New Standards for Corrosion-Resistant Prestressed Piling & Precast Bent Cap

Steve Nolan, P.E.
State Structures Design Office
Design Technology Unit – Structures Standards Group

CRPP & PIBC: Outline

Part 1

Corrosion-Resistant Prestressed Piling (Index 22600 series)

- Research
- Demonstration Project
- Standardization
- FDOT Specs
- What's Next

Part 2

Precast Intermediate Bent Cap Standard (Index 20700 series) – *(pending)*

- Research
- Development
- Example Project
- Implementation & Training
- Resources

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Part 1:

Corrosion-Resistant Prestressed Piling Standards

(Index 22600 series)

Overview

Invitation to Innovation

- New technology implementation

Research

- FSU, USF & Georgia Tech.

Standardization

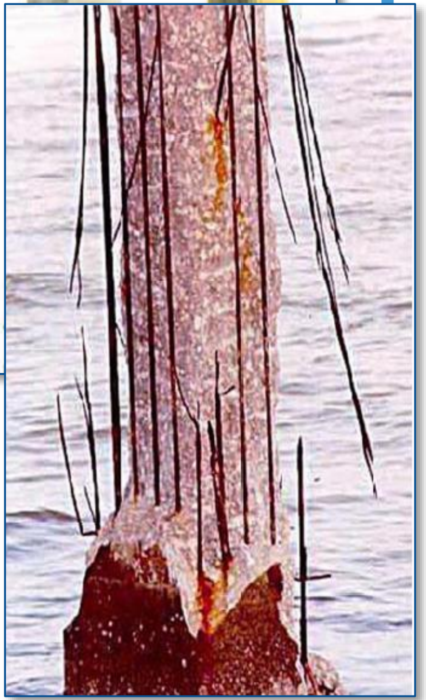
- *Developmental* D20600 series (CFRP prestressed only) – Halls River Bridge Replacement
- *Design Standard* Index 20600 series (SS or CFRP strand)

FDOT Specifications:

- *Developmental Specifications*
- Standard Specifications

What's Next:

- Other Standards
- Questions



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FDOT's Invitation to Innovation

Office of Design / Invitation to Innovation

Invitation to Innovation

INVITATION TO INNOVATION

Recently, the Department embarked into a new bold era for innovative ideas, Success in this new era depends on the ability to innovate the products and provides its users. The Florida Department of Transportation's desire for innovat or employ "outside the box" thinking to generate new and better value for every t

After researching and evaluating many innovative ideas, the Central Office has services that may be the best solution to the project's needs or design challeng developed, and only need tailoring to your project. We encourage you to prop project specific solutions with confidence of approval by the Districts. Other ite coordination with and approval by the District's Design Office. Many of th implemented in other states and countries. Not all projects benefit from thes advocating the general use of new products or designs where an economical w appropriate solution for the situation.

Please consider these innovations as possible solutions to your project-specific listed in the links below. Additional innovations will be added as they are questions, details and contact information are included within the information fo

Structures Design Office

- **Prefabricated Bridge Elements and Systems**
- **Curved Precast Spliced U-Girder Bridges**
- **Geosynthetic Reinforced Soil Integrated Bridge System**
- **Geosynthetic Reinforced Soil Wall**
- **Segmental Block Walls**
- **Fiber Reinforced Polymer Reinforcing**

http://www.dot.state.fl.us/structures/innovation/FRP.shtm

Structures Design

Structures Design / Transportation 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
- Technology Transfer (T[2])
- Contact

Photo Slideshow

FRP bars in a bridge
Photo courtesy of Hughe

Play

Overview

The deterioration of reinforcing and prestressing steel within concrete is one of the prime causes of failure of concrete structures. In addition to being exposed to weather, concrete transportation structures in Florida are also commonly located in aggressive environments such as marine locations and inland water crossings where the water is acidic. Cracks in concrete create paths for the agents of the aggressive environments to reach the reinforcing and/or prestressing steel and begin the corrosive oxidation process. An innovative approach to combat this major issue is to replace traditional steel bar and strand reinforcement with Fiber Reinforced Polymer (FRP) reinforcing bars and strands. FRP reinforcing bars and strands are made from filaments or fibers held in a polymeric resin matrix binder. FRP reinforcing can be made from various types of fibers such as glass (GFRP) or carbon (CFRP). A surface treatment is typically provided that facilitates a bond between the reinforcing

INVITATION TO INNOVATION

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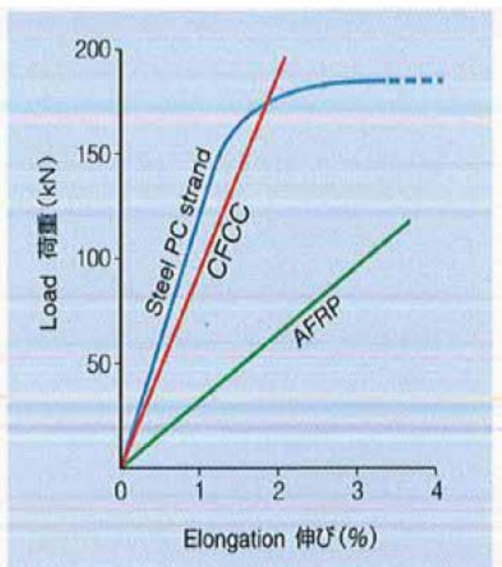
Research

CFRP Prestressed Pile Research:

- Roddenberry M, Mtenga P, Joshi K, (2014). “Investigation of Carbon Fiber Composite Cables (CFCC) in Prestressed Concrete Piles”, FAMU-FSU College of Engineering, for FDOT Project BDK83-977-17, April 2014.
  - http://www.dot.state.fl.us/structures/structuresresearchcenter/Final%20Reports/2014/FDOT-BDK83-977-17-rpt.pdf



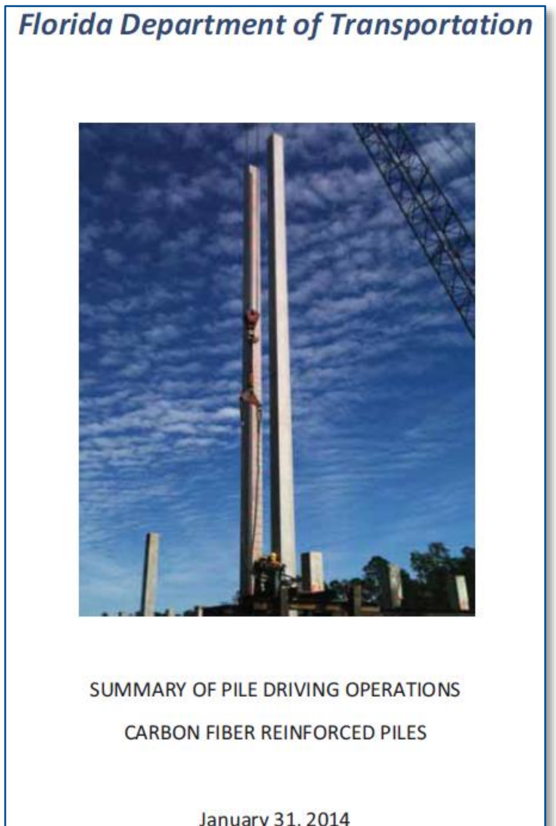
Load and elongation diagram (Source: Tokyo Rope)

Figure 5.4: EDC installation

Research

CFRP Prestressed Pile Research:

- Roddenberry M, Mtenga P, Joshi K, (2014). "Investigation of Carbon Fiber Composite Cables (CFCC) in Prestressed Concrete Piles", FAMU-FSU College of Engineering, for FDOT Project BDK83-977-17, April 2014.



Florida Department of Transportation

SUMMARY OF PILE DRIVING OPERATIONS

CARBON FIBER REINFORCED PILES

January 31, 2014

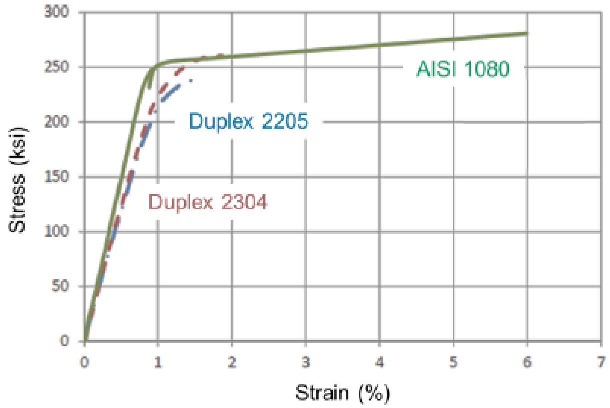
Figure 12 – Diesel Covered Pile with Spalled Sections

Research

Stainless Steel Prestressed Pile Research:

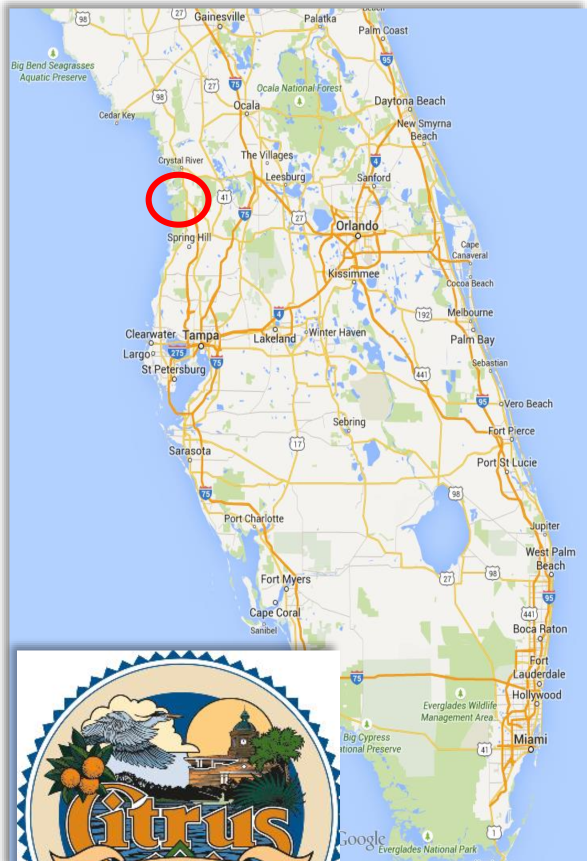
- Paul A, Kahn L.F, Kurtis K.E, (2015).”*Corrosion-Free Precast Prestressed Concrete Piles Made with Stainless Steel Reinforcement: Construction Test and Evaluation*”, Report No. FHWA-GA-15-1134, Georgia Institute of Technology, for Georgia Department of Transportation, March 2015.
  - http://g92018.eos-intl.net/eLibSQL14_G92018_Documents/11-34.pdf
- Mullins G, Sen R, (2014). “*Design and Construction of Precast Piles with Stainless Reinforcing Steel*”, Report No. BDK-84-977-07, University of South Florida, for Florida DOT, February 2014.
  - http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_STR/FDOT-BDK84-977-07-rpt.pdf

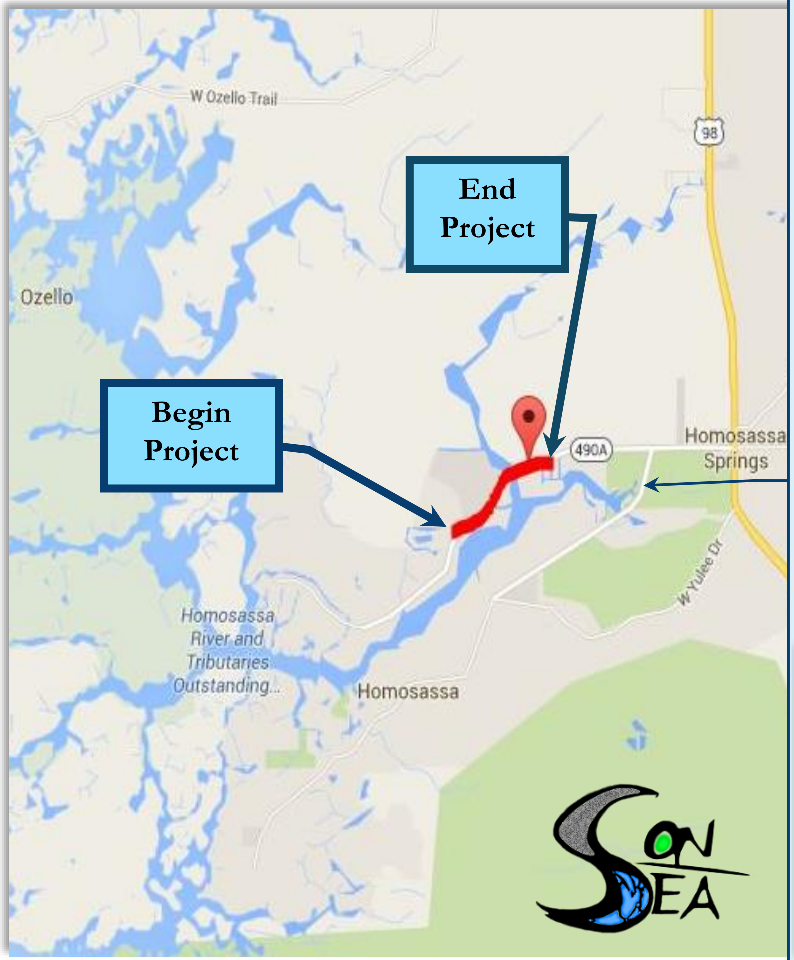
Figure 5.4 Driving of pile HSSS #2



FDOT FRP Demonstration Project

HALLS RIVER BRIDGE REPLACEMENT





Ellie Schiller Homosassa Springs Wildlife State Park

Wild Manatees reside in the park year round.

Lu the hippo, honorary citizen of Florida since 1991.

Vintage Postcard: "T.V.'s Gentle Ben makes his home at the Ivan Tors Animal Actors Training Academy here, and is on hand to greet visitors when not on filming location." *Homosassa Springs.*

Contract Letting: 15th June, 2015

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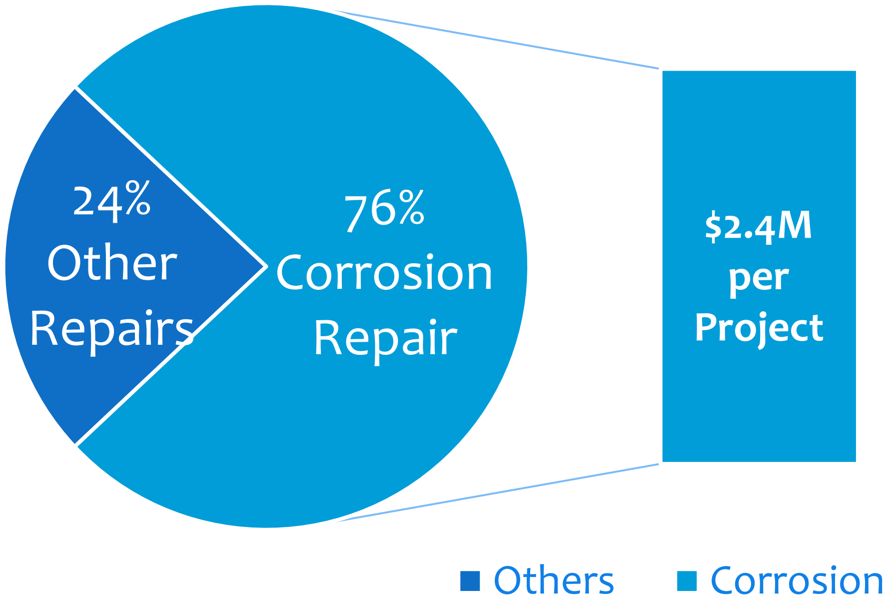
FDOT FRP Demonstration Project

CORROSION COSTS

- District 7 (FY 02/03 to Present)

54 Total Bridge Projects

- 20 Steel
- 34 Concrete



Source: FDOT D7 District Structures Maintenance Office (DSMO) & T.Y. Lin

FDOT FRP Demonstration Project

CORROSION COSTS

- Prevention Methods:
  - ✓ Adequate Cover
  - ✓ Concrete Quality
  - Alternative Reinforcements
  - ✓ Corrosion Inhibiting Admixtures
  - Corrosion Protection of Bridge members
    - New Construction
    - ✓ Existing Bridge
      - Pile Jacket
      - FRP Wrap
      - Cathodic Protection

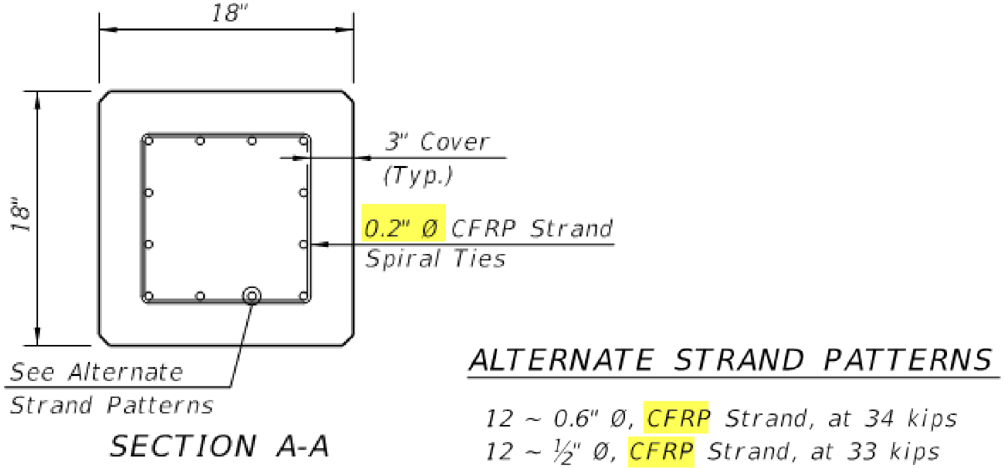
Halls River Bridge

- Glass Fiber Reinforced Polymer (GFRP)
- Carbon Fiber Reinforced Polymer (CFRP)

- Hybrid Composite Beam (HCB)

Standardization –
Developmental Design Standards
- Prestressed Concrete Piles (with CFRP only)

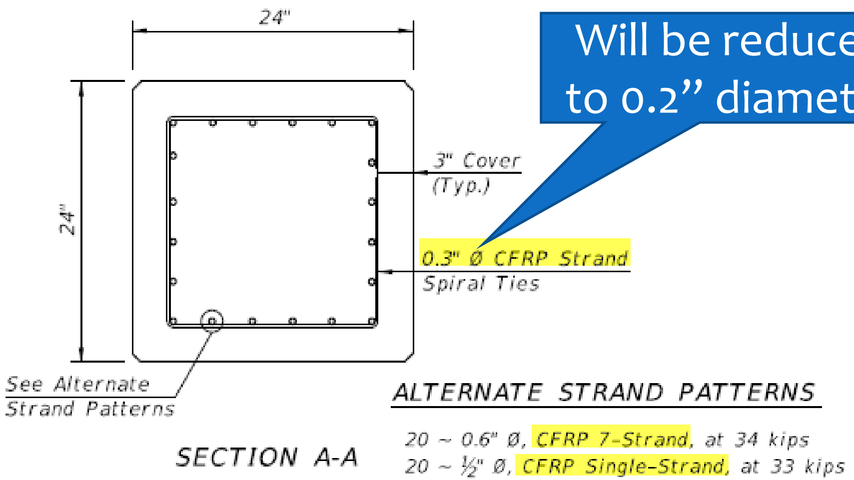
- ***Indexes D22600, D20601, D22614, 22618 & 22624***
  - New corrosion resistant piling for intermediate bridge pile bents in Extremely Aggressive Environments (splash zone);
  - Used for Halls River Demonstration Project.

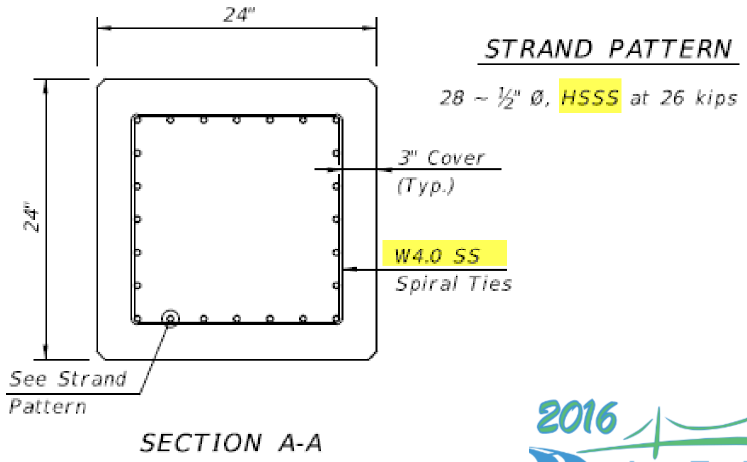


Standardization – ***Design Standards***

- Prestressed Concrete Piles (with CFRP or SS)

- ***Indexes* 22600, 20601, 22612, 22614, 22618, 22624, & 20630**
  - New corrosion resistant piling for intermediate bridge pile bents in Extremely Aggressive Environments (marine)
    - *see **Structures Design Bulletin 15-10** for more information and*
    - *SDG Table 3.5.1-1 for application.*
  - Carbon FRP strands (single or 7-strand) & spiral reinforcing or Stainless Steel strand (7-wire) and spiral reinforcing *(at contractor's/producer's option)*

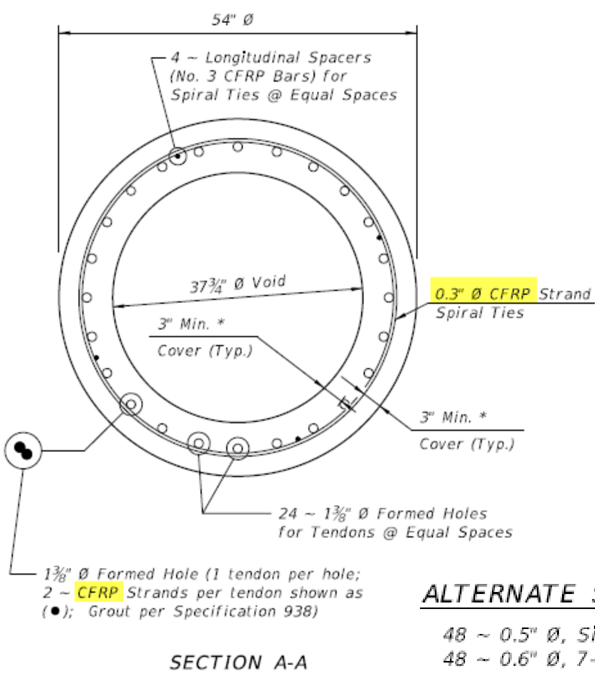




Standardization – ***Design Standards***

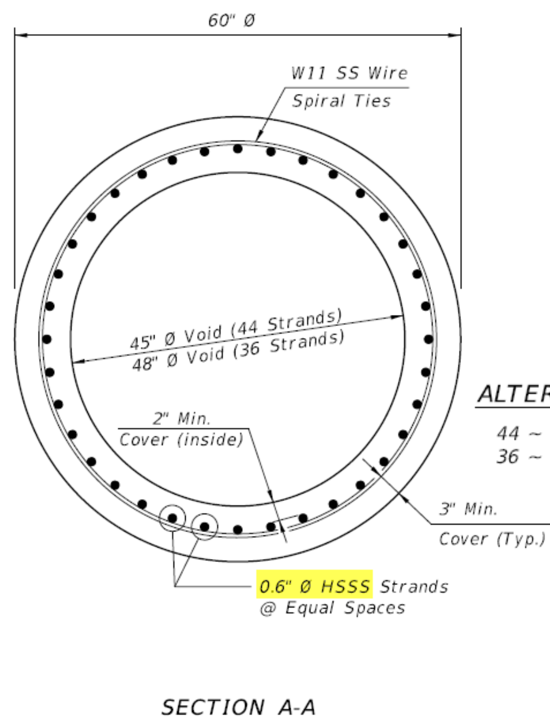
- Prestressed Concrete Cylinder Piles (with CFRP or SS)

- ***Indexes* 22654, & 20660**
  - Carbon FRP strands (single or 7-strand) & spiral reinforcing <u>or</u> Stainless Steel strand (7-wire) and spiral reinforcing *(at contractor's/producer's option)*



ALTERNATE STRAND PATTERNS

48 ~ 0.5" Ø, Single-Strand, at 28 kips
48 ~ 0.6" Ø, 7-Strand, at 29 kips



ALTERNATE STRAND PATTERNS

44 ~ 0.6" Ø, HSSS Strand, at 36 kips
36 ~ 0.6" Ø, HSSS Strand, at 36 kips

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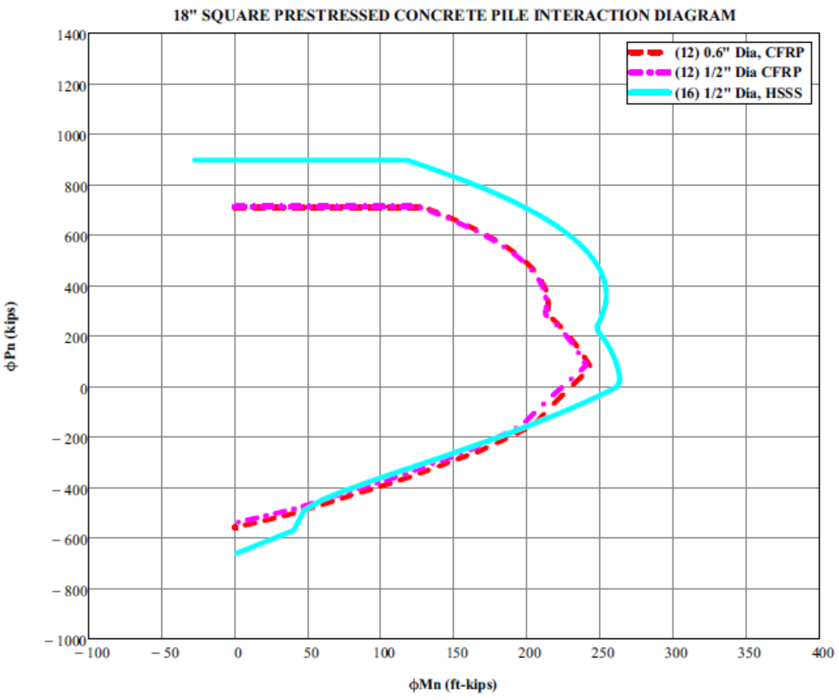
Standardization – ***Design Standards***

- Prestressed Concrete Piles (with CFRP or SS)

- ***Instructions – IDS-22600, 22654, & 20660***
  - Slight differences in Strength Limit States due to reduced resistance factors for CFRP prestressing. Refer to the ***Design Aid*** M-N Charts



Standardization – *Design Standards*

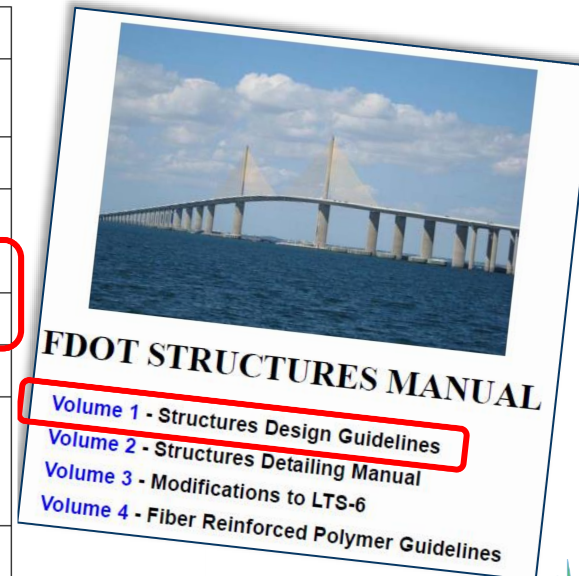
- Prestressed Concrete Piles (with CFRP or SS)

- ***SDG Table 3.5.1-1***
  - Piles in the “splash zone” (= Intermediate Pile Bents in marine environments), preferred use of Carbon FRP strands & spiral reinforcing or Stainless Steel strand and spiral reinforcing.

Table 3.5.1-1 Concrete Pile Size and Material Requirements

Pile Location			Minimum Square Pile Size (inches)		Minimum Cylinder Pile Diameter (inches)	Material Properties for All Pile Sizes[1]		
			Vehicular Bridges	Pedestrian Bridges & Fishing Piers		Strand Type	Spiral Type	Reinforcing Bar Type
Pile Bents	On land or in water in environments that are Extremely Aggressive due to chlorides	Widenings	24[2]	18	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
		New bridges and fishing piers[3]	24	18	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
			18	14	54	CFRP, Spec 933	CFRP, Spec 932	GFRP or CFRP, Spec 932
						Stainless steel, Spec 933	Stainless steel, Spec 931	Stainless steel, Spec 931
	On land or in water in all other environments		18	14	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
Footings	In water (waterline or mudline) in environments that are Extremely Aggressive due to chlorides		24[2]	18	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
	On land or in water (waterline or mudline) in all other environments		18	14	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931

[3] The use of FRP or stainless steel strand and reinforcing is preferred for use in splash zones.



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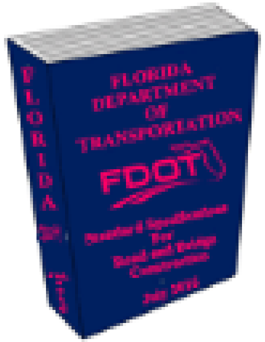
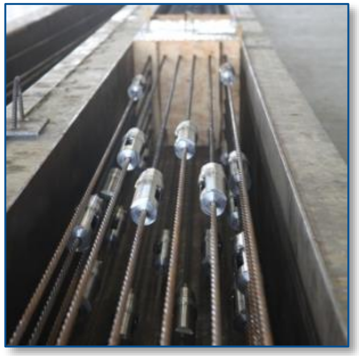
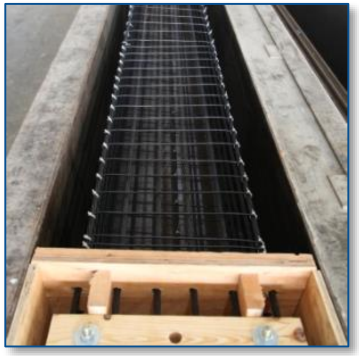
FDOT Specifications



a) Standard Specifications (effective July 2016):
- Implemented previous ***Developmental Specifications*** for FRP materials;
- Added Stainless Steel Bar, Wire & Strand;
- ***931*** Metal Accessory Materials for Concrete Pavement and Concrete;



b) Previous Developmental Specifications:
- ***Dev400FRP*** Concrete Structures – Fiber Reinforced Polymer Reinforcing;
- ***Dev410FRP*** Precast Concrete Box Culvert;
- ***Dev415FRP*** Reinforcing for Concrete;
- ***Dev450FRP*** Precast Prestressed Concrete Construction – Fiber Reinforced Polymer (FRP);
- ***Dev932FRP*** Nonmetallic Accessory Materials for Concrete Pavement and Concrete Structures;
- ***Dev933FRP*** Prestressing Strand;



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FDOT Specifications

Standard Specifications (effective July 2016):

- ***931*** Metal Accessory Materials for Concrete Pavement and Concrete

931-1.2.2 Stainless Steel Wire Reinforcement: Plain and deformed stainless steel wire reinforcement shall meet the requirements of ASTM A276, UNS S30400.

- ***933*** *Prestressing Strand and Bar*

933-1 Strands for Prestressing.

933-1.1 Carbon Steel Strands for Prestressing: The steel strands for prestressing concrete members shall be Grade 270, low-relaxation seven wire strand and shall conform to the requirements of ASTM A416.

933-1.2 Stainless Steel Strands for Prestressing: The stainless steel strands for prestressing concrete members shall be a high strength stainless steel (HSSS) conforming to the chemical requirements of ASTM A276 , UNS S31803 or S32205 (Type 2205) and the mechanical and dimensional requirements of ASTM A416, except the minimum ultimate tensile strength shall be 240 ksi.

933-1.3 Carbon Fiber Reinforced Polymer (CFRP) Strands for Prestressing: CFRP strand shall meet the requirements of ACI 440.4, following the test methods from ACI 440.3. The CFRP strand shall meet the additional requirements of this Section following the sampling frequency and number of specimens required by ACI 440.6.

What's Next ?

- CFRP/GFRP Prestressed Concrete Sheet Piles (Index D22440 → Index 22440 ***FY2017-18***);

- New Hybrid - GFRP Reinf./Steel Prestressed Concrete Sheet Piles (Index D22440);

- Pile Bent Caps (with FRP reinforcing) – Halls Bridge Demonstration project:

  Index D20700 series – Precast Intermediate Bent Cap GFRP Option in Mathcad Design Program

What's Next – Closer Look…

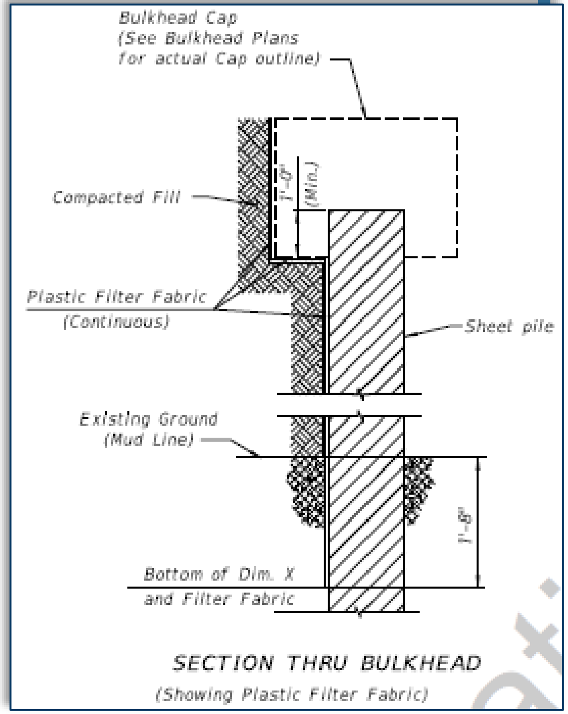
Cantilever Concrete Sheet Pile Walls (with CFRP/GFRP)

A. **Components**
   i. CFRP/GFRP Prestressed Concrete Sheet Piles (Index D22440)
   ii. GFRP-RC Bulkhead Cap (SM-Vol 4…)

B. **Structural System**
   i. Cantilevered
   ii. Anchored/Tied-Back Wall

C. **Other FDOT projects**
   i. Cedar Key SR 24 over Channel 5 bulkhead cap rehab
   ii. Sunshine Skyway South Rest Area seawall rehab

D. **Challenges**
   i. No AASHTO design specs;
   ii. ACI 440.4R strand jacking forces limits are too conservative;
   iii. FDOT concrete tensile stress limits not optimized for FRP reinforced systems.



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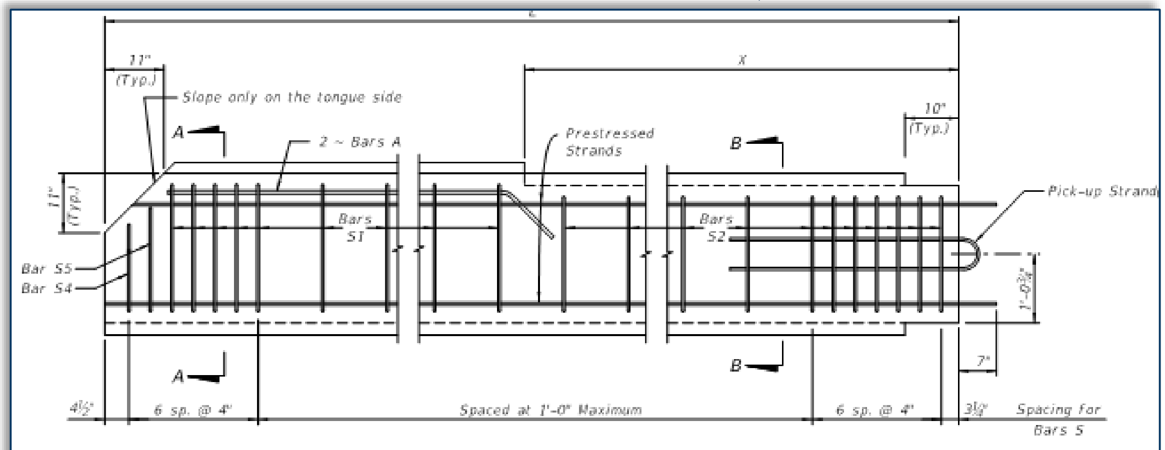
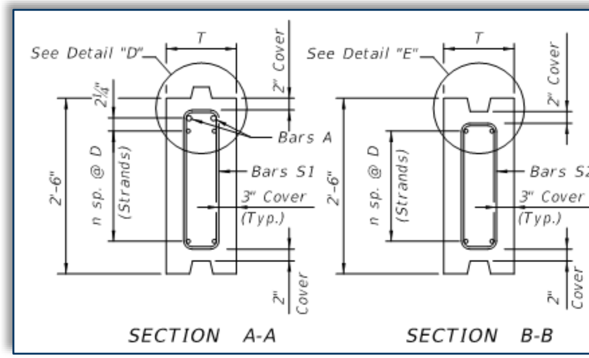
What's Next – Closer Look…

Cantilever Concrete Sheet Pile Walls (with CFRP/GFRP)

Developmental Index D22440: (used for Halls River Demonstration Project with reduced number of strands)



TYPICAL PILE



Wall Thickness	CFRP STRAND DIA. (in.)	MAXIMUM L **	n	D (in.)	TOTAL # OF STRANDS	SECTION MODULUS (in.^{3})	* STRESS (psi)
T=10 in.	0.49 (12.5mm)	26'-0"	4	4	10	500	730
	0.5 (12.7mm)	27'-0"	3	5¼ (2)	8	500	830
	0.6 (15.2mm)	27'-0"	3	5¼ (2)	8	500	840
T=12 in.	0.49 (12.5mm)	31'-0"	5	3¼ (1)	12	720	730
	0.5 (12.7mm)	31'-0"	3	5¼ (2)	8	720	700
	0.6 (15.2mm)	31'-0"	3	5¼ (2)	8	720	710

* Unit Prestress after losses.
** Based on lifting using single point pick-up.

Alternate symmetrical strand patterns:
(1) 4 sp. @ 2" & 1 sp. @ 8"
(2) 2 sp. @ 4" & 1 sp. @ 8"

Part 1 - Questions?

Contact Information:

Steven Nolan

State Structures Design Office

Design Technology –
Structures Standards Group

Steven.Nolan@dot.state.fl.us

Ph. 850-414-4272

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Part 2:

Precast Intermediate Bent Cap Standard

(Index 20700 series)

Overview

Introduction:

- Past FDOT Projects & 1996 FDOT Precast Substructure Study
- Other States (Iowa DOT, WSDOT, SCDOT & TxDOT)
- FHWA's ***Every Day Counts*** Initiative
- FDOT's ***Invitation to Innovation*** – EDC-PBES

Research

- NCHRP Report 681
- SHRP2 Project R04-RR1

Example FDOT Project

- US 90 Demonstration project (IBRD) – Overview, Specification Modifications & Lessons Learned

Development:

- FDOT ***Developmental Design Standard*** – Index D20700
- Aesthetic Levels and Configurations
- Mathcad Design Program

Implementation:

- Schedule & Training
- Information References & Questions

Past Florida Precast Bent Cap Projects
(1990 - 2004)

Example Projects:

- US 41 (Business) Edison Bridge (1993);
- I-295 Southbound Buckman Bridge (1997);
- Reedy Creek WDW (1997 -*Privately Funded*);
- SR 300 St George Island Bridge (2004).

Photo: Berger/ABAM Engineers Inc.

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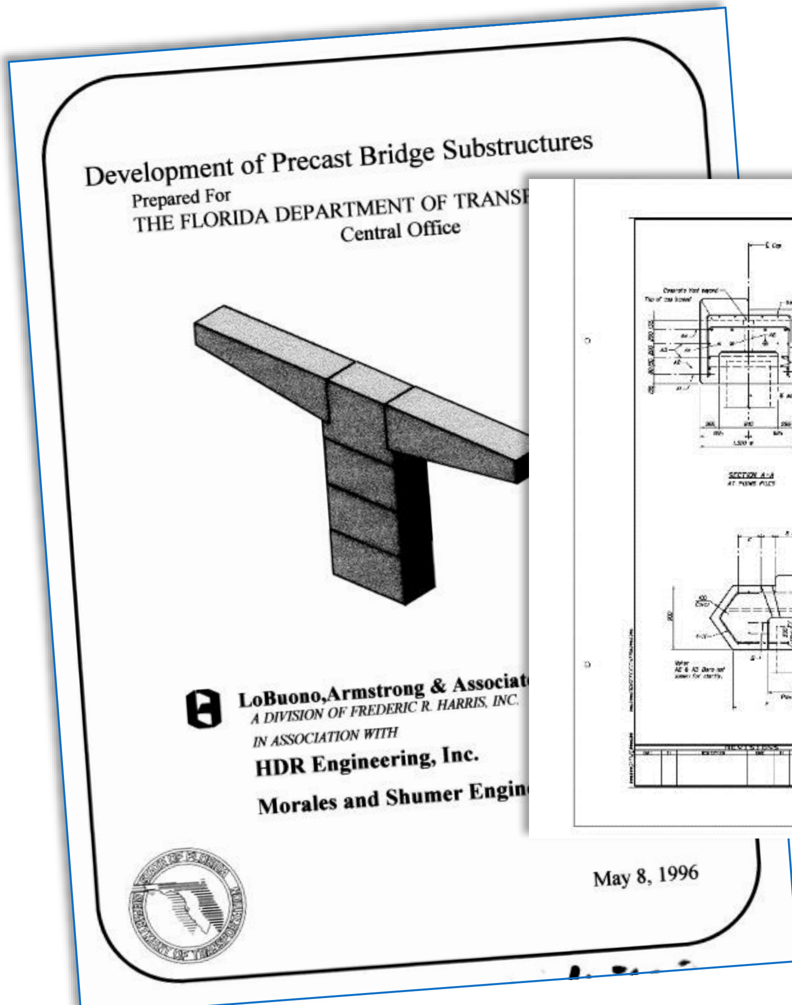
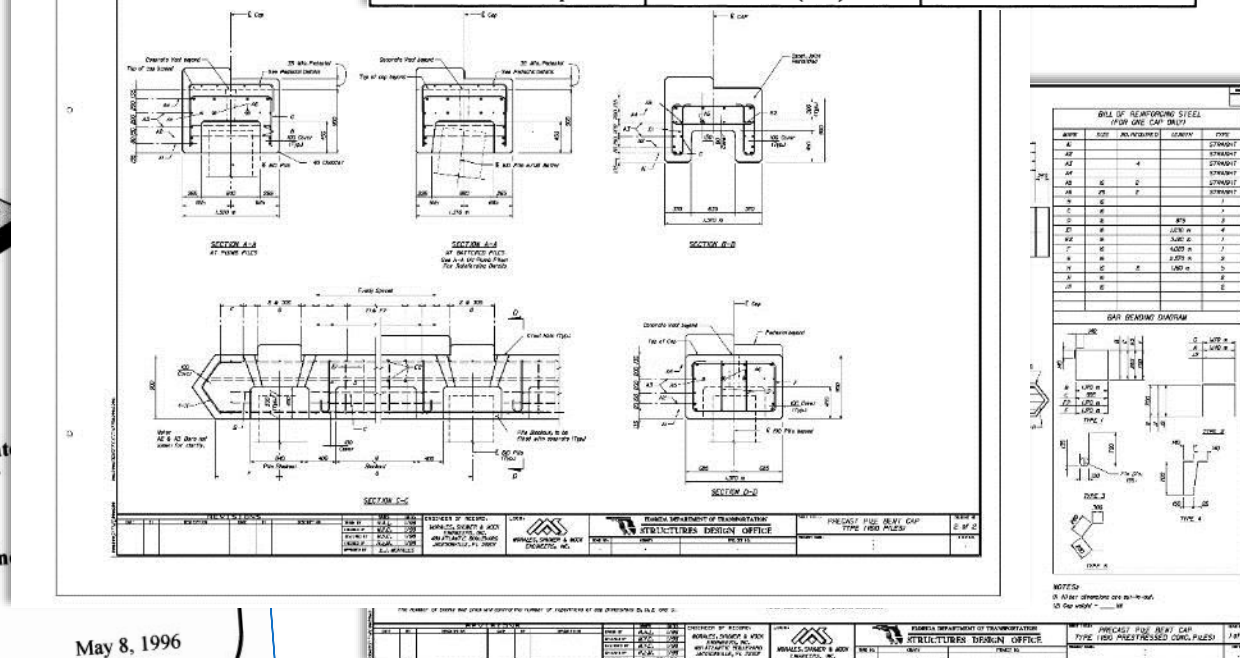
1996 FDOT Precast Substructure Study

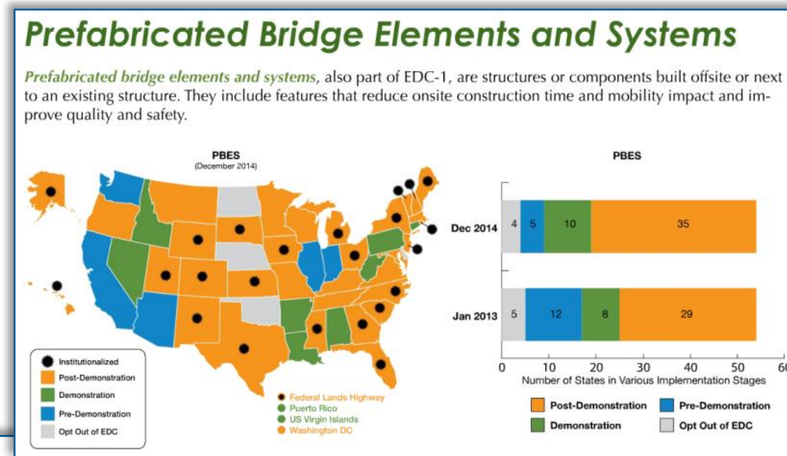


Component	Configuration	Configuration
Multi-Column Pier Cap	Solid Rectangle (IA)	Inverted U (III)
Multi-Column Pier Column	Hollow Rectangle - Rounded Corners (IIIB)	I-Shaped (IVA)
Pile Bent Caps	Solid Rectangle (IV)	Inverted U (I)
Hammerhead Pier Column	Hollow Rectangle - Rounded Corners (IIB)	Double I-Shaped (III)
Hammerhead Pier Cap	Solid Cantilever (IRB)	

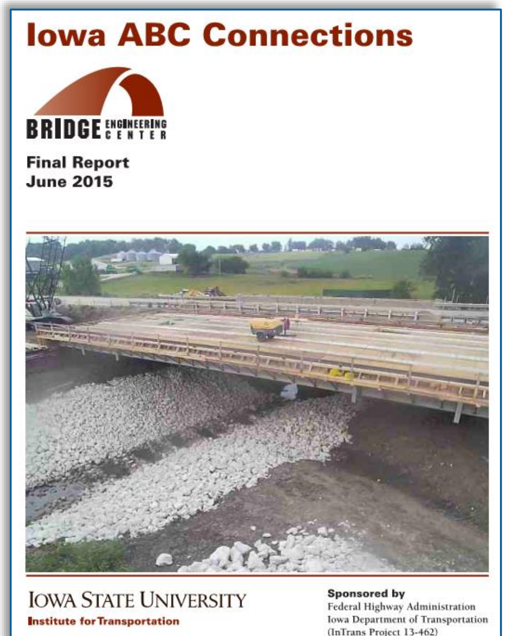


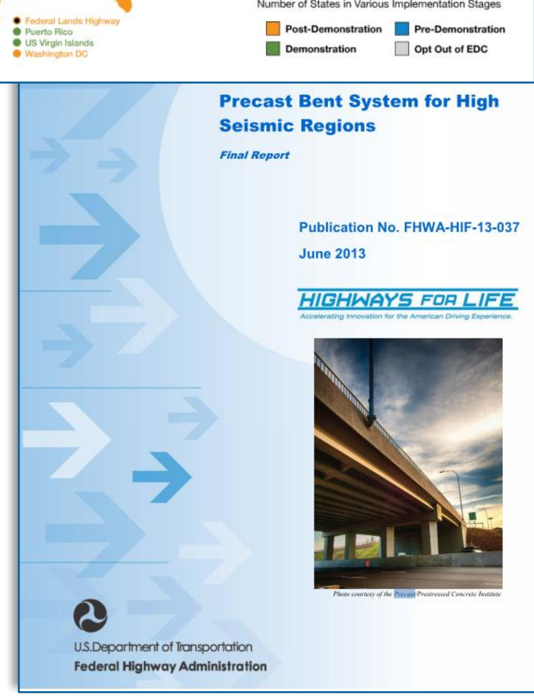
Other State DOT's - Precast Bent Caps

- Iowa
- South Carolina
- Washington
- Texas …



Source: EDC-2 Final Report. FHWA, March 2015, pg. 15.





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TxDOT- Research, Projects & Standards

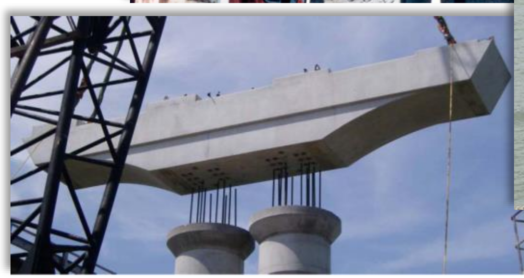
Research: TxDOT sponsored research projects at ***CTR*** related to Precast Bent Cap Systems and Connections:

Center for Transportation Research
The University of Texas at Austin

- 1410-2F (1998), "A Precast Substructure Design For Standard Bridge Systems"
- 1748 (2001), "Development of a Precast Bent Cap System"
- 4176 (2006), "Anchorage for Grouted Vertical-Duct Connectors in Precast Bent Cap Systems"
- Miller, C., Holt, J. and McCammon, V., (2014) "*Precast, Pretensioned, Rectangular Bent Caps*", Accelerated Bridge Construction-University Transportation Center, Proceedings: 2014 National ABC Conference, Miami FL., December 4-5, 2014.

Example Projects:

- Red Fish Bay and Morris-Cummings Cut Bridge (1994)
- Lake Ray Hubbard Bridge (2002)
- Lake Belton Bridge (2004)



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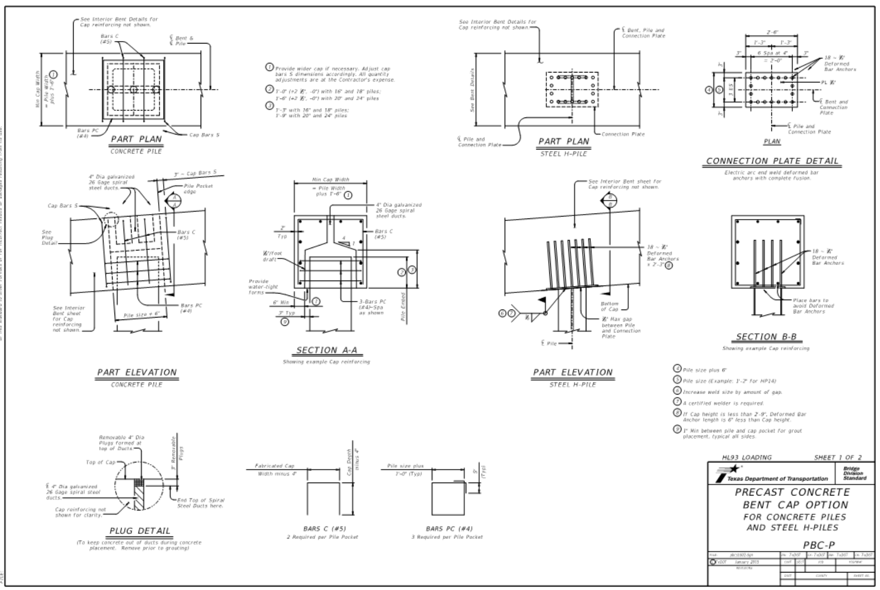
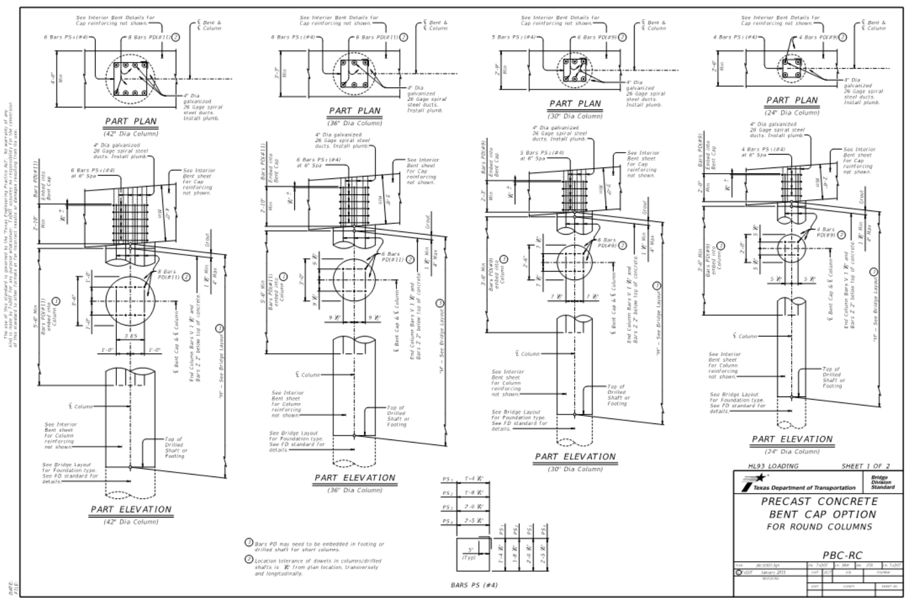
TxDOT- Research, Projects & Standards

Bridge Standards ***PBC-P*** and ***PBC-RC:***

- Initially released in 2011
  Webinar from Feb 2012: http://ftp.dot.state.tx.us/pub/txdot-info/brg/0212_webinar/holle.pdf
- Drawings updated January 2015
  http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/bridge-e.htm



Square Concrete or Steel H-Piles



Round Columns

Bridge Standards (English)

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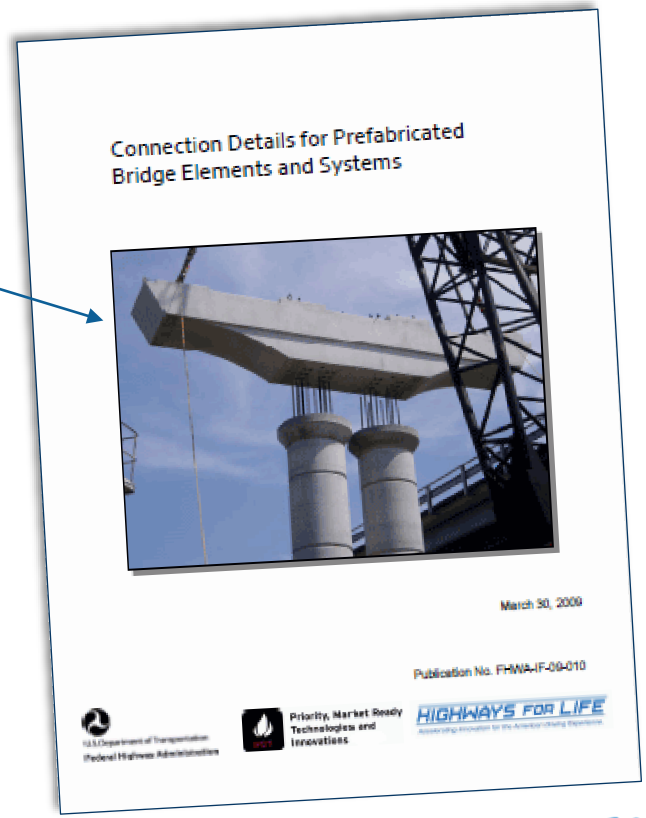
FHWA's Every Day Counts Initiative

Connection Details for Prefabricated Bridge Elements and Systems (2009): *http://www.fhwa.dot.gov/bridge/prefab/if09010/*

Lake Belton Bridge


Connection Details for Prefabricated Bridge Elements and Systems

March 30, 2009

Publication No. FHWA-IF-09-010

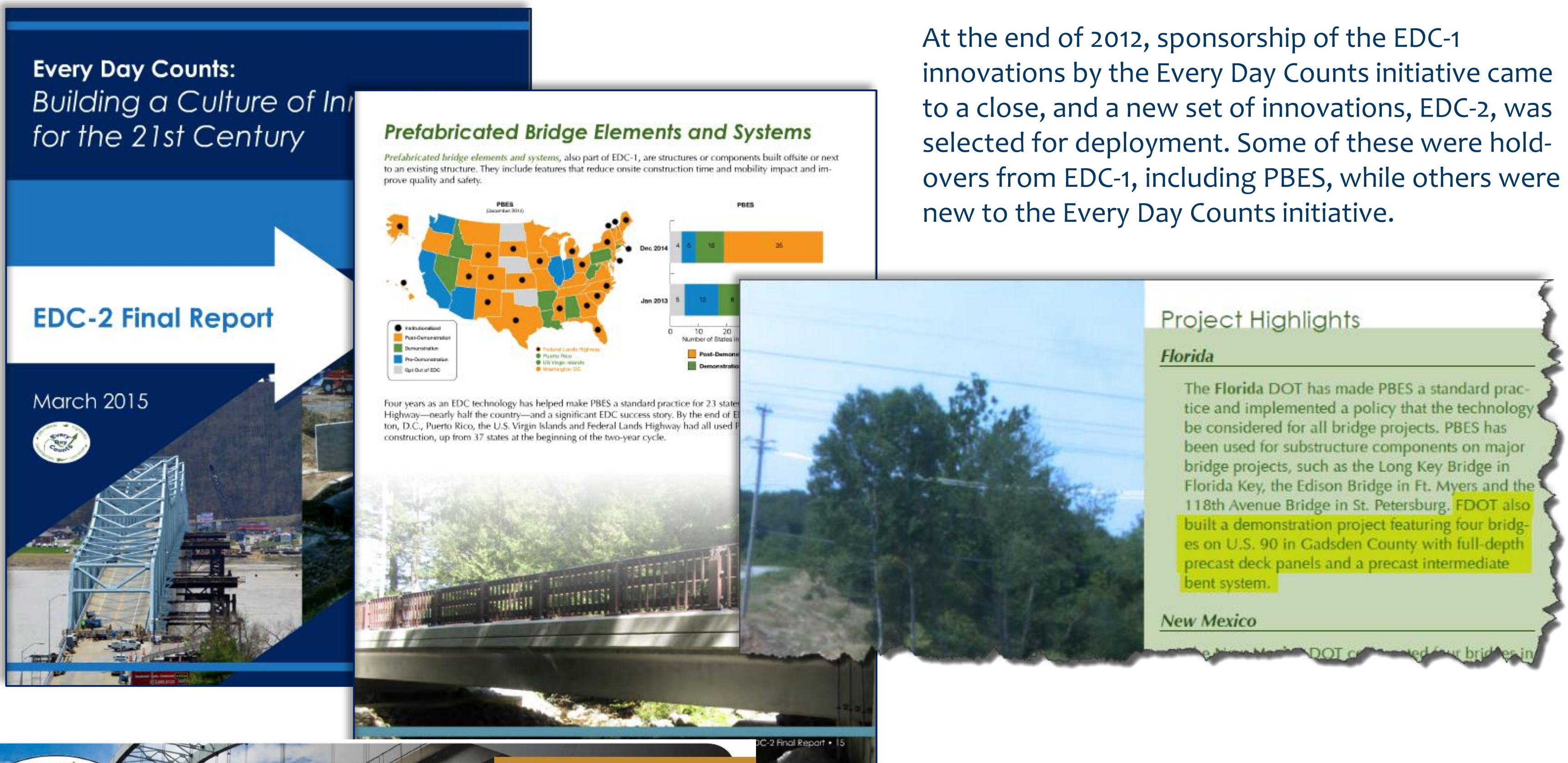
Priority, Market Ready Technologies and Innovations

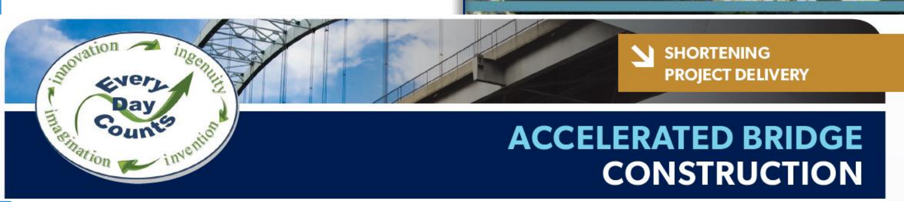
HIGHWAYS FOR LIFE

FHWA's Every Day Counts Initiative

EDC-2 Report: http://www.fhwa.dot.gov/everydaycounts/reports/edc-2-finalreport/

At the end of 2012, sponsorship of the EDC-1 innovations by the Every Day Counts initiative came to a close, and a new set of innovations, EDC-2, was selected for deployment. Some of these were hold-overs from EDC-1, including PBES, while others were new to the Every Day Counts initiative.





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FDOT's Invitation to Innovation – PBES

http://www.dot.state.fl.us/structures/innovation/PBES.shtm

Office of Design / Invitation to Innovation

Invitation to Innovation

Recently, the Department embarked into a new … Success in this new era depends on the ability … provides its users. The Florida Department of Tra… or employ "outside the box" thinking to generate n…

After researching and evaluating many innovative … services that may be the best solution to the proj… developed, and only need tailoring to your projec… project specific solutions with confidence of appr… coordination with and approval by the District's … implemented in other states and countries. Not … advocating the general use of new products or de… appropriate solution for the situation.

Please consider these innovations as possible sol… listed in the links below. Additional innovations … questions, details and contact information are inclu…

Structures Design Office

- Prefabricated Bridge Elements and Systems
- Curved Precast Spliced U-Girder Bridges
- Geosynthetic Reinforced Soil Integrated Bridge…
- Geosynthetic Reinforced Soil Wall
- Segmental Block Walls
- Fiber Reinforced Polymer Reinforcing

Structures Design / Transportation Innovation

Every Day Counts - Prefabricated Bridge Elements & Systems (EDC-PBES)

Structures Design - Transportation Innovation

Every Day Counts - Prefabricated Bridge Elements & Systems (EDC-PBES)

Photo Slideshow

- Overview
- EDC-PBES Website
- Design Criteria
- Implementation Plan
- Usage Restrictions / Parameter…
- Contact

Overview

The FHWA has deployed a new … intended to highlight some adva… and FDOT support the use of a… precast/prefabricated bridge ele… quality, reduce costs and const… innovative concepts aids in solv… revolutionizing bridge construct…

Prefabricated bridge elements … demanded specialized details a… This same approach can be us… reducing construction time. Inve… conventional construction helps… indirect costs while delivering th… impact to the traveling public.

Structures Design

EDC - Prefabricated Bridge Elements & Systems

Website Overview - Video (WMV)

Plans Preparation Manual (***PPM***), Volume 1, Section 26.9.2.9 provides expanded direction for investigating prefabricated bridge alternates during the Bridge Development Report (BDR) phase of design. The referenced section of the ***PPM*** formalizes the process for evaluating whether prefabricated options should be considered based on feasibility questions, then, when warranted, how to develop and select prefabricated options through an assessment matrix. An assessment matrix methodology allows for alternate selection based on less than perfect knowledge. Both direct and indirect costs for prefabricated and conventional options are to be reported in the BDR. See ***PPM*** Exhibit 26-F for additional background information.

This website is intended to provide design guidance for developing prefabricated bridge alternates and gives examples on how to estimate both direct and indirect costs. To date, the FDOT does not have sufficient historical bid data for prefabricated bridge alternates in order to develop reasonable cost estimates from average unit material costs. To fill this gap, the Structures Design Office has developed several training videos for the purpose of educating designers on factors for consideration related to use of PBES for Accelerated Bridge Construction (ABC). Sample contractor estimates are provided to show how project costs may be developed to compare conventional construction methods versus a prefabricated ABC approach.

INVITATION TO INNOVATION

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FDOT's Invitation to Innovation – PBES

New The 2015 FDOT ***Structures Manual*** has been released. Chapter 25 of the ***Structures Detailing Manual*** (***SDM***) has been added and provides design considerations for detailing PBES for FDOT contract plans. A compilation of PBES concepts with annotated notes to designers that supplement this new chapter of the SDM is provided here (**PDF**).

25 PREFABRICATED BRIDGE ELEMENTS AND SYSTEMS (PBES) (Rev. 01/15)

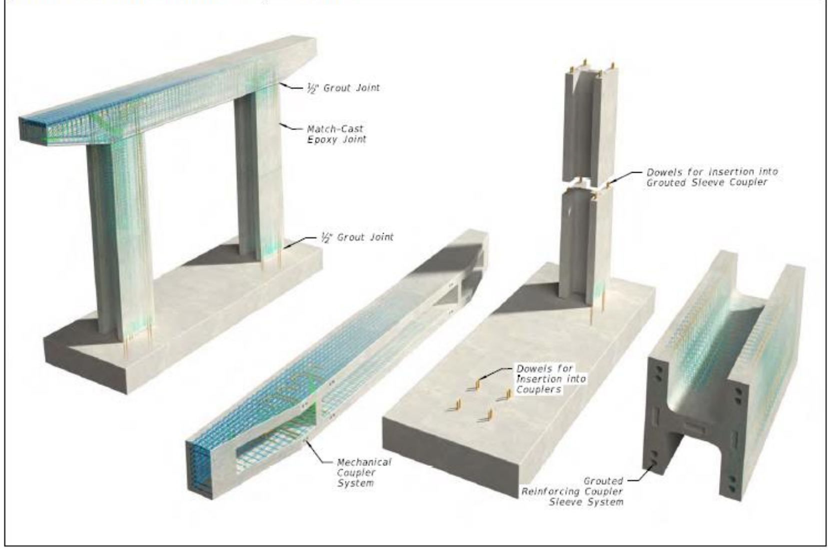
25.1 DESIGN CONSIDERATIONS - GENERAL

Prefabricated Bridge Elements a bridge fabricated offsite or in a n construction time as compared t designs, PBES are project specif shapes of components and conn and viable means of transportatio designer and CADD technician is all design, detailing, and constru herein is for general design cons to develop a quality set of PBES

A. This Chapter contains PBES

1. Applicability
2. Connections
3. Components

Figure 25.4.3.1-1 Precast Pier Assembly



INVITATION TO INNOVATION

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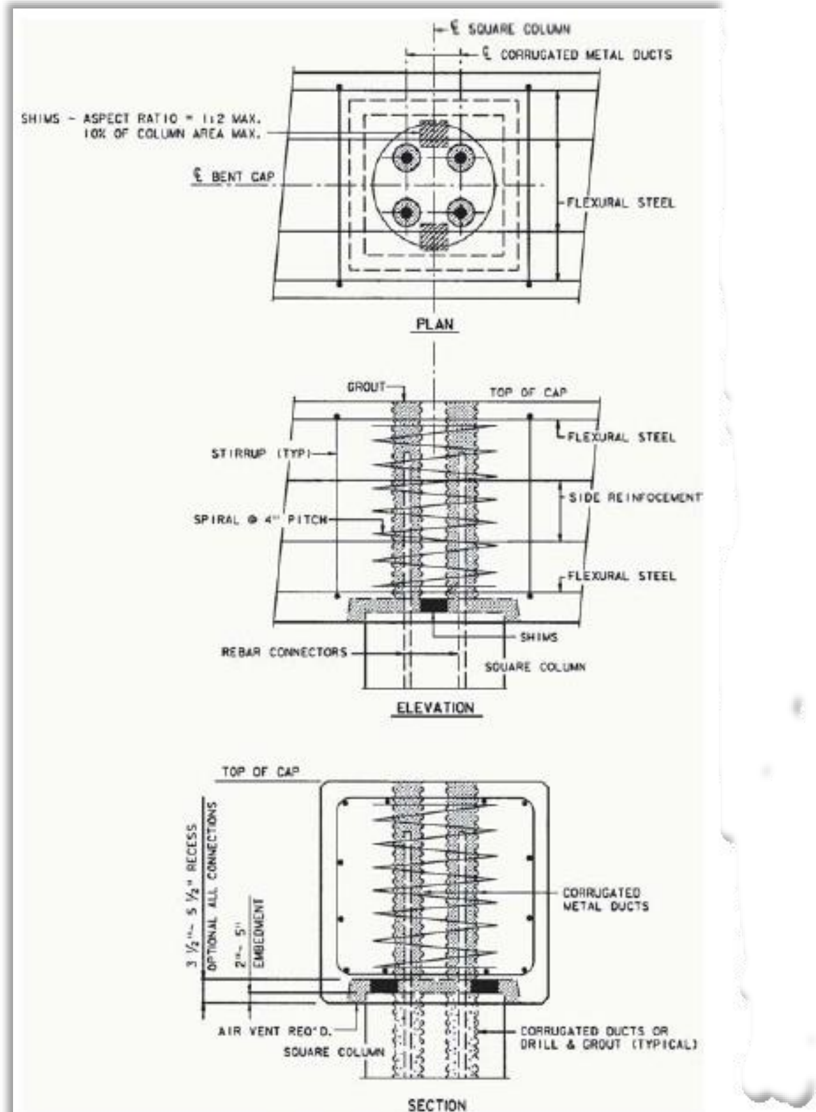
Research - NCHRP Report 681

(Project 12-74)

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_681.pdf (October 2010)

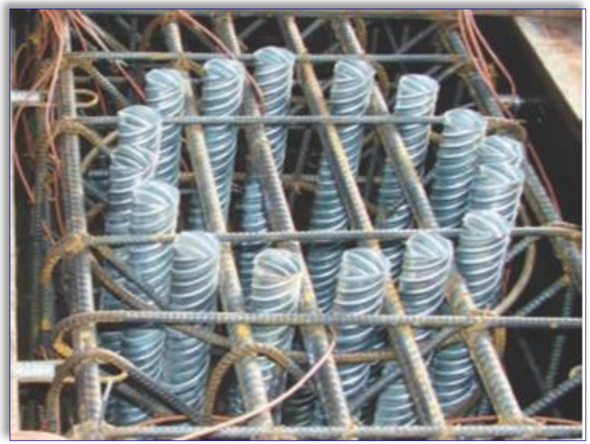


(a) Grouted Duct

Figure 3.1. Alternative precast bent cap connections for SDC A

Research - SHRP2 Project R04-RR-1 & 2

http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R04-RR-1.pdf (Oct. 2007 – March 2014)

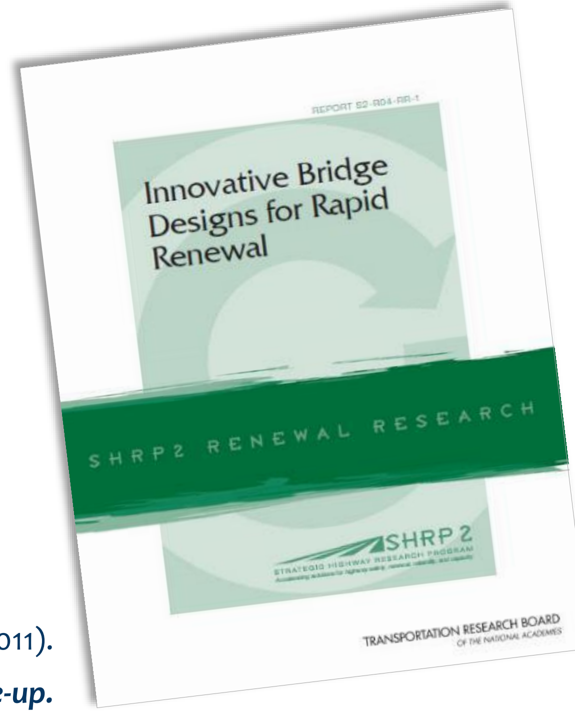


Source: NCHRP 12-74 (Restrepo et al., 2011).

Figure 3.33. Grouted duct connection.

Source: NCHRP 12-74 (Restrepo et al., 2011).

Figure 3.35. Cap pocket connection close-up.



Source: NCHRP 12-74 (Restrepo et al., 2011).

Figure 3.34. Cap pocket connection.

Table 3.5. Connection Types for U.S. Seismic Regions

Column-to-Cap Connection Type	Seismic Design Category
Grouted splice sleeve[a]	A, B, C
Grouted duct	A, B, C, D
Cap pocket[b]	A, B, C, D

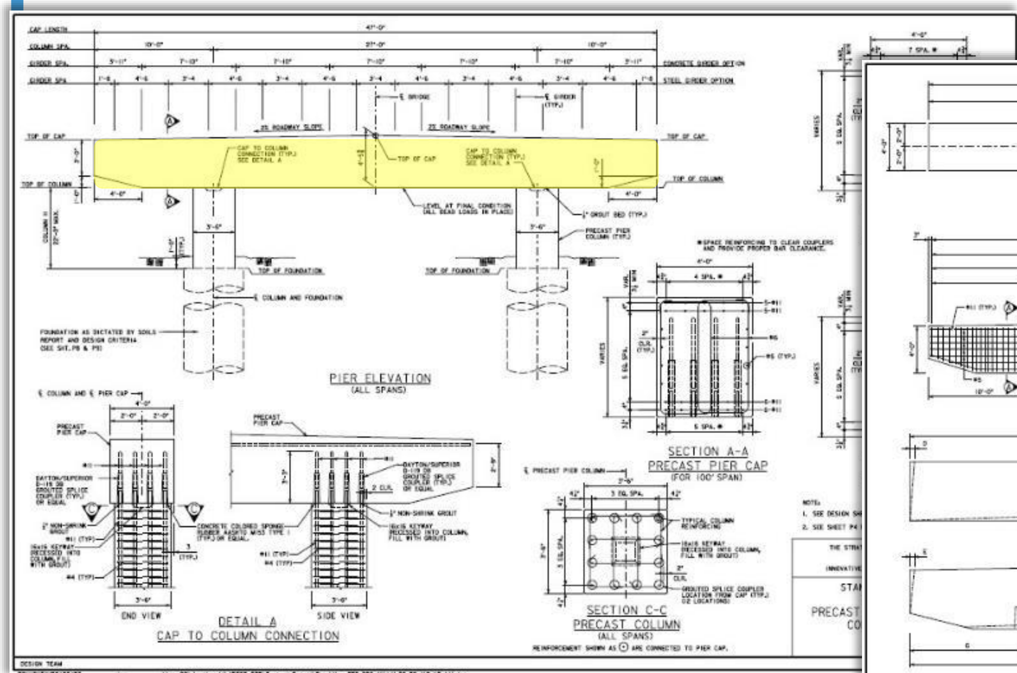
[a] NCHRP 12-74 has recommended use for limited-ductility applications only.
[b] NCHRP 12-74 tested both a limited-ductility and a full-ductility cap pocket connection.

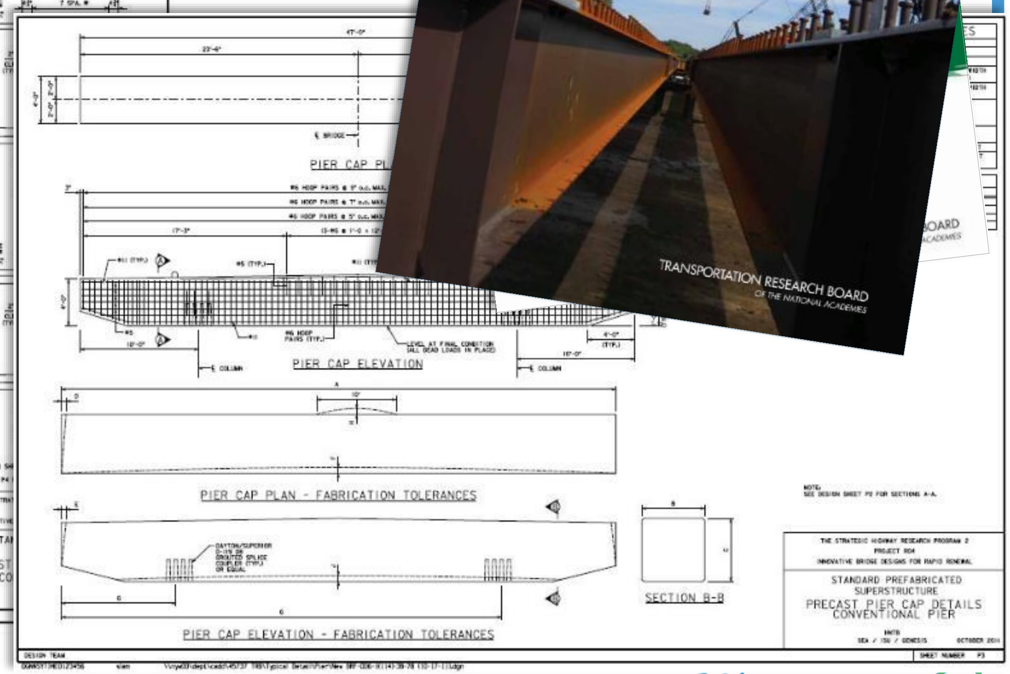
Research - SHRP2 Project R04-RR-1 & 2

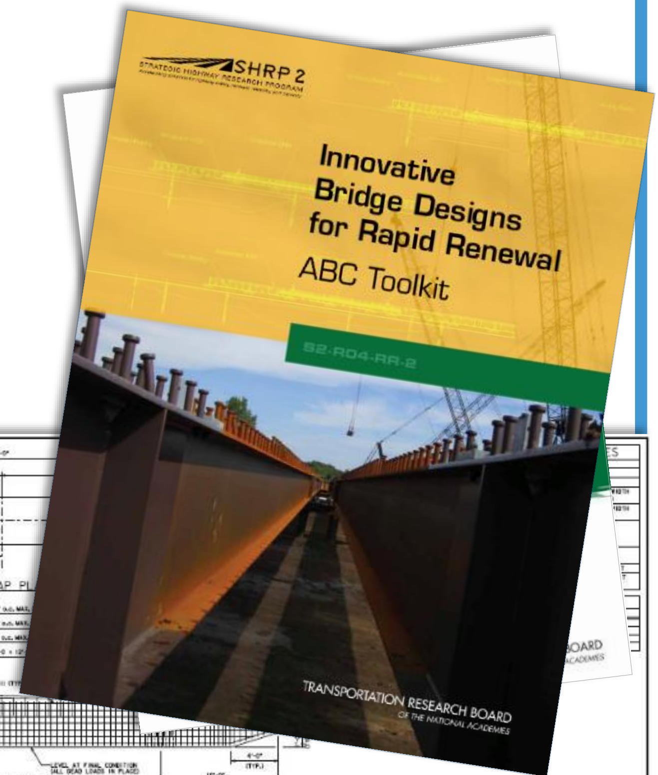
http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R04-RR-2.pdf (June 2013)

STRATEGIC HIGHWAY RESEARCH PROGRAM 2
PROJECT R04
INNOVATIVE BRIDGE DESIGNS FOR RAPID RENEWAL

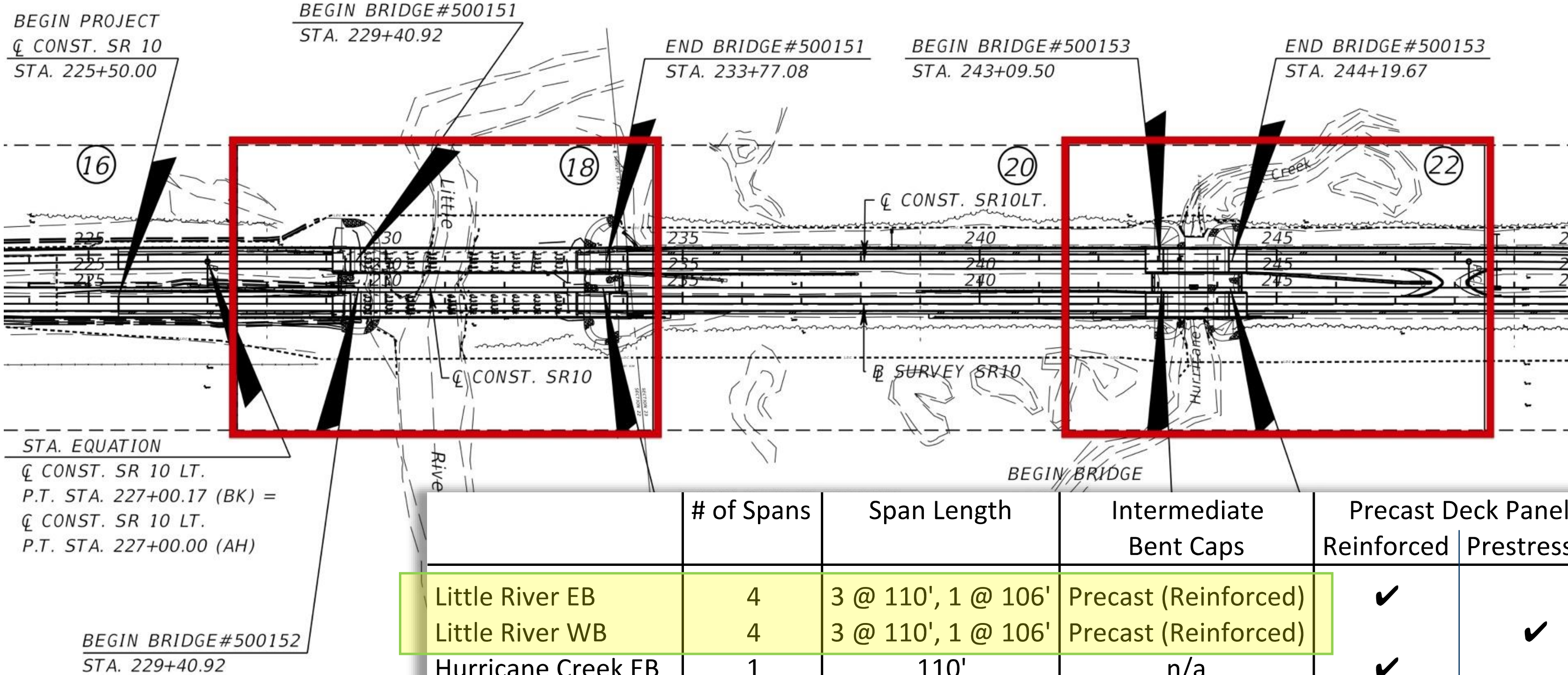
STANDARD PLANS FOR ABC MODULAR SYSTEMS







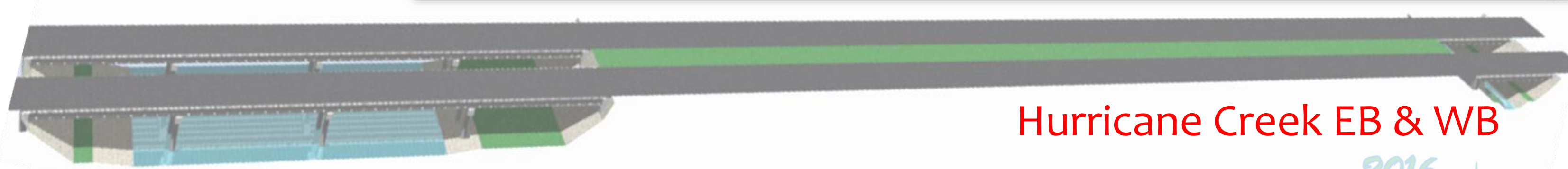
US 90/Little River PBES Demonstration - Example Project -



	# of Spans	Span Length	Intermediate Bent Caps	Precast Deck Panels Reinforced	Precast Deck Panels Prestressed
Little River EB	4	3 @ 110', 1 @ 106'	Precast (Reinforced)	✔	
Little River WB	4	3 @ 110', 1 @ 106'	Precast (Reinforced)		✔
Hurricane Creek EB	1	110'	n/a	✔	
Hurricane Creek WB	1	110'	n/a		✔

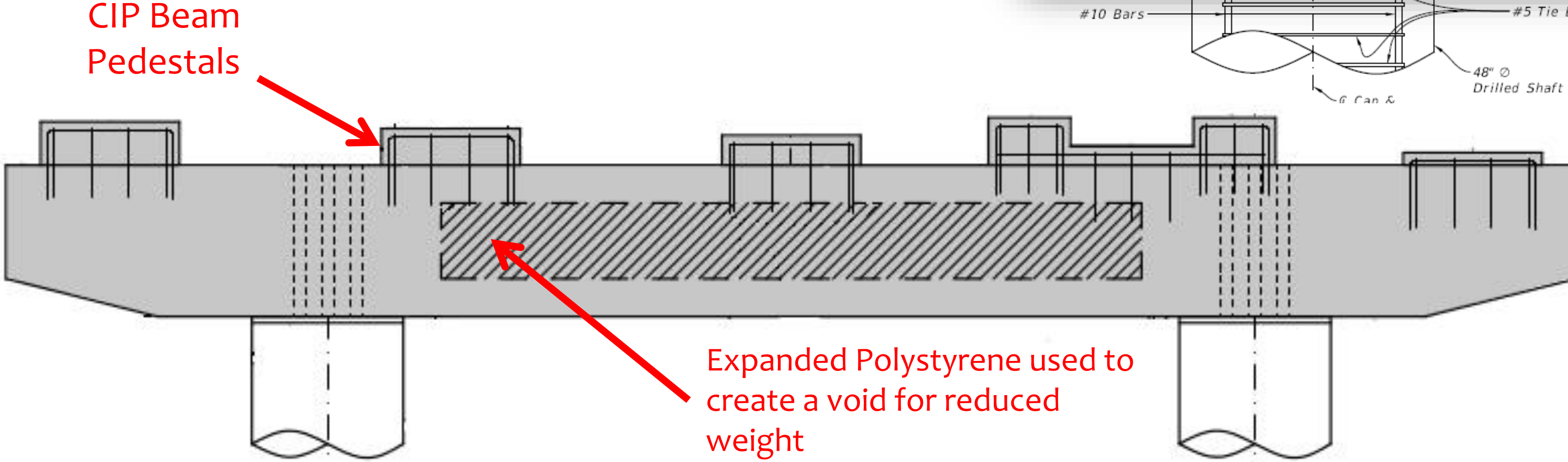
All bridges have cast-in-place abutments, drilled shafts, and precast/prestressed FIBs

Little River EB & WB



Hurricane Creek EB & WB

US 90/Little River PBES Demonstration - Example Project -



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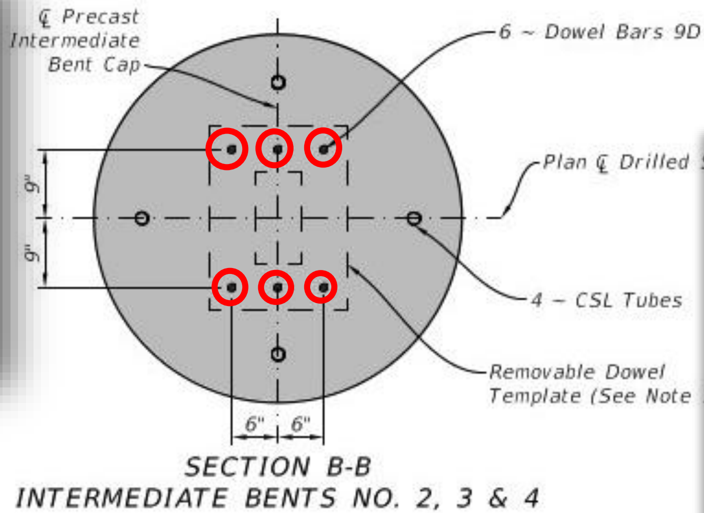
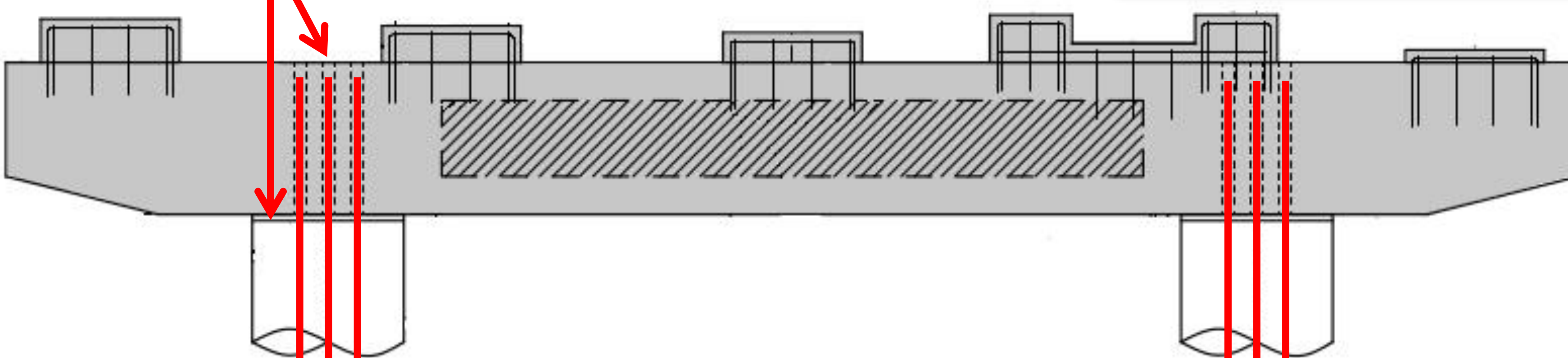
US 90/Little River PBES Demonstration
- Example Project -



Grout holes
& Fill joint



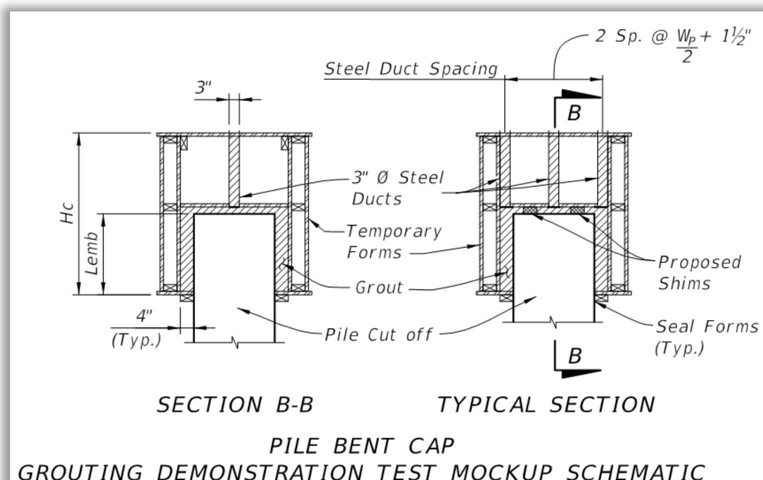
US 90/Little River PBES Demonstration - Specification Modifications-

Required submittals of:

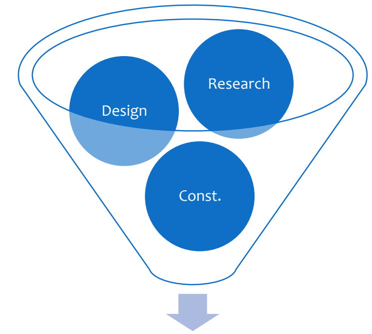
- Precast Placement Plan
- ABC-PBES Erection Stability
- Grouting Plan
  - Material
  - Equipment
- Grout Demo/ Mock-Up

Specified:

- Materials (MSP 934)
- Tolerances (MSP 455)
- Minimum Ages & Strength (Dev404 & MSP450)
- Installation (Dev404)
- Grouting (Dev404)



US 90/Little River PBES Demonstration
- Lessons Learned -



1. Pre-approved grouts expedite construction;
2. Need grouts with greater tolerance to ambient temperature change (less temperature sensitivity);
3. Pre-construction mock-up was valuable;
4. C-I-P Beam seats provided versatility;
5. Lifting from precast bed is critical for controlling cracks in slender non-prestressed elements;
6. ABC cost increase mostly due to deck panels. Precast bent caps are cost competitive with C-I-P construction.

FDOT *Developmental Design Standard*

- Index D20700 series -

Centennial FDOT 1915 ★ 2015

Florida Department of **TRANSPORTATION**

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Office of Design

Office of Design / Design Standards / Developmental Design Standards

Developmental Design Standards

Developmental Design Standards (DDS) are to be released by the appropriate sec
implement new technologies in a limited trial fashion on an as-needed or an as-avail
Design Bulletin will be issued to announce its availability. Designers wishing to use
Design Standards Usage Process which is posted in the link provided below. Plans r
in a plan set is permitted for the use by confirming the project's FPID number which i

START HERE → **Developmental Design Standards Usage for Design-Bid-Build Projects**

Developmental Design Standard (PDF)	Title	Monitor Contact	Inst Deve D (
* TRAFFIC RAILINGS *			
D450 Certification Statement	High Tension Cable Barrier Summary-of-Cable-Barrier.xlsm Permitted Projects FPID No(s):	Derwood Sheppard	IDE
	Thrie-Beam Panel Retrofit (Concrete Handrail) (NOTE: Migrated to the *Design Standards*		

Design Standards Development Report — Proposed Index No. D20700

DESIGN STANDARDS DEVELOPMENT REPORT FOR PRECAST INTERMEDIATE BENT CAP – Phase I (Final Draft) (Proposed Developmental Index No. D20700)

NEED:
Precast Bent Caps have been identified a cost effective mean
Accelerated Bridge Construction (ABC) under the FHWA initia
projects in Florida and nationwide have used precast bent ca
designs and connection details. Standardized components an
consistent design assumptions, leverage economy of scale fr
perceived risk and develop Contractor expertise. Due to the r
higher risk for C.I.P. construction, initially Precast Intermedia
considering expanding Florida practice to complete precast s

BACKGROUND:
The State Structures Design Office commissioned an effort to
1990's under Project No. 510703 [1] (see *Attachment "A"*). Th
this project were never implemented for unknown reasons. P
successful use of precast bent caps on at least two major FDO
41(Business) Edison Bridge (1993); and I-295 Southbound Bu
other FDOT projects have successfully incorporated precast b
George Island Bridge (2004); and US 90 Eastbound over Little
"B").

There have also been several state and national initiatives on
Development of a Precast Bent Cap System for Seismic Regi
Standard ABC Plans (see *Attachment "C"*); and Texas DOT sta
[7].

The most recent FDOT experience is from a pilot project invol
replacement highway bridges on *FPID 422823-1-52-01: US 90*
Creek in Gadsden County, Florida. By utilizing precast compo
knowledge about construction techniques and cost of precas
of FDOT's efforts to promote understanding, characterize the
improve future applications of Precast Bridge Element System
testing study is underway. Positive initial project results have
the first ABC-PBES element to be standardized in Florida.

PROPOSED DESIGN:
A new FDOT Developmental Design Standard will provide co
project, initially based on ***NCHRP Report 681*** and considering
the ***SHRP2 R04-RR-1*** project. A modified version of the FDOT
development as a design tool to assist in completing the nece
implementation on Department projects.

May 2015

Details for the Multi-Column Pier Cap will be similar to the ***SHRP2 R04-RR1*** project except the connection design will utilize the recommendations from ***NCHRP Report 681*** with the alternate details for regions of low seismicity. Details for the Pile Bent Caps will incorporate some of the work from the 1996 study under FDOT Project No. 510703, improvements based on the first generation TxDOT standards for Prestressed Concrete Piles, and development of a Steel Pipe Pile and H-Pile option. All options draw on experience gained from past FDOT projects incorporating similar elements.

The Developmental Design Standard will be refined over the next several years based on the ongoing US90 study and several small projects, and may be incorporated into the predesigned Off-System Bridge Standards currently under in-house development. Similar to past projects including the I-295 Buckman and SR 300 St George Island bridges, several long lower level bridge projects are planned within the next five years where this standardize application could provide significant time and cost savings. Potential projects include: the new westbound 118th Ave Viaduct East of 40th St (1,600 ft.) and Howard Frankland Northbound Bridge replacement (15,000 ft.) in Tampa Bay area; and Pensacola Bay Bridge replacement (15,000 ft.) in the Florida panhandle (see *Figures 1 & 2*).

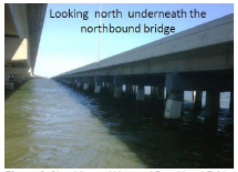

Figure 1: Northbound Howard Frankland Bridge

Figure 2: Proposed Pensacola Bay Bridge

ESTIMATED COST:
No change in substructure cost is expected for short and medium length bridges, however savings are expected for long bridges and bridge over waterways. Construction time is expected to be reduced by 15-30 days for each bent, especially if precast beam seats are utilized.

OTHER AFFECTED DOCUMENTS:
1. Design Standard Data Tables will be required and included in the FDOT CADD system;
2. Structures Manual – Review minimum concrete cover for internal EPS voids;
3. Plan Preparation Manual – No change;
4. Basis of Estimates Manual – New pay items to be developed;
5. Specifications – Refine Dev404 and MSP934 from FPID 422823-1-52-01.

IMPLEMENTATION PLAN:
1. Deployment of Developmental Index D20700 could be accomplished for August 2015, allowing use on projects with lettings beginning in January 2016.
2. Data Tables will be included in the 2015FDOT CADD system updates scheduled for July 2015.

http://fdotsharepoint.dot.state.fl.us/sites/Officeofdesign/DSD/Lists/DSDR/Attachments/19/DSDR-20700-PhaseIall.pdf

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FDOT ***Developmental Design Standard***

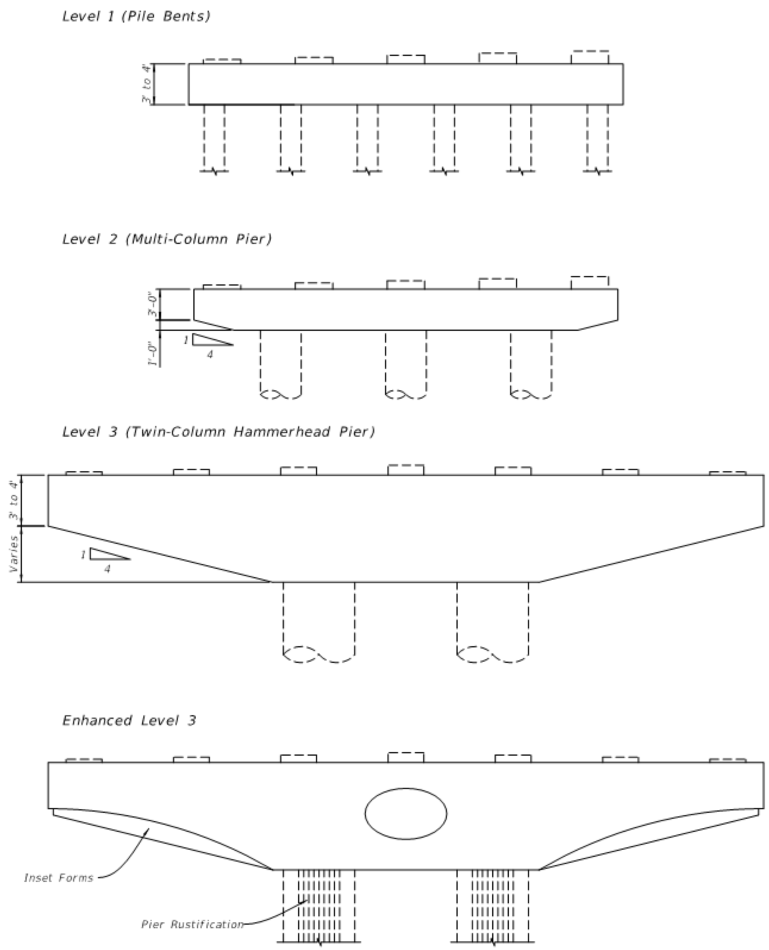
- Index D20700 series -

Level 1:
Pile Bents
(20710 series)

Level 2:
Multi-Column Pier
(20720 series)

Level 3:
Twin-Column Hammerhead Pier
(20730 series)

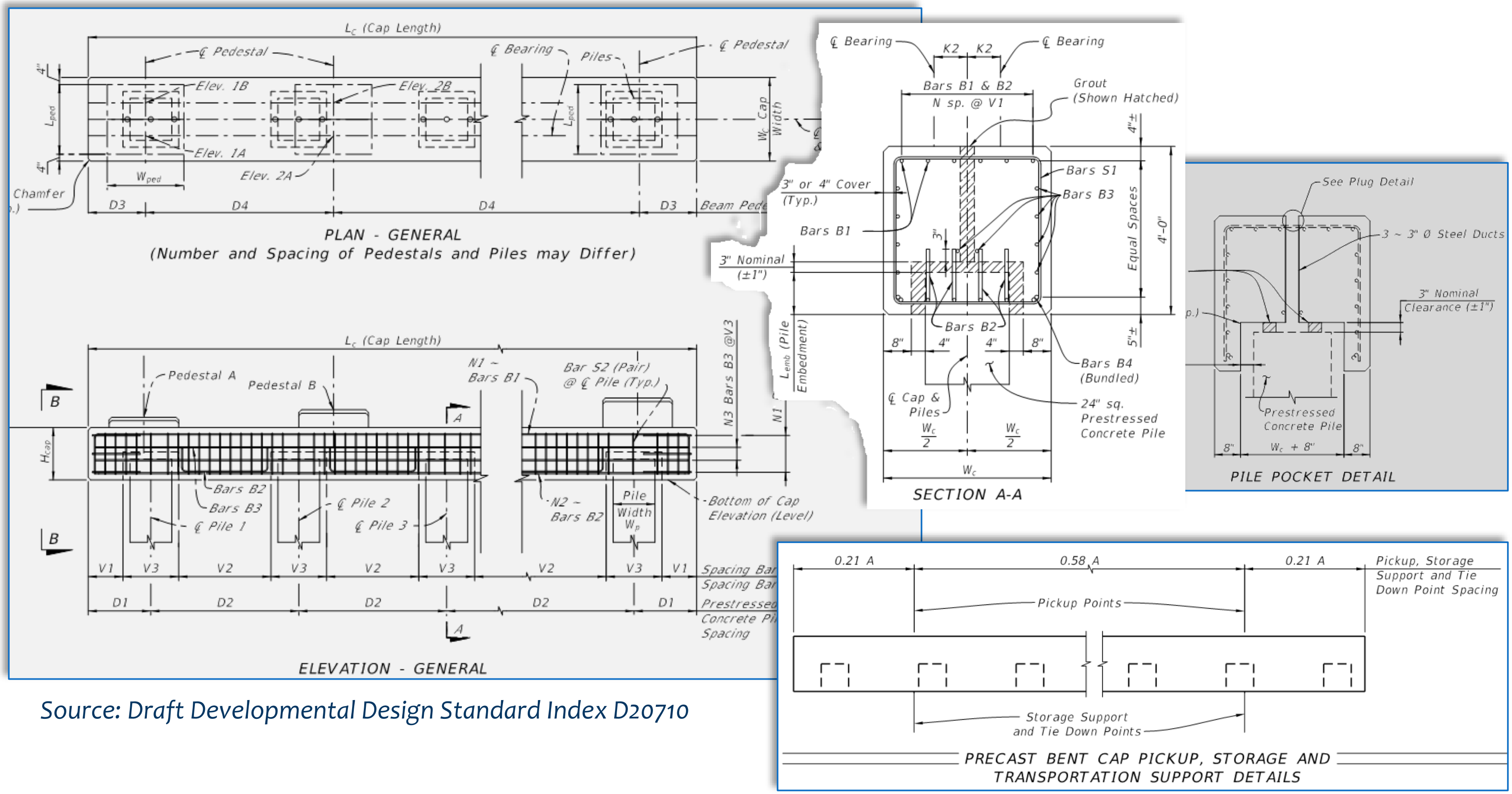
Enhanced Level 3:
Project Specific



Levels of Aesthetics and Precast Bent/Pier Cap Configurations

FDOT ***Developmental Design Standard***

- Index D20710 series -



Source: Draft Developmental Design Standard Index D20710

Pile Bent with Pile Pocket Connections
– Prestressed Concrete and Steel Pipe Piles **(Level 1)**

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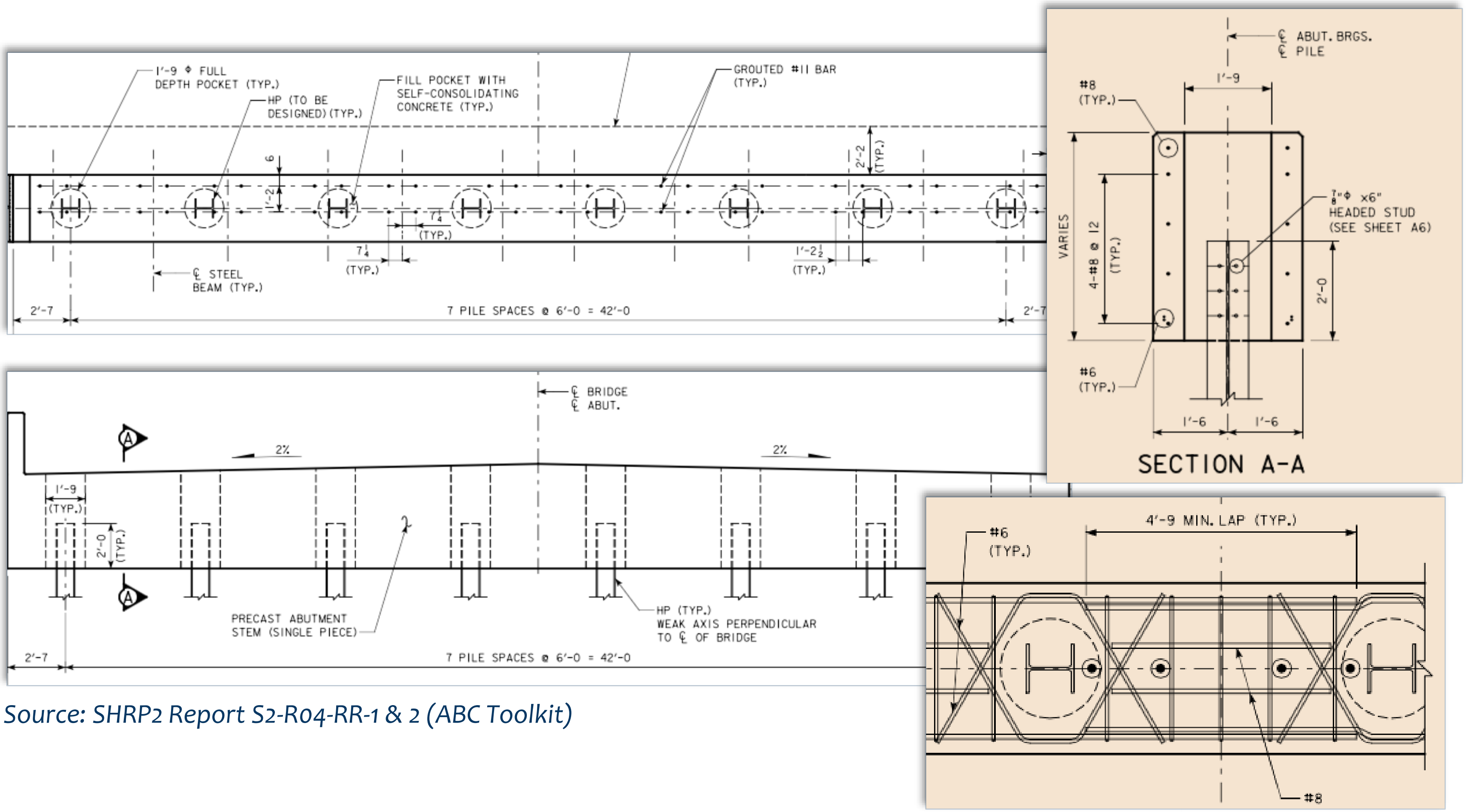
- Index D20710 series -



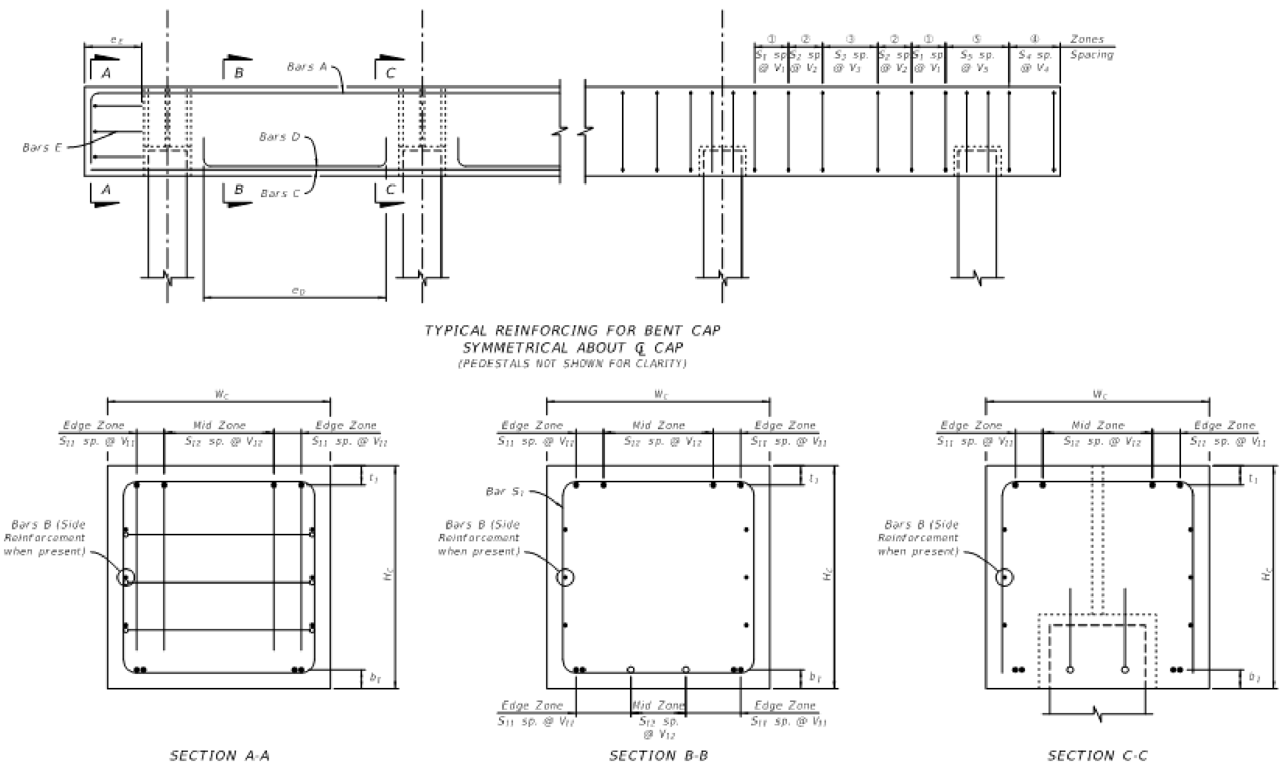
Source: SHRP2 Report S2-R04-RR-1 & 2 (ABC Toolkit)

Pile Bent with Open Cap Pocket Connections
– Steel H-Piles **(Level 1)**

FDOT ***Developmental Design Standard***

- Index D20710 series -

STRUCTURAL COMPONENT DIMENSIONS														Table Date XX/XX/16
	BEAM DETAILS		PEDESTAL DETAILS			CAP DETAILS			PILE DETAILS			DUCT DETAILS		
BENT NO.	CAP END TO ℄ EXTERIOR BEAM SPACING (ft)	INTERIOR BEAM SPACING (ft)	PEDESTAL WIDTH (ft)	PEDESTAL HEIGHT (ft)	NO. OF PEDESTALS	CAP LENGTH (ft)	CAP HEIGHT (ft)	CAP WIDTH (ft)	PILE SIZE (DIAMETER OR WIDTH) (in)	OVERHANG (ft)	SPACING BETWEEN PILES (ft)	DUCT DIAMETER (ft)	NO. OF DUCTS	DUCT SPACING
	L_3	L_4	W_{ped}	L_{ped}	X_{beam}	L_C	H_C	W_C	W_P	L_1	L_2	W_d	n_d	x_d



Data Tables: Pile Bent Cap – Dimensions

– Prestressed Concrete and Steel Pipe Piles **(Level 1)**

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FDOT *Developmental Design Standard*

- Index D20710 series -

BENT CAP FLEXURAL REINFORCEMENT										Table Date XX/XX/16
BAR TYPE		ROW NUMBER	BAR ID	NO. OF BARS	VERTICAL DISTANCE TO C.G. OF ROW (in)	BAR LENGTH (in)	EDGE ZONE		MID ZONE	
							NO. OF BARS	AT SPACING (in)	NO. OF BARS	AT SPACING (in)
					t_i or b_i *	e_{Xi} **	n_{i1}	V_{i1}	n_{i2}	V_{i2}
TOP REINFORCING	BAR A (Continuous Longitudinal Bars)	ROW 1								
		ROW 2								
SIDE FACE REINFORCING	BAR B (Continuous Bars along Side Faces)	ROW 1								
		ROW 2								
BOTTOM REINFORCING	BAR C (Continuous Longitudinal Bars)	ROW 1								
		ROW 2								
	BAR D (Supplemental Long. between Int. Piles)	ROW 1								
		ROW 2								
END FACE REINFORCING	BAR E (Horizontal End Face Reinforcing)	ROW 1								
		ROW 2								

* i = Row Number (1, 2, 3, or 4)
** X = Bar Type (A, B, C, D, or E)

BENT CAP SHEAR REINFORCEMENT															Table Date XX/XX/16
BENT NO.	Zone ①			Zone ②			Zone ③			Zone ④			Zone ⑤		
	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)
		S1	V1		S2	V2		S3	V3		S4	V4		S5	V5

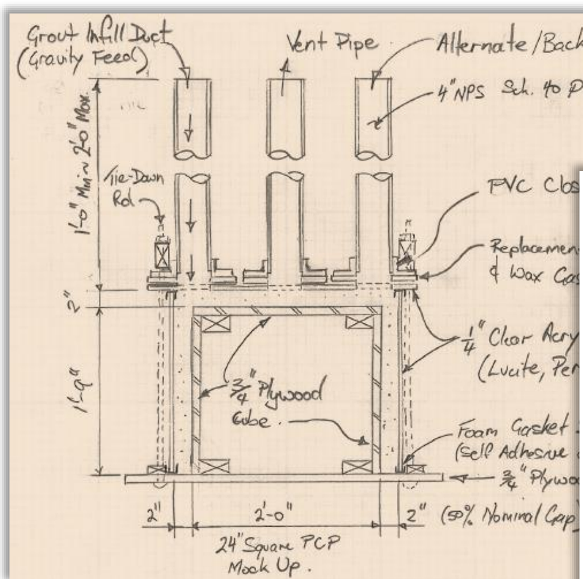
Data Tables: Pile Bent Cap – Reinforcing
– Prestressed Concrete and Steel Pipe Piles **(Level 1)**

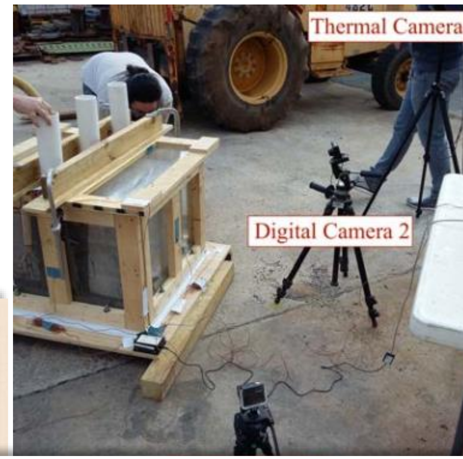
FDOT *Developmental Design Standard*

- Index D20710 series -

Grout Rheology Mockup Testing (Project BDV30 977-16):

- Typical Efflux Time 20-30 seconds;
- Typical Temperature 70-80 degrees:





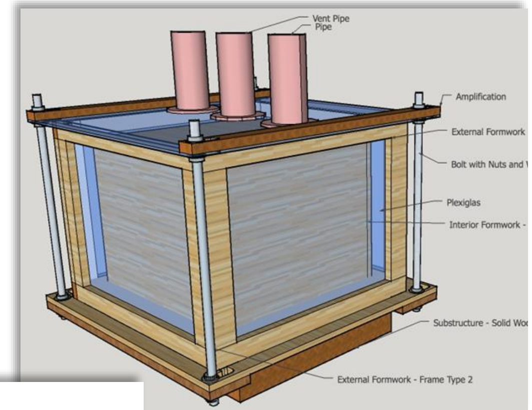


Table 1: Test matrix

	Specimen	Pile Surface	Minimum Gap mm	Minimum Gap in.	Temp. Range °C	Temp. Range °F	Efflux Range† s
Task 1	MU1	Concrete	50	2	21-24	70-75	35-45
	MU2	Plywood					
	MU3				27-29	80-85	
	MU4				29-32	85-90	20-30
	MU5		12.5 (2 Sides and Top)	0.5			
	MU6						
Task 2‡	MU7	Plywood	190 (2 Sides)	7.5	29-32	85-90	max. 48
	MU8						
	MU9		50 (different tapered heads)	2			
	MU10						
	MU11		TBD		TBD		

† Flowability is measured by the cone discharge time of a 0.456 gallon (1.725 L) sample of fresh grout through a 0.5 in. (12.7 mm) tube orifice at the bottom of the cone.
‡ All specimens in Task 2 will have differently pigmented grout layers, will be filled through a smaller (2 in.) duct to simulate heavily reinforced bent caps, and the pocket in the bent cap will be tapered (towards the center) to promote ventilation and to reduces air entrapment.

Recommended Temperature Guidelines for Precision Grouting

	MINIMUM °F (°C)	PREFERRED °F (°C)	MAXIMUM °F (°C)
Foundation and plates	45 (7)	50 – 80 (10 – 27)	90 (32)
Mixing water	45 (7)	50 – 80 (10 – 27)	90 (32)
Grout at mixed and placed temp	45 (7)	50 – 80 (10 – 27)	90 (32)

Source: BASF Masterflow® 928

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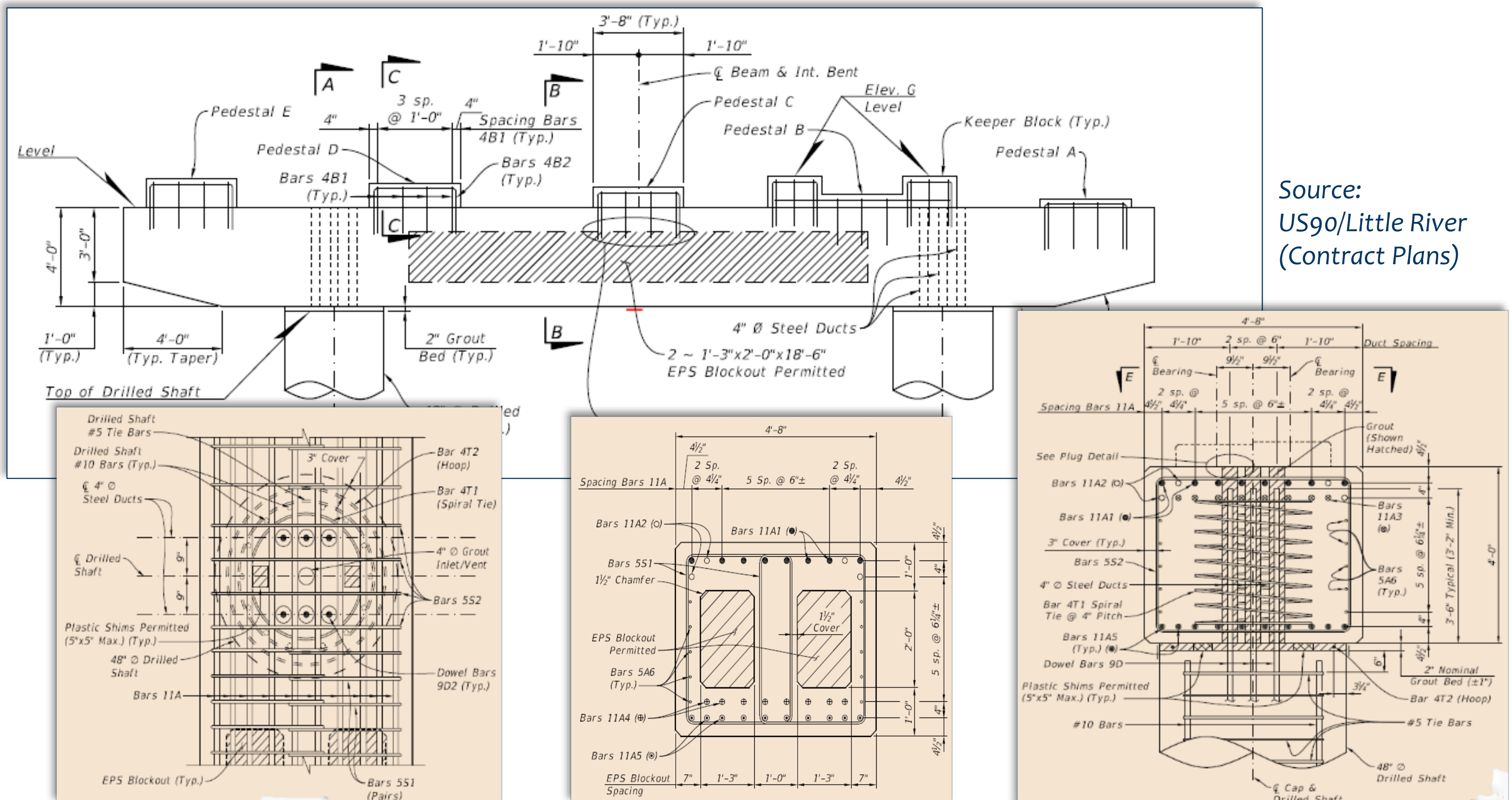
- Index D20720 series -



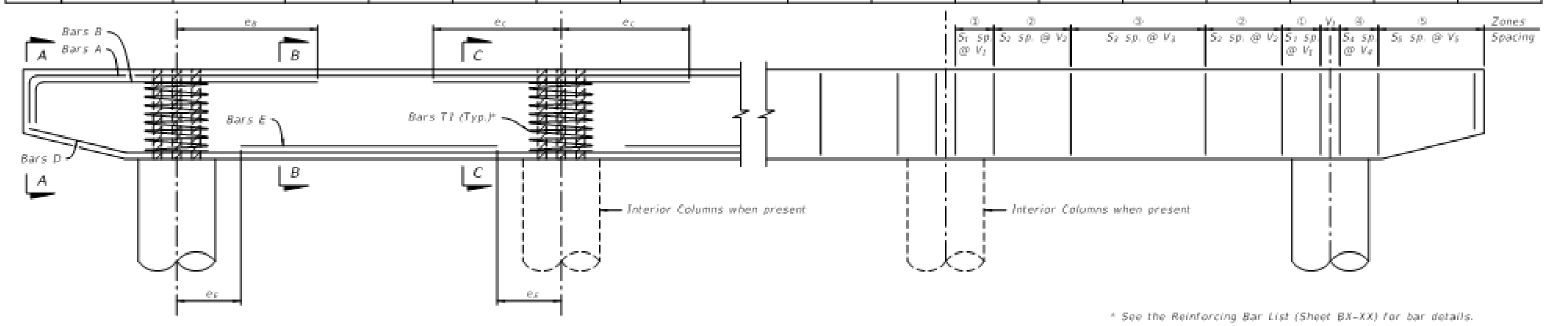
Source: US90/Little River (Contract Plans)

Multi-Column Pier Cap with Grouted Duct Connections – Concrete Columns & Drilled Shafts **(Level 2)**

FDOT ***Developmental Design Standard***

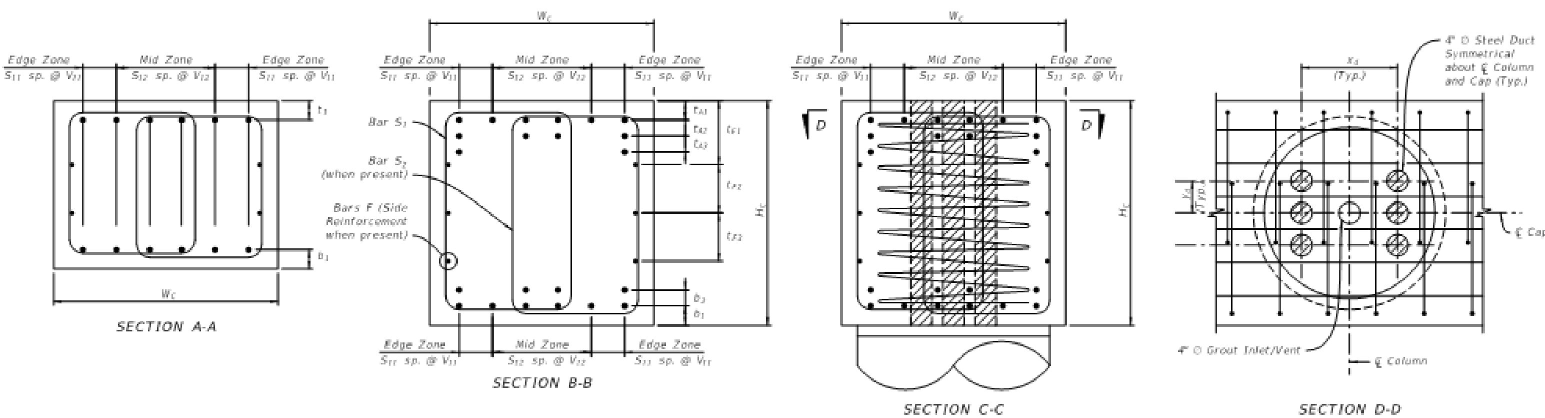
- Index D20720 series -

STRUCTURAL COMPONENT DIMENSIONS																	Table Date XX/XX/16
	BEAM DETAILS		PEDESTAL DETAILS			CAP DETAILS					COLUMN DETAILS			DUCT DETAILS			
PIER NO.	CAP END TO ℄ EXTERIOR BEAM SPACING (ft)	INTERIOR BEAM SPACING (ft)	PEDESTAL WIDTH (ft)	PEDESTAL HEIGHT (ft)	NO. OF PEDESTALS	CAP LENGTH (ft)	CAP HEIGHT (ft)	CAP WIDTH (ft)	TAPER LENGTH (ft)	TAPER HEIGHT (ft)	COLUMN DIAMETER (ft)	OVERHANG (ft)	SPACING BETWEEN COLUMNS (ft)	DUCT DIAMETER (ft)	NO. OF DUCTS	DUCT SPACING	
	L_3	L_4	W_{ped}	L_{ped}	X_{beam}	L_C	H_C	W_C	L_T	H_T	W_{col}	L_1	L_2	W_d	n_d	x_d	y_d



* See the Reinforcing Bar List (Sheet BX-XX) for bar details.

TYPICAL REINFORCING FOR MULTI-COLUMN PIER CAP
SYMMETRICAL ABOUT ℄ CAP
(PEDESTALS NOT SHOWN FOR CLARITY)



Data Tables: Multi-Column Pier Cap – Dimensions
– Concrete Columns & Drilled Shafts **(Level 2)**

FDOT *Developmental Design Standard*

- Index D20720 series -

PIER CAP FLEXURAL REINFORCEMENT										Table Date XX/XX/16
BAR TYPE		ROW NUMBER	BAR ID	NO. OF BARS	VERTICAL DISTANCE TO C.G. OF ROW (in)	BAR LENGTH (in)	EDGE ZONE		MID ZONE	
							NO. OF SPACES	SPACING (in)	NO. OF SPACES	SPACING (in)
					t_{Xi} or b_{Xi} *	e_{Xi} **	S_{11}	V_{11}	S_{12}	V_{12}
TOP REINFORCING	BAR A (Continuous Longitudinal Bars)	ROW 1								
		ROW 2								
		ROW 3								
		ROW 4								
	BAR B (Supplemental Longitudinal over Ext. Columns)	ROW 1								
		ROW 2								
		ROW 3								
		ROW 4								
	BAR C (Supplemental Longitudinal over Int. Columns)	ROW 1								
		ROW 2								
		ROW 3								
		ROW 4								
BOTTOM REINFORCING	BAR D (Continuous Longitudinal Bars)	ROW 1								
		ROW 2								
		ROW 3								
		ROW 4								
	BAR E (Supplemental Longitudinal over Int. Columns)	ROW 1								
		ROW 2								
		ROW 3								
		ROW 4								
SIDE FACE REINF.	BAR F (Continuous Bars along Side Faces)	ROW 1								
		ROW 2								
		ROW 3								
		ROW 4								

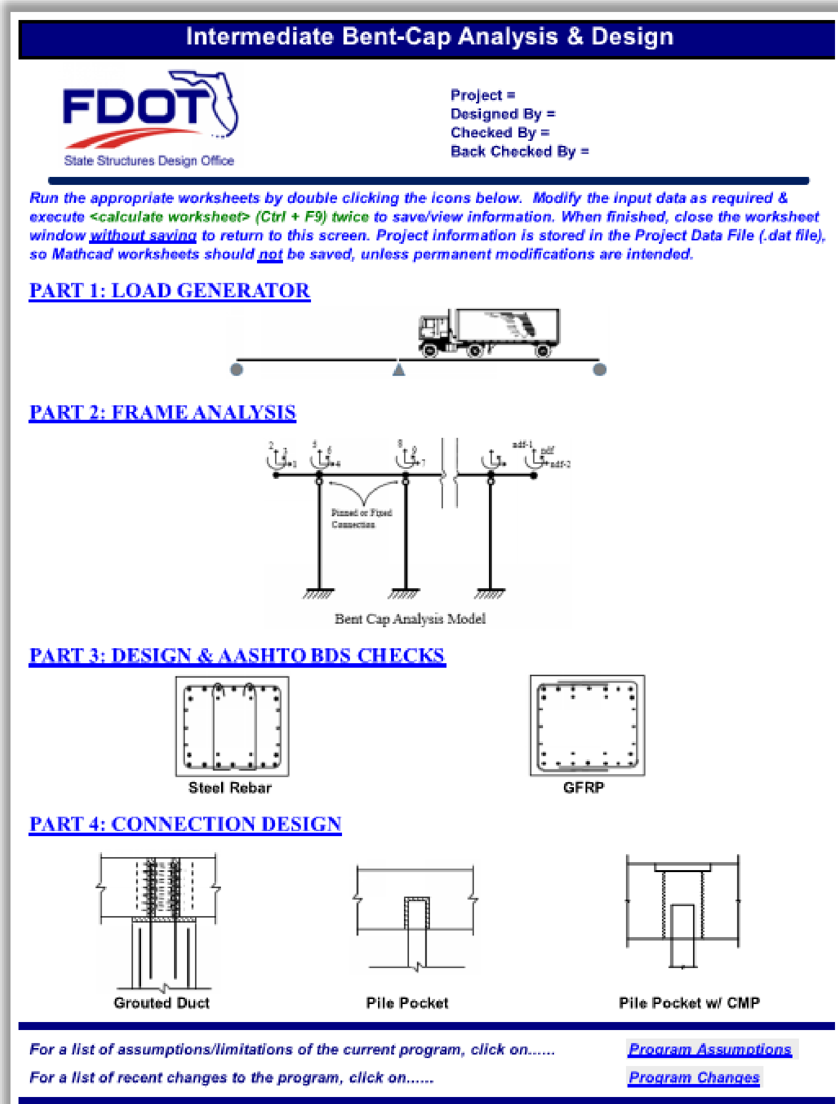
* i = Row Number (1, 2, 3, or 4)
** X = Bar Type (A, B, C, D, E or F)

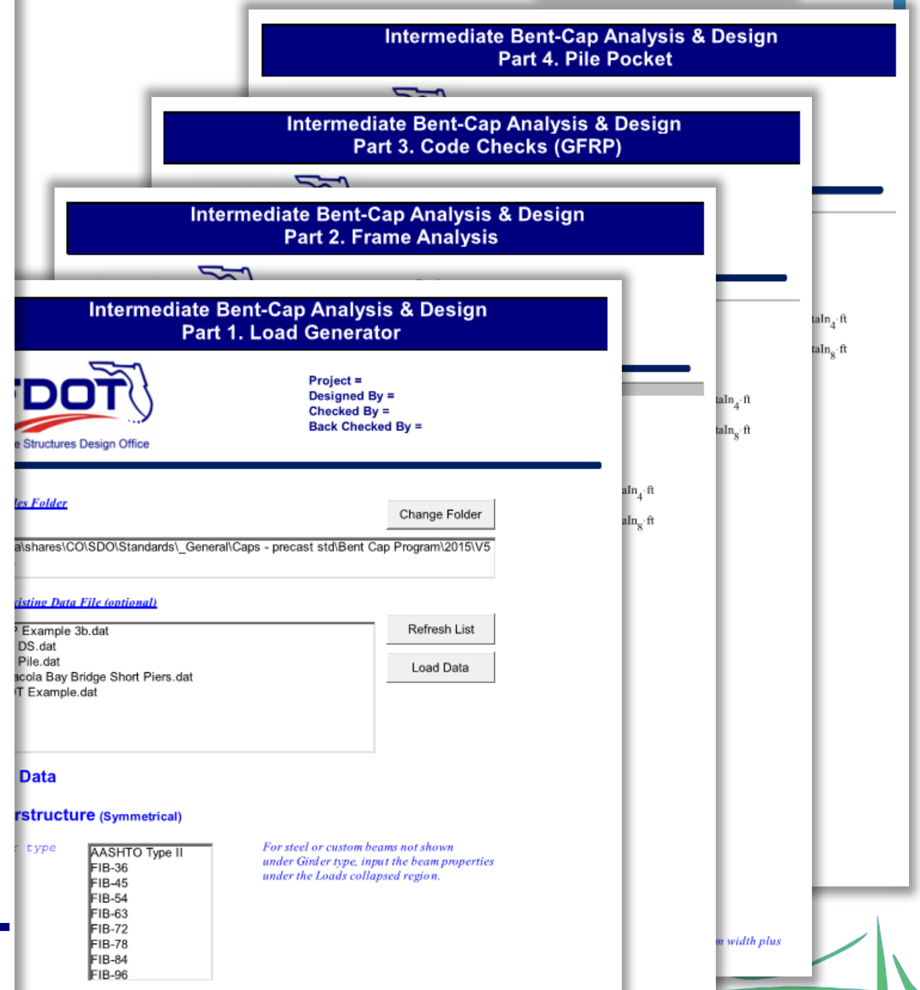
PIER CAP SHEAR REINFORCEMENT															Table Date XX/XX/16
PIER NO.	Zone ①			Zone ②			Zone ③			Zone ④			Zone ⑤		
	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)	BAR ID	NO. OF SPACES	AT SPACING (in)
		S1	V1		S2	V2		S3	V3		S4	V4		S5	V5

Data Tables: Multi-Column Pier Cap - Reinforcing – Concrete Columns & Drilled Shafts **(Level 2)**

2016 Design Training Expo

Mathcad Design Program





Design Training Expo

Mathcad Design Program

US90 Project: 2-Drilled Shaft Cap Design	Str_I $+M_u$ (kip*ft)	Str_I $-M_u$ (kip*ft)	V_u at Int. face of Ext. Col. (kip)	$+M_r$ w/ 18#11 (kip*ft)	$-M_r$ w/ 20#11 (kip*ft)	V_r w/ #5@6" (4 legs) (kip)
EOR's Design	2988	-3255	598	4818	5298	719
FDOT Mathcad (conc.)	3196	-3286	895	4825	5274	687
FDOT Mathcad (distr.)	2947	-3286	798			
Difference (distributed)	1.4%	-0.9%	-25.1%	-0.1%	0.5%	4.7%
RC Pier	3471	-2874	773	4891	4710	715
RC Pier vs. Mathcad Diff.	17.8%	-12.5%	-3.1%	1.4%	-10.7%	4.1%

US90 Project: 6 x Pile Bent Cap	Str_I $+M_u$ (kip*ft)	Str_I $-M_u$ (kip*ft)	Vu (kip)	$+M_r$ w/ 7#9 (kip*ft)	$-M_r$ w/ 8#6 (kip*ft)	V_r w/ #5@7.5" (2 legs) (kip)
EOR's Design	1255	-520	330	1348	921	365
FDOT Mathcad (conc.)	981	-443	467	1347	924	458
FDOT Mathcad (distr.)	753	-421	322			
Difference (distributed)	-21.8%	-14.8%	-2.4%	-0.1%	0.3%	25.5%
RC Pier	590	-495	412	1160	959	453
RC Pier vs. Mathcad Diff.	-21.6%	17.5%	28.1%	-13.9%	3.8%	-1.0%

SHRP2 Example 3b: 2-Column Cap Design	Str_I $+M_u$ (kip*ft)	Str_I $-M_u$ (kip*ft)	Vu (kip)	$+M_r$ w/ 10#11 (2 rows) (kip*ft)	$-M_r$ w/ 8#11 (kip*ft)	V_r w/ #6@ 9" (4 legs) (kip)
SHRP2 Example 3b	1901	-2263	354	2823	2396	809
FDOT Matchcad (dist.)	2626	-1799	351	2823	2396	711
Difference	38.2%	-20.5%	-0.9%	0.0%	0.0%	-12.1%
RC Pier	2504	-1613	276	2802	2422	663
RC Pier vs. Mathcad Diff.	-4.6%	-10.3%	-21.3%	-0.7%	1.1%	-6.8%

SHRP2 Example 3b: 2-Column Cap Design	Str_I $+M_u$ (kip*ft)	Str_I $-M_u$ (kip*ft)	Vu (kip)	$+M_r$ w/ 10#11 (2 rows) (kip*ft)	$-M_r$ w/ 8#11 (kip*ft)	V_r w/ #6@ 9" (4 legs) (kip)
SHRP2 Example 3b	1901	-2263	354	2823	2396	809
FDOT Matchcad (dist.)	2626	-1799	351	2823	2396	711
Difference	38.2%	-20.5%	-0.9%	0.0%	0.0%	-12.1%
RC Pier	2504	-1613	276	2802	2422	663
RC Pier vs. Mathcad Diff.	-4.6%	-10.3%	-21.3%	-0.7%	1.1%	-6.8%

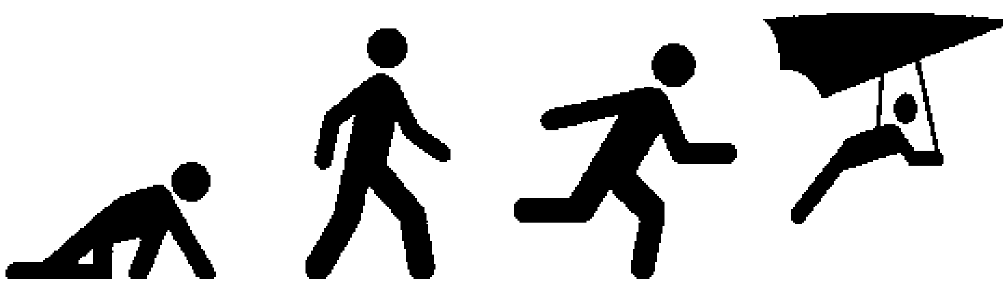
Comparisons of US 90 Demonstration project designs with new FDOT Mathcad program.

Comparison with two designs recently completed in-house, a published TxDOT Pile Bent Design Example (June 2010), the SHRP2 R04-RR-1 two-column bent cap design example, and analysis with Bentley's RC Pier software showed good correlation of results. Deviations in the results can be explained by the refinements in modeling and loading assumptions for the different designs.

Comparisons of other design examples with new FDOT Mathcad program

Implementation, Training & Tracking

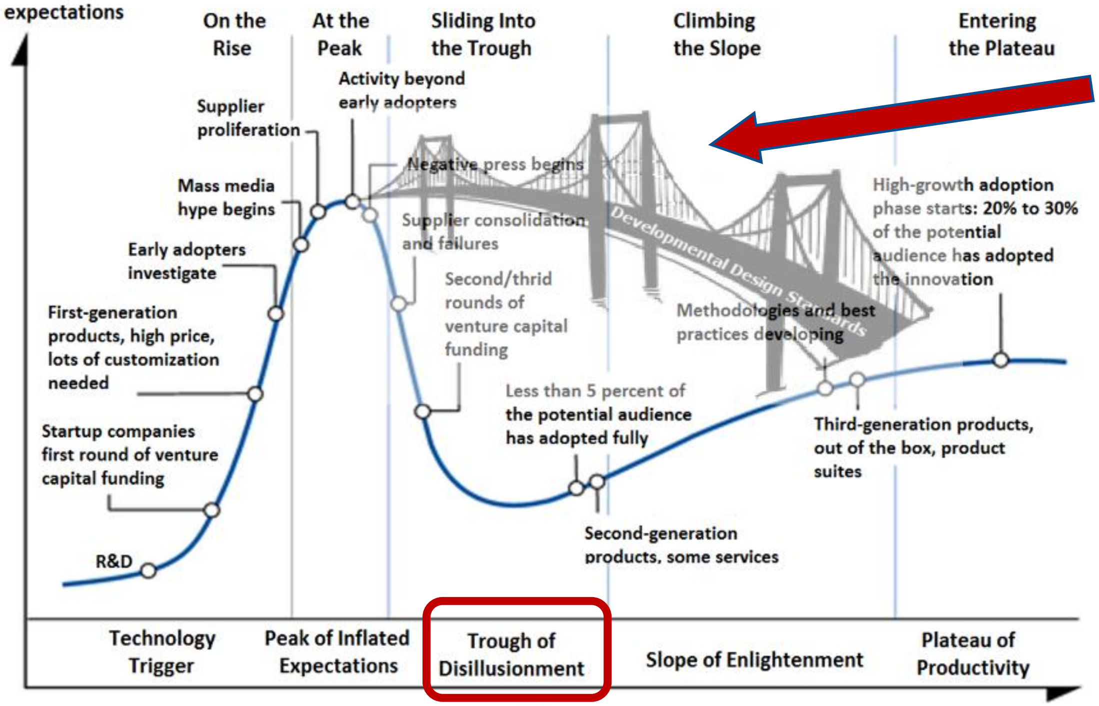
- Beta Testing of Mathcad Program – Oct-April 2015
- Draft ***Developmental Design Standard*** (***DDS***) Index D20710 & D20720 District & Industry Review – August 2016
- Preliminary Release - November 2016
- Draft D20730 - ?
- Design Update Training - February 2017
- Project Tracking and Monitoring – 2017 & 18
- Full ***Design Standard*** Implementation - ???



New NY Bridge (Tappan Zee) Precast Column Cap (Photo: courtesy of Coastal Precast Systems)

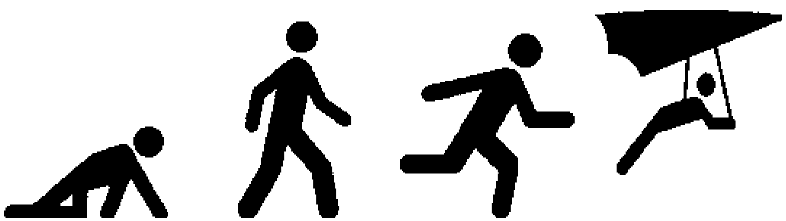
Research --> Demonstration Project --> DDS --> Design Standard Index

Implementation, Training & Tracking



Source: Gartner Inc. Hype Cycle

Developmental Design Standards (***DDS***) can provide a bridge across the *"Trough of Disillusionment"* (*Valley of Death*) for effective implementation!



Research --> Demonstration Project --> DDS --> Design Standard Index

2016 Design Training Expo

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http://www.dot.state.fl.us/structures/innovation/PBES.shtm

http://www.fhwa.dot.gov/everydaycounts/

Questions?

Contact Information:

Steven Nolan

State Structures Design Office

Design Technology –
Structures Standards Group

Steven.Nolan@dot.state.fl.us

Ph. 850-414-4272