AASHTO GFRP-Reinforced Concrete Design Training Course

GoToWebinar by:
Professor Antonio Nanni


FDOT

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Center for Integration of Composites into Infrastructure

Introducing the Schedule

9:35 am **Introduction & Materials** *(Prof. Antonio Nanni)*

→ Review Questions *(Dr. Francisco De Caso)*

10:30 am **Flexure Response** *(Prof. Antonio Nanni)*

→ Review Questions *(Dr. Francisco De Caso)*

***** Coffee Break *****

→ *Design Example: Flat Slab (Roberto Rodriguez)*

12:00 pm **Shear Response** *(Prof. Antonio Nanni)*

→ Review Questions *(Dr. Francisco De Caso)*

***** Lunch Break (1 hour) *****

1:30 pm → *Design Example: Bent Cap (Nafiseh Kiani)*

2:00 pm **Axial Response** *(Prof. Antonio Nanni)*

→ Review Questions *(Dr. Francisco De Caso)*

→ *Design Example: Soldier Pile (Roberto Rodriguez)*

***** Coffee Break *****

3:00 pm **Case Studies & Field Operations**

(Prof. Nanni & Steve Nolan)

Introducing our Presenters & Support

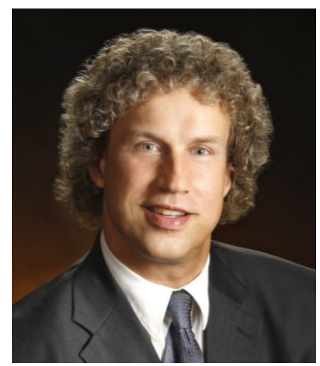
Prof. Antonio Nanni
P.E. PhD.

Roberto Rodriguez,
P.E. (PhD. Candidate)

Dr. Francisco DeCaso
P.E. PhD.

Nafiseh Kiani
(PhD. Candidate)

Alvaro Ruiz,
(PhD. Candidate)



Christian Steputat,
P.E. (PhD. Candidate)

Steve Nolan, P.E.

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COURSE SECTION	TOPIC	TENTATIVE SCHEDULE
1 Nanni	INTRODUCTION TO FRP-RC & MATERIAL PROPERTIES a. Problem Statement b. Where to Use Glass FRP c. FRP Material Properties d. Durability e. Design Guides and Standards f. Concluding Remarks	9:30 am
1.1 De Caso	REVIEW QUESTIONS: Fundamentals Refer to workbook. Opportunity to actively participate, review concepts, and discussion time	
2 Nanni	FLEXURE RESPONSE OF GFRP-RC a. General Considerations b. Bending Moment Capacity c. Serviceability d. Static & Cyclic Fatigue e. Anchorage and Development f. Special Considerations g. Concluding Remarks	10:30 am
2.1 De Caso	REVIEW QUESTIONS: Fundamentals Refer to workbook. Opportunity to actively participate, review concepts, and discussion time	
Short Break		
2.2 2.3 2.4 Rodriguez	DESIGN EXAMPLE: Flat Slab Step-by-step Flexural design of flat slab. Refer to Annex A, Sections A and B Creep rupture under sustained load. Refer to Annex A, Section D Minimum Reinforcement. Refer to Annex A, Section E	
3 Nanni	SHEAR RESPONSE OF GFRP-RC a. General Behavior b. Shear Capacity c. Punching Shear d. Special Considerations e. Concluding Remarks	12:00 am
	Lunch Break	12:30-1:30 (60 min)

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COURSE SECTION	TOPIC	TENTATIVE SCHEDULE
3.1 De Caso	REVIEW QUESTIONS: Fundamentals Refer to workbook. Opportunity to review, take notes and discussion	1:30 pm
3.2 Kiani	DESIGN EXAMPLE: Bent Cap Refer to Annex B Step-by-step design of flexure and shear bent cap using Mathcad worksheet	
4 Nanni	AXIAL RESPONSE OF GFRP-RC a. Strength of GFRP-RC Columns b. Design Considerations c. P-M Diagram Example. Refer to Annex C d. Slenderness Effect e. Concluding Remarks	2:00 pm
4.1 De Caso	REVIEW QUESTIONS: Fundamentals Refer to workbook. Opportunity to review, take notes and discussion	
Short Break		
4.2 Rodriguez	DESIGN EXAMPLE: Solider Pile in Wing Wall Overview of a soldier pile in a wing wall design with GFRP reinforcement.	
5 Nanni & Nolan	CASE STUDIES & FIELD OPERATIONS: a. iDock (Marine Dock) b. NE 23rd Avenue Bridge over Ibis Waterway (FPN 434359-1-52-01) c. Halls River Bridge (FPN 430021-1-52-01) d. SR-A1A Flagler Beach (Segment 3) (FPN 440557-7-52-01) e. FDOT Fast Facts	3:00 pm
	END OF COURSE	4:30 pm

LIST OF COURSE ANNEXES

Annex A (Section 2.2): LFRD Flat Slab Bridge Design Example

Annex B (Section 3.2): Intermediate Bent-Cap Analysis & Design

Annex C (Section 4.0): LRFD Design P-M Diagram of GFRP Reinforced Pile Example

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DESIGN TOOLS FROM FDOT/AASHTO AND EXISTING EXAMPLES

This table provides a list of available tools from FDOT Structures Design (https://www.fdot.gov/structures) located under the 'Structures Manual' section. As a reference, when framing and solving the examples, design is focus on the **resistance side**. Load demand calculation, geotechnical design, etc. are kept to a minimum unless they differ from what traditionally done with steel-RC.

Design Example	Tools from FDOT and other sources		Existing Examples / Description
	Existing	Comments	
1.A. Definition of material properties and design values based on specifications and codes.	• FDOT Structures Manual Volume 4 (Link) • FDOT Materials Manual Section 12 (Link) • FDOT Standard Specifications 932-3 (Link) • FDOT FRP Bar Bending Details (Index D21310) • ASTM D7957/D7957M-17 (Link) • AASHTO LRFD BDGS GFRP-2 (Link)	None	Definition of mechanical properties and factorization per existing standards
1.B. Definition of material properties and design values when a specific manufacturer and product are selected (value engineering).	• FDOT Material Acceptance (Link) • List of certified manufacturers (Link) • List of certified testing labs (Link)	None	Properties as specified by a fictitious manufacturer and factor them as per existing standards
2.A. Flat slab bridge superstructure	• Mathcad Worksheet for flat slab bridges. • LRFD Design Example 2A developed as master's thesis at UM (Internal UM Link)	Most recent version of the Mathcad worksheet used for the 23rd Ave. bridge	• 23rd Ave. Bridge over Ibis Waterway (434359-1-52-01)
3.B. Shallow foundations, pavements, slabs on grade.	• Rectangular Spread Footingv1.1 (Link) (Does not include GFRP) • Approach Slabs – GFRP Reinforced (Flexible Pavement Approach) Index D22900	None	• UM slab on grade for Student Village
3.C. Cantilevered Retaining Wall	• FDOT Retaining Wall v3.3 (Link) (Does not include GFRP) • FDOT Retaining Wall v4.0 (Internal UM Link) (includes GFRP, not publicly available)	None	• UM cantilevered wall for Student Village
3.D Sheet Pile Wall: Cantilevered and tied back	• Precast Concrete CFRP/GFRP Sheet Pile Wall (Index D22440) (Link) • FDOT Retaining Wall v4.0 (Internal UM Link) (includes GFRP, not publicly available, can be adapted to design sheet pile walls)	None	• Anchored and cantilevered sheet pile seawalls for North Miami Beach & other cities/counties

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2.B. Deck (empirical & traditional)	• Refer to Annex A	Most recent version of the Mathcad spreadsheet used for the deck of the Halls River Bridge	• Halls River Bridge (430021-1-52-01) • Toledo Bridge (Ohio) • Calculations for TxDOT index
2.C. Girders	• FDOT Girder v5.3 (Link) (not including FRP) • FDOT Girder v5.4 (not publicly available, modified at UM, includes CFRP-PC) • (can be adapted to design GFRP-RC girders)	Most recent version of the Mathcad spreadsheet developed for FRP-PC girders	*Only GFRP-RC Girders* • Alternative design for the Halls River Bridge (430021-1-52-01) (Rossini et al. 2013)
2.D. Bent Cap	• FDOT Bent Cap v1.0 (Link)	None	• 23rd Street Bridge over Ibis Waterway (434359-1-52-01) • Halls River Bridge (430021-1-52-01)
2.E. Railings	• Design Standards Development Report for 32" F Shape Traffic Railing (GFRP) (Internal UM Link) • Mathcad Worksheets developed for verifying design of concrete barriers with GFRP as master's thesis at UM. (Link) – Official FDOT in development • FDOT GFRP Railing Index D22420 • ODOT Railing Index BR-1-13	Most recent version of the Mathcad spreadsheet used for traffic railings	FDOT developmental standard available
3.A. Precast Pile	• Design standards exist for CFRP with GFRP stirrups piles (Index Series 22600) • Developmental standard for square CFRP Prestressed Concrete Pile Splices (Link)	None	• iDock

USEFUL RESOURCES FROM DOTs

Software:
https://www.fdot.gov/structures/ProgLib.shtm

FDOT Index:
https://www.fdot.gov/roadway/DS/18/STDs.shtm

TxDOT Index:
http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/bridge-e.htm

ODOT Index:
http://www.dot.state.oh.us/Divisions/Engineering/Structures/standard/Bridges/Standard%20Drawings/Forms/AllItems.aspx

Developmental Index:
https://www.fdot.gov/roadway/DS/Dev.shtm#30000

Structures manual:
https://www.fdot.gov/structures/StructuresManual/CurrentRelease/StructuresManual.shtm

Construction and material specs:
https://www.fdot.gov/programmanagement/Implemented/SpecBooks/

FRP Projects in Florida:
http://www.arcgis.com/apps/webappviewer/index.html?id=7800e1da894e433ba81ffac6962349f6

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GENERAL REFERENCES

FDOT Specifications

- FDOT Structures Manual, Volume 4. Fiber Reinforced Polymer Guidelines (FRPG)
- FDOT Materials Manual, Section 12.1, Volume II. Fiber Reinforced Polymer Composites
- FDOT Standard Specifications for Road and Bridge Construction, Section 932. Nonmetallic Accessory Materials for Concrete Pavement and Concrete Structures
- FRP Bar Bending Detail, D21310

Railings

- Design Standard Development Report for 32" F Shape Traffic Railing (GFRP Reinforced) (Developmental Index D22420)
- Rocchetti, Paolo, "RC Traffic Barrier with GFRP Reinforcement" (2017). *Open Access Theses*. 685. https://scholarlyrepository.miami.edu/oa_theses/685

Flat Slab

- Approach Slab – GFRP Reinforced (Flexible Pavement Approach) (Developmental Standard D22900)

FDOT Software

- FDOT Structure Design Office – Programs Library, "Bent Cap v1.0", https://www.fdot.gov/structures/proglib.shtm
- FDOT Structure Design Office – Programs Library, "Retaining Wall v4.0 Beta" https://www.fdot.gov/structures/proglib.shtm. Available upon personal request.

Specifications & Design Guides (GFRP)

- ASTM D7957/D7957M-17. Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement.
- AASHTO LRFD Bridge Design Guide Specifications for GFRP- Reinforced Concrete 2nd Edition.
- ACI Committee 440.1R-15. Guide for the Design and Construction of Structural Concrete Reinforced with Fiber Reinforced Polymer Bars.

Books and Papers

- Rossini, M., Matta, F., Nolan, S., Potter, W., & Nanni, A. (2019). AASHTO Design Specifications for GFRP-RC Bridges: 2nd Edition. In M. Di Prisco & M. Menegotto (Eds.), Proceedings of Italian Concrete Days 2018. Lecco, IT: Springer International Publishing. https://doi.org/10.1007/978-3-030-23748-6

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COURSE CONTENT REFERENCES

Afifi, M., Z., Mohamed, H. M., & Benmokrane, B. (2014). Strength and Axial Behavior of Circular Concrete Columns Reinforced with CFRP Bars and Spirals. *Journal of Composites for Construction*, 18(2).

Bischoff, P. H. "Member Stiffness for Frame Analysis of GFRP Reinforced Concrete Structures". *39th IABSE Symposium – Engineering the Future, Vancouver, Canada, Sept. 21 – 23, 2017*, pp. 1847-1854.

Bresler, B. (1960) Design criteria for reinforced concrete columns under axial load and biaxial bending. *ACI Journal* 57(5) 481-490.

Cadenazzi, T., Dotelli, G., Rossini, M., Nolan, S., & Nanni, A. (2019). Life-cycle cost and life-cycle assessment analysis at the design stage of a fiber-reinforced polymer-reinforced concrete bridge in Florida. Advances in Civil Engineering Materials, 8(2), 128–151.

De Luca, A. Matta, F., and Nanni, A. (2010). Behavior of Full-Scale Glass Fiber-Reinforced Polymer Reinforced Concrete Columns under Axial Load. *ACI Structural Journal*, 107(5): 589-596

De Luca, A. Matta, Nanni, A. (2009). Behavior of Full-Scale Concrete Columns Internally Reinforced with Glass FRP Bars under Pure Axial Load. *Composites & Polygon.* Tampa: American Composites Manufacturers Association.

De Luca, A., Nardone, F., Matta, F., Nanni, A., Lignola, G. P., and Prota, A. (2011). Structural Evaluation of Full-Scale FRP-Confined Reinforced Concrete Columns. Journal of Composites for Construction, ASCE, 7(1): 112-123

Dietz, D., H., Harik, I. E., and Gesund, H. (2003). Physical properties of glass fiber reinforced polymer rebars in compression. *Journal of Composites for Construction*. Vol 7. No. 4. pp. 363-366.

Guérin, M., Mohamed, H. M., Benmokrane, B., Nanni, A, Shield, C. K. (2018) Eccentric Beh… Poly…

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Mirmiran, … Inter… 98, I…

Mohamed … Colu… Spir…

Rossini, M… GFF… https…

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Ruiz Emparanza, A., De Caso y Basalo, F., Kampmann, R., Rodrigues de Castro Jalles, P., & Nanni, A. (2019). Durability of Mechanical Properties of GFRP Rebars Exposed to Seawater. 5th International Conference on Sustainable Construction Materials and Technologies (SCMT5). London.

Ruiz Emparanza, A., Kampmann, R., & De Caso y Basalo, F. (2017). State-of-the-Practice of Global Manufacturing of FRP Rebar and Specifications. ACI Fall Convention. Anaheim, CA.

Support Material - Handouts

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Guérin, M., Mohamed, H. M., Benmokrane, B., Nanni, A, Shield, C. K. (2018) Eccentric Behavior of Full-Scale Reinforced Concrete Columns with Glass Fiber-Reinforced Polymer Bars and Ties. *ACI Journal*, 115(2), pp. 489-499

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MacGregor, J. G. (1993). "Design of Slender Concrete Columns – Revisited." *ACI Structural Journal*, 90(S32).

MacGregor, J. G., Breen, J. E., and Pfrang, E. O. (1970). "Design of Slender Concrete Columns." *ACI Journal*.

Mirmiran, A.; Yuan, W.; and Chen, X., 2001, "Design for Slenderness in Concrete Columns Internally Reinforced with Fiber-Reinforced Polymer Bars," *ACI Structural Journal*, V. 98, No. 1, Jan.-Feb., pp. 116-125.

Mohamed, H., Afini, M., Benmokrane, B. (2014) Performance Evaluation of Concrete Columns Reinforced Longitudinally with FRP Bars and Confined with FRP Hoops and Spirals under Axial Load. *Journal of Bridge Engineering*, 19(7).

Rossini, M., Saqan, E., & Nanni, A. (2019). Prediction of the Creep Rupture Strength of GFRP Bars. Construction and Building Materials, 227, 116620(1-11). Retrieved from https://doi.org/10.1016/j.conbuildmat.2019.08.001

Support Material - Workbook

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AASHTO GFRP - REINFORCED CONCRETE DESIGN

TRAINING COURSE
COMPANION WORKBOOK

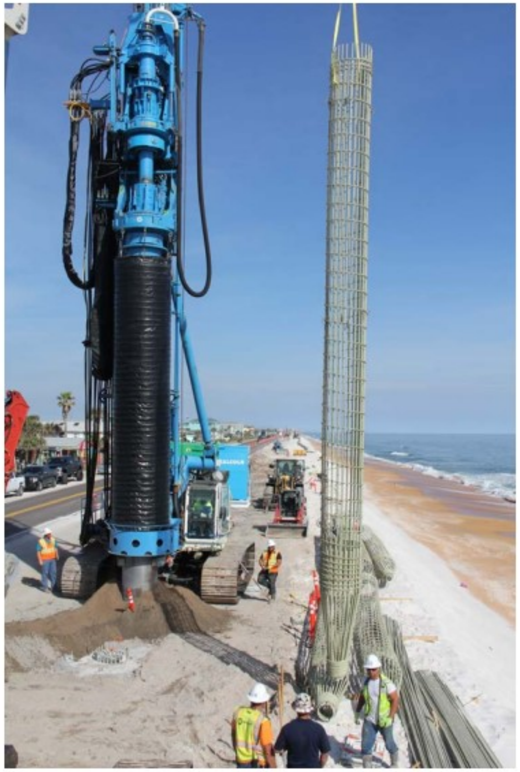

PHOTO: Installation of first GFRP pile cage on A1A Flagger beach project, April 2019.

This document has been developed by the University of Miami, College of Engineering Dept. of Civil, Architectural and Environmental Engineering. Contents offered in this document are based on current and available information at the time of its issue and may be subject to revision as additional information becomes available.
This companion workbook is for the purposes of demonstration only.

Support Material - Workbook

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PHOTO: GFRP cage assembly for the Halls River Bridge Project, April 2017.

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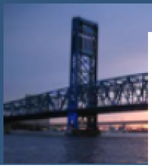
Other Support Material - FDOT

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

Structures Design

Structures Design / Design Innovation

Fiber Reinforced Polymer Reinforcing



Structures Design - Transportation Innovation

Fiber Reinforced Polymer (FRP)
Reinforcing Bars and Strands

Overview
Usage Restrictions / Parameters
Design Criteria
Specifications
Standards
Producer Quality Control Program
Projects
Technology Transfer (T^2)
FDOT Research
Contact

2020

- TRB 2020 Workshop 1063 (Jan 12, 2020):
  - **Externally Bonded Wraps**
  - **FRP Design Tools, CBB Implementation & Pedestrian Bridges**
- **FDOT Executive Workshop** (January 15, 2020)
- FTS2020 **"FRP Reinforced and Prestressed Concrete Designer Training Introduction"** (June 30, 2020)
- **FDOT/FRP Industry 4th RC/PC Workshop** (August 4, 2020)
- FDOT GFRP-RC Designer Training for Bridges & Structures (August 10, 2020) - **Webinar Registration Link**
- FDOT GFRP-RC Designer Training for Bridges & Structures (September 9, 2020) - **Webinar Registration Link**

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Another Training Opportunity

CFRP-Prestressed Concrete Designer Training for Bridges & Structures
– Professor Abdeldjelil "DJ" Belarbi, on September 9th, 2020

This 6-hour online training is focused on providing practical designer guidance to FDOT engineers and consultants for structures utilizing Carbon Fiber-Reinforced Polymer (CFRP) Strands for pretensioned bridge beams, bearing piles, and sheet piles. Basic design principles and design examples will be presented for typical FDOT bridge precast elements.

Register Now at:
https://attendee.gotowebinar.com/register/5898046861643311883

There is no cost to attend this webinar training.

A short preview of this training was provided at the June 30th **FDOT Transportation Symposium Webinar Series** presentation:
FRP Reinforced and Prestressed Concrete Designer Training Introduction

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Let Us Begin !!

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