Database Completion (BDV30 986-01)	- Technology Transfer (FTS-2019 & BEI-2019) - Final Report
PROJECT DELIVERABLES	- LRFD Guide Design Spec. (in AASHTO format) - Testing Spec. (in ASTM format) - Construction Spec. (in FDOT format)	- Test Reports - Electronic Database of physical and mechanical properties	T ² Workshop in central Florida for information dissemination and training
	•	•	
PROJECT TIMELINE	Month 1-11	Month 7- 15-23 <u>31</u>	Month 15-17 & 24 <u>36</u>

Table 1- Project Summary (update 3/28/19 & 10/24/19, & 11/30/20), *completion delayed due to COVID-19.

Activities March-September 2018:

- 04/05/2018 - Funding authorization from Division FHWA approved under 2018 STIC Incentive Proposal: STIC-004-00A / FPID 443377-1.
- 05/21/2018 - Procurement completed for Principle Investigator of Phase 1 & 2b: Technology Review, Specifications & Database Development. Research Task Work Order (TWO) issued under FDOT research project **BDV30-986-01**.
- 05/30/2018 - Kickoff meeting held for **BDV30-986-01**.
- 09/11/2018 - **BDV30-986-01**, Task 1 completed and Deliverable 1 (BFRP Technology Review Report) approved.
- 09/14/2018 - Collaboration meeting on design of Full-Scale demonstration of BFRP-RC element for testing and monitoring.

Activities October-May 2019:

- 12/7/2018 - **BDV30-986-01**, Task Work Order Amendment#1 executed for time extension due to manufacturer delays in providing BFRP rebar samples for testing.
- 1/11/2019 - Procurement completed for Principle Investigator of Phase 2a BFRP-FRC Link-Slab Demonstration Project. Research Task Work Order issued under FDOT research project **BDV34-986-02**.

3. 2/6/2019 - **BDV34-986-02**, (BFRP-FRC Link-Slab Demonstration Project) Kickoff Meeting held.
4. 2/4/2019 - **BDV30-986-01**, Draft Deliverable 2 (BFRP Testing Procedure and Results) submitted. Revisions requested by PM.
5. 2/28/2019 - **BDV30-986-01**, Task 2 completed and Deliverable 2 (BFRP Testing Procedure and Results) approved.
6. 2/28/2019 - **BDV30-986-01**, Draft Deliverable 3 (BFRP Material Specification Recommendation Report) submitted. Revisions requested by PM.
7. 3/26/2019 - **BDV30-986-01**, Task 3 completed and Deliverable 3 (BFRP Material Specification Recommendations) approved.
8. 3/4/2019 - **BDV34-986-02**, Draft Deliverable 1 (BFRP-FRC Link-Slab Demonstration Project - Literature Review) submitted. Revisions requested by PM.
9. 3/24/2019 - **BDV34-986-02**, Task 1 completed and Deliverable 1 (BFRP-FRC Link-Slab Literature Review) approved.
10. 5/4/2019 - **BDV30-986-01**, Draft Deliverable 4 (BFRP Design Specification Recommendations) submitted. Revisions requested by PM.
11. 5/13/2019 - **BDV34-986-02**, Draft Deliverable 2 (BFRP-FRC Link-Slab Demonstration Project: Instrumentation and Monitoring Plan) submitted and under review.
12. **BEI-2019** Mini-Symposium/Session organization with Prof. Jimmy Kim (TRB co-sponsored event June 22-25: <http://www.beibridge.org/BEI2019.html>). Three Abstracts accepted.

Activities May-October 2019:

1. 5/24/2019 - **BDV30-986-01**, Revised Deliverable 4 (BFRP Design Specification Recommendations) accepted by PM (see Final Report).
2. 5/31/2019 - **BDV30-986-01**, Deliverable 5 (Draft Final Report) received, then revised and accepted by PM (see Final Report).
3. 5/31/2019 - **BDV30-986-01**, Deliverable 6 (Closeout Video Conference) held.
4. 6/4/2019 – **Technology Transfer 1: FDOT Transportation Symposium FRP-RC Designer Training - Part 1, Part 2, & Part 3.**
5. 6/30/2019 - **BDV30-986-01**, Deliverable 7 (Final Report – “Performance Evaluation, Material and Specification Development for Basalt FRP Reinforcing Bars Embedded in Concrete”) submitted and accepted 7/17/2019.
6. 7/22/2019 – **Technology Transfer 2: HDOT Peer Exchange** BFRP Designer Training - **Part 1, Part 2, Part 3, & Part 4).**
7. 7/24/2019 - **Technology Transfer 3: BEI-2019** FRP Composites II Session -. Three papers presented ([*see Conference Proceedings*](#)):
 - a. *Basalt FRP-RC Standardization for Florida DOT Structures (pp 514-523)*
 - b. *Effect of the Fiber Content on the Tensile Strength Properties of Basalt Fiber Reinforced Polymer Rebars (pp 527-531)*
 - c. *Bond-to-Concrete Characteristic of Basalt Fiber-Reinforced Polymer Rebars for Design Code Implementation (pp 551-562)*
8. 8/23/2019 – Material Specification Section 932-3 updates for BFRP rebar completed Industry Review and submitted as Supplemental Specification to FHWA for approval in 2020 Workbook

9. 8/30/2019 - **BDV34-986-02**, Revised Deliverable 2 (BFRP-FRC Link-Slab Demonstration Project: Instrumentation and Monitoring Plan) re-submitted and under review.
10. 10/11/2019 – Test pile driving began for link-slab demonstration bridge under FPID 435390-1-52-01: US 41 from Midway Blvd to Enterprise project.

Activities Nov-April 2020:

1. 11/20/2019 - Approved **BDV34-986-02** revised Deliverable 2 (BFRP-FRC Link-Slab Demonstration Project: Instrumentation and Monitoring Plan) accepted.
2. 1/17/2020 – Executed Amendment #2 for **BDV34-986-02**, Task 3 for purchase of instrumentation gages and ancillary equipment to be used in monitoring the BFRP bars in the link-slab, based on Deliverable 2 recommendations.
3. 1/21/2020 - Posting of FDOT Specification Section 932-3 approved updates including BFRP reinforcing for July 2020 Workbook.
4. 3/2/2020 – Executed Amendment #3 for **BDV34-986-02**, Task 3 to include time and travel reimbursement for instrumentation installation activities.
5. 3/6-7/2020 - **BDV34-986-02**, Task 3 (BFRP-FRC Link-Slab Demonstration Project: Installation of instrumentation and monitoring.

Activities May-Nov 2020:

1. 8/8/2020 - Demonstration Project #1 construction of UHPC link-slab completed, and transverse cracking in FRP-BFRP link-slab observed (see photos in Appendix A)
2. 9/30/2020 – Executed Amendment #4 for **BDV34-986-02**, to include additional contract time due to COVID-19 travel restrictions.
3. 10/30/2020 - Added Demonstration Project #2 to demonstration BFRP bent bars, specifically as closed stirrups for one quadrant of the seawall-bulkhead on SR30 over St Joe Bay Inlet.
4. 11/14/2020 – Demonstration Project #1 (Morning Star Waterway) Research Team installed some surface mounted crack gages and displacement transducers but was hampered by lack of access for side mounted installations. Data Logger information downloaded and batteries replaced.

Planned Activities for Dec 2020-May 2021

Phase 1:

1. Complete

Phase 2:

2. Continued monitoring of full-scale BFRP-FRC Link-Slab under FPID 435390-1-52-01: US 41 from Midway Blvd to Enterprise project. Perform Load testing if funding comes available.
3. Visual monitoring of BFRP-UHPC link-slab under FPID 435390-1-52-01: US 41 from Midway Blvd to Enterprise project cast in August 2020.

Phase 3:

4. Completed initial proposed T² activities.
5. Additional T² opportunities will be explored with Principal Investigators while STIC project is ongoing. Continued engagement with BFRP rebar manufacturers including: Basanite (FL); MAFIC/Pultrall (NC/ON); NoRust Rebar (FL); BasTech (UK); ASA.TEC (Austria); Nuevokas (MI); SISgroup (VA).

6. Final Report Draft.**Budget**

No invoices were received or paid this cycle. BDV29 986-02 Task 3 was partially completed with installation of some instrumentation and retrieval of strain gage data, but several activities remain outstanding.

Project Line Item	FHWA STIC Contribution	FDOT In-Kind Match (20%)	Total Budget
Phase 1 <i>(100% BDV30 986-01)</i>	\$48,000	\$12,000	\$60,000
Phase 2 <i>(50% BDV30 986-01; 50% BDV34 986-02 & Demonstration Project Monitoring; FPID 435815-1 project addition of ~ 70 BFRP stirrups Demonstration)</i>	\$36,000	\$9,000	\$45,000
Phase 3	\$16,000	\$4,000	\$20,000
Total Project	\$100,000	\$25,000	\$125,000

Table 2- Project Phase Funding Distribution (update 5/21/18, 11/30/2020)

FINANCIAL INFORMATION: Item Segment 443377-1

For details click on highlighted Financial Project or Phase Group; then use your Back button to return to this screen

Phase	Version	Scheduled Start Date	Financial Project	Status	Programmed	Authorized	Committed	Present Day Cost
PE CONSULTANT	AD (ADOPTED)		443377-1-32-01	Open For Charges	\$25,000	\$25,000	\$24,447.00	\$25,000
RESEARCH CONSULTANT	AD (ADOPTED)		443377-1-B2-01	Open For Charges	\$100,000	\$100,000	\$98,646.82	\$100,000
** Grand Total					\$125,000	\$125,000	\$123,093.82	\$125,000

FEDERAL PROJECTS: Item Segment 443377-1

For details click on highlighted Federal Project; then use your Back button to return to this screen

Federal Project	Status	FAC	Description	%	Total Approved
STIC-004-A	ACTIVE, 04/02/2018	Z37E	TECH INNOVAT DEPLOY STIC FAST	100.00	\$100,000
** Grand Total					\$100,000

Phase Group: B , RESEARCH - Managed by, District 50

Phase: B2 , RESEARCH CONSULTANT - AD (ADOPTED)

Financial Project: 443377-1-B2-01 , Open For Charges, 04/02/2018

[Current Year Commitments](#)[Life to Date Commitments](#)[Project Cost Overview](#)

Fund: TSM , TRANSPORT SYSTEMS MANAGEMENT

Program: 00 , REGULAR PROGRAM

FAC: Z37E, TECH INNOVAT DEPLOY STIC FAST

Dstr Area: n/a Bud Dist: 40 , STATE HIGHWAY ENG.

Alloc Type: 1, REGULAR

Category: 088857, MATERIALS AND RESEARCH

Last Activity: 03/12/2020

LTD Authorized: 100,000

LTD Committed: 98,646

Auth Remaining: 1,354

Pending: 0

Pending Remaining: 1,354

Fiscal Year	Programmed	Present Day	Encumbrance	Expenditures	Remaining	Revenue	Retainage	Payables	Future	Status
		Cost	Balance						Encumbrances	
2019	80,447	80,447	.00	80,446.35	1	.00	.00	.00	.00	5 CLOSED
2020	18,200	18,200	17,213.79	986.68	1	.00	.00	.00	.00	4 AUTH
2021	1,353	1,353	.00	.00	1,353	.00	.00	.00	.00	4 AUTH
Fund Totals	100,000	100,000	17,213.79	81,433.03	1,355	.00	.00	.00	.00	
Fin Proj Totals	100,000	100,000	17,213.79	81,433.03	1,355	.00	.00	.00	.00	
Grand Totals	100,000	100,000	17,213.79	81,433.03	1,355	.00	.00	.00	.00	

Project Schedule

Work Phase	Month																																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	22	32	33	34	35	36	37*													
1. Develop Design, Materials and Construction Specifications																																					
2a. Demo #1 : Full-scale slab instrumentation and monitoring																																					
2c. Demo #2: bulkhead cap closed stirrups																																					
2b. BFRP Supplemental bar testing and Database																																					
3. Technology Transfer Workshop and Final Report																																					

Table 3- Project Timeline: Month 1 = April 2018 (updated 10/17/19) * completion delayed due to COVID-19.
[Month 37 = April 2021](#)

Appendices include:

Appendix A - [FPID 435390-1-52-01 & BDV34 986-02 "Construction Progress Photos from August-Nov, 2020"](#) (2 pages)

Appendix B - [FDOT Demonstration Project #2 \(FPID 435815-1, T3632\) "Seawall-bulkhead BFRP closed stirrups proposal"](#) (2 pages)

Appendix A

FPID 435390-1-52-01 & BDV34 986-02 BFRP-RC Construction Progress **Photos from August-Nov, 2020)**

(2 pages)

Morningstar Waterway – BFRP-FRC Link Slab:



Photo 1: Transverse shrinkage crack in link-slab at centerline Bent 2, showing base of parapet at open joint. Observed in August 2020.



Photo 2: Transverse shrinkage crack in link-slab at centerline Bent 2, showing center of link-slab. Observed in August 2020.

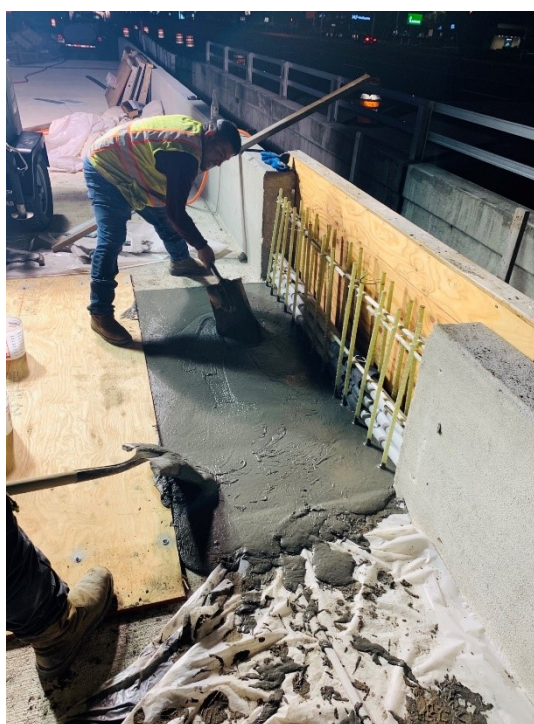


Photo 3: Accessing Data Loggers and attempt to install side mounted displacement transducers.
(November 14, 2020).

Sunset Waterway – B/GFRP-UHPC Link Slab:



(a)



(b)

Photos 3a & 3b: Link-slab casting with UHPC showing 50% replacement of BFRP longitudinal bars (August 8, 2020).

Appendix B

FDOT Demonstration Project 2 (FPID 435815-1, T3632)

Seawall-bulkhead cap BFRP closed stirrups proposal

(2 pages)

Closed Stirrups 5W01 (Revision #2, Contract Plans extract):

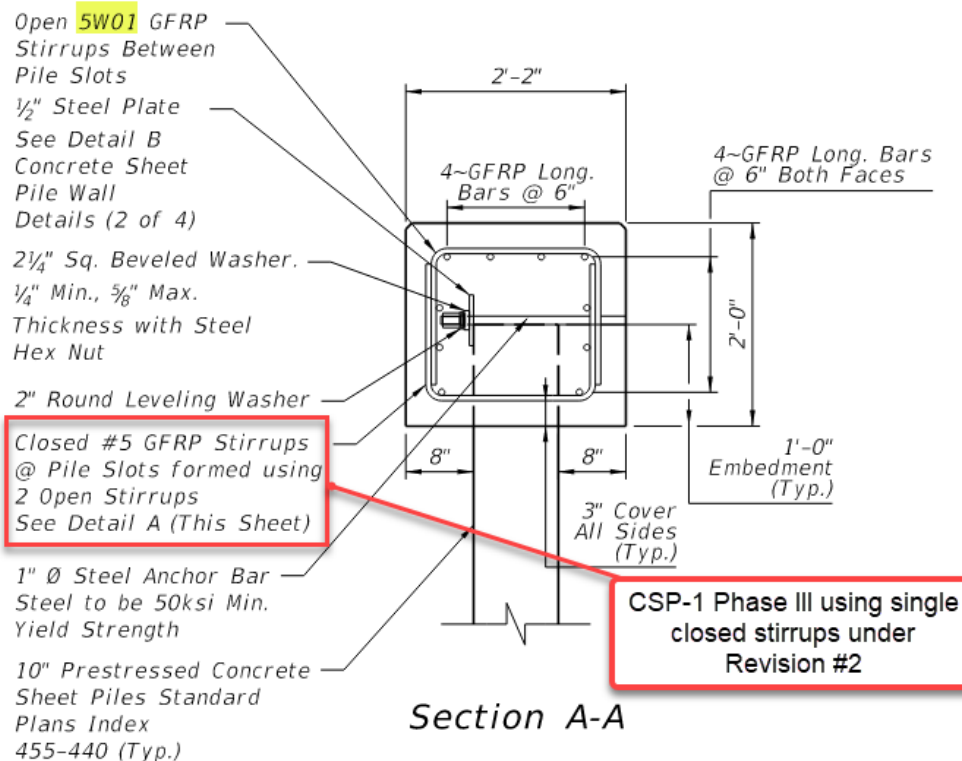
5 **set**

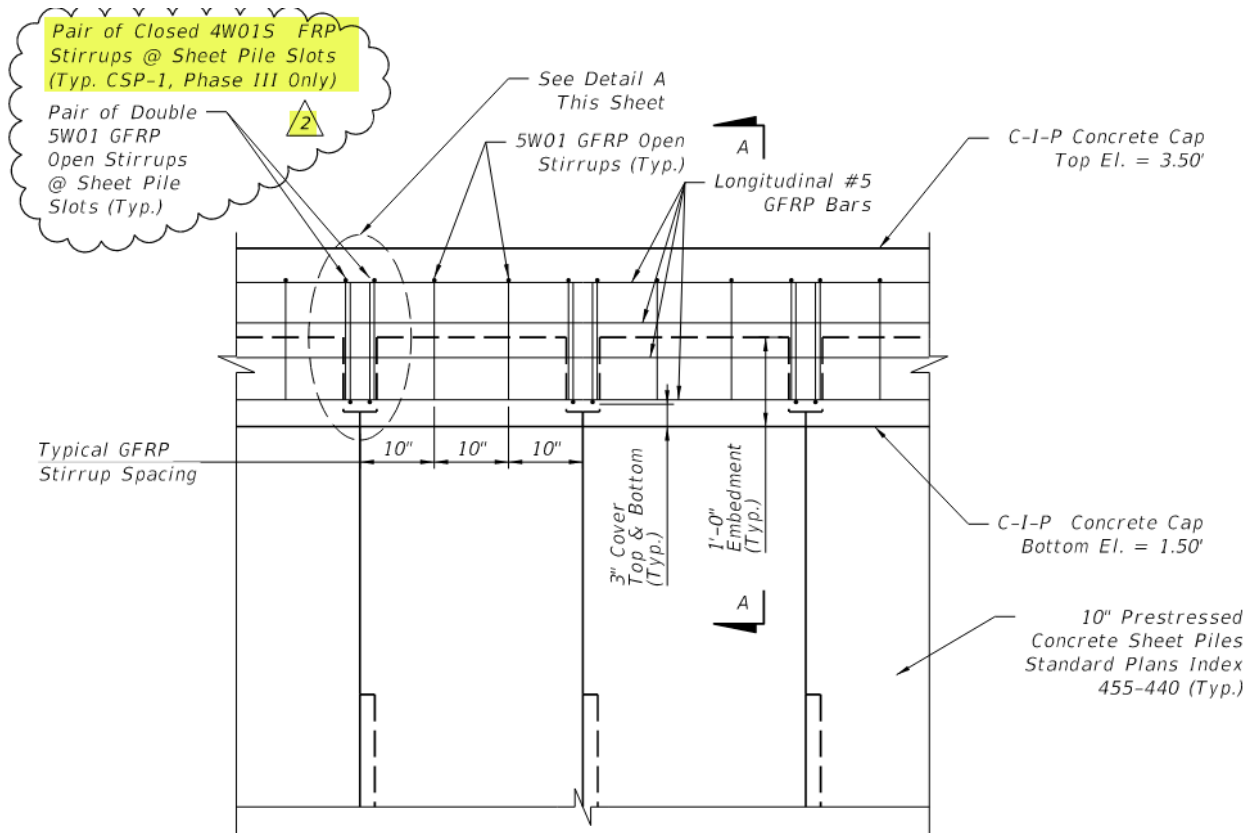
* #5 Thermoset GFRP closed stirrups (Bars 5W01S) are included in the quantity for Pay Item 0415 10 5, Fiber Reinforced Polymer Bar, #5 Bar.

5

LOCATION CSP-2 PHASE III									
5	W01	4- 8	70	11	1- 8	1- 6	1- 6		
5	W05	8- 0	6	12	4- 0	4- 0			
5	W05B	8- 0	6	12	4- 0	4- 0			
5	W09	8- 0	4	13	2- 0	2- 0	2- 0		
5	W09B	6- 0	4	13	2- 0	2- 0	2- 0		
5	LONG	99- 0	10	2	2- 0	93- 0	2- 0		
** 5	W01B	7- 4	72	7	1- 8	1- 8	1- 4	1- 4	1- 4
5- 8		LOCATION CSP-2 ANCHOR PILES PHASE III							

**** #5 Thermoset BFRP closed stirrups (Bars 5W01B are included in quantity for Pay Item 0415 10 5.**





Typical Wall Elevation

