2015 Design Training Expo

PBES – Full Depth Precast Deck Panel Development and Implementation

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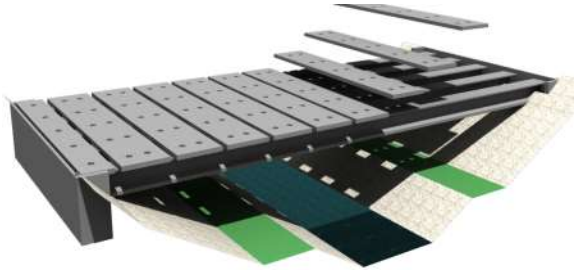
Agenda

- **Introduction to EDC, ABC & PBES**
- **Pilot Project**
- **Precast Deck Panel Design**
- Beam Design
- SRC Mock-UP
- Contract Documents
- Construction
- IBRD



As part of FHWA's *Every Day Counts* (ABC) initiative, Prefabricated Bridge Elements and Systems (PBES) are used with goals to:

- Improve safety on the construction site,
- Reduce onsite construction time,
- Improve constructability, and
- Improve quality.

In Florida:

- Most common bridge type → Prestressed Beam with C.I.P. Deck
- Cast-In-Place Deck → Significant portion of the Construction Time
- Improved durability

Initial Design Considerations for Full Depth Precast Deck Panels

Longitudinal Post-Tensioning ✗

Specialized labor/equipment | Shop Drawings Required | Inspections

Deck Continuity over Intermediate Bents ✗

No Expansion Joints | Transverse Joints will be less subjected to shrinkage & temperature effects

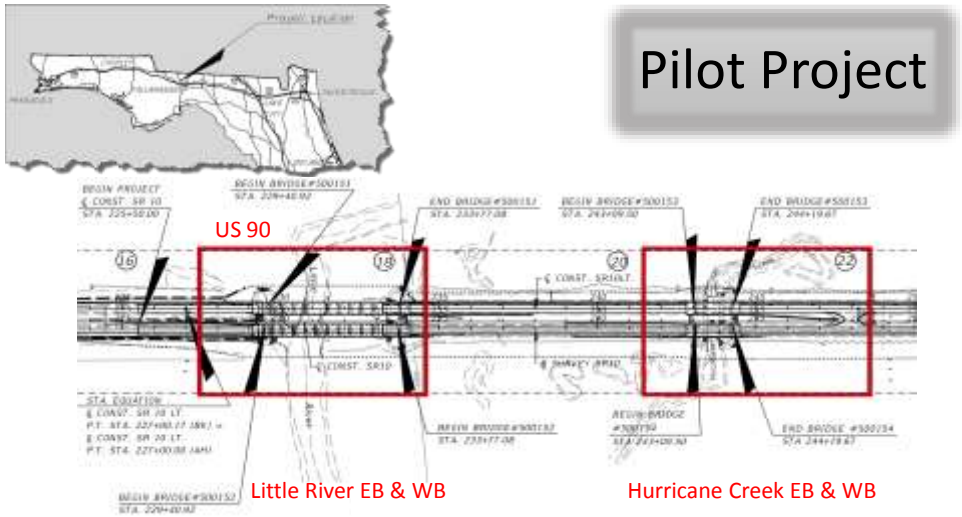
Transverse Prestressing ✓

Future Widening | Specialized labor/equipment | Consider on-site or near-site casting

Mild Reinforced (Non-prestressed) ✓

Innovative Solutions for tomorrow's transportation needs

Pilot 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

Precast Deck Panels Development for US 90

Preliminary Analysis
- Different Girder Spacings (6, 9, 12 ft)
- Preliminary Models
- Thickened Edge Study

→ **Design**
- Flexure
- Stresses
- Construction Cases

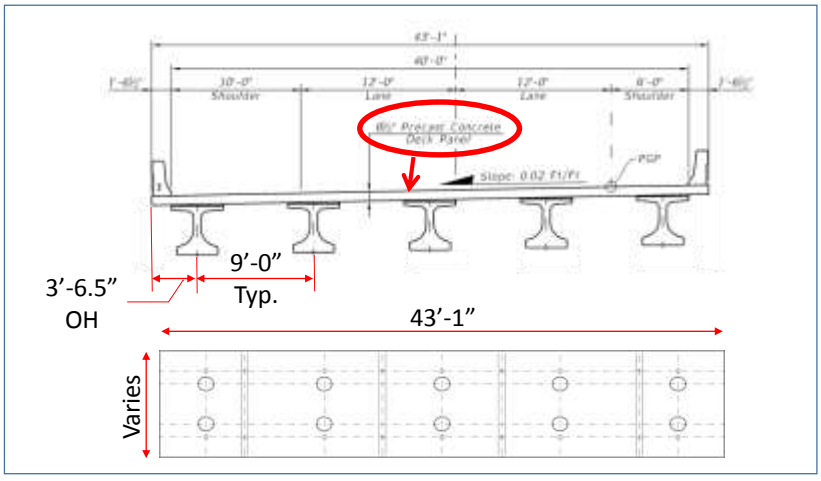
→ **Analysis**
- -Lifting – Different Support Conditions & Different Methods
- Leveling – Different Support Conditions
- Differential Creep – PT Panels

↓

Refined Design
- Different Panel Thicknesses for PT Panels
- Stresses Due to Lifting

→ **Testing** → **Structural Plan Sheets & Details**

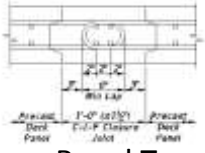
Geometry



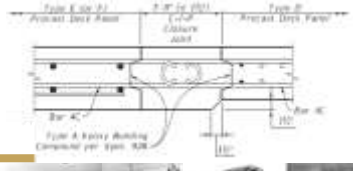
Panel Types

Note:
Reinforced Panels – Eastbound Bridges
Prestressed Panels – Westbound Bridges

- Mild Reinforcement – All Panels 8.5" Deck Thickness
  - Type A – Typical Panel 8'-0" x 43'-1"
  - Type B – Edge Panel 7'-6" x 43'-1"
  - Type C – Edge Panel 5'-0" x 43'-1"



- Prestressed – Varying Deck Thickness Among Panel Type
  - Type D – Typical Panel 8'-0" x 43'-1" → 8.5" Deck Thickness
  - Type E – Edge Panel 7'-6" x 43'-1" →10" Deck Thickness
  - Type F – Edge Panel 5'-0" x 43'-1" → 10" Deck Thickness



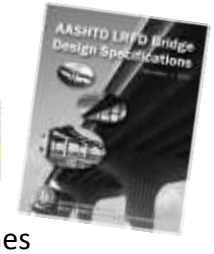
Design & Design Methods

- LOADS:
  - Construction – Lifting & Leveling
    - Dead Load – Self Weight → 8.5" (or 10") Deck Thickness
    - Live Load – 20 psf (Leveling Only)
    - IM = 1.5
  - Final
    - Dead Load – Self Weight → 8" (or 9.5") Deck Thickness & Future Wearing
    - Live Load – HL-93
    - IM = 1.33
- SUPPORT CONDITIONS:
  - Lifting → 4 support points
  - Leveling & Final → 5 support points

Design & Design Methods

- DESIGN – Strength I & Service I:
  - Construction – Lifting & Leveling →Finite Element Model (FEM)*
  - Final
    - Dead Load – Beam Line Model*
    - Live Load - AASHTO LRFD Appendix 4A, Deck Slab Design Table

S		Positive Moment	Negative Moment: Distance from CL of Girder to Design Section for Negative Moment						
			0.0 in.	3 in.	6 in.	9 in.	12 in.	18 in.	24 in.
8"	-6"	5.99	6.66	5.82	4.98	4.14	3.61	2.96	2.58
8"	-9"	6.14	6.74	5.90	5.06	4.22	3.67	3.15	2.79
9"	-0"	6.29	6.81	5.97	5.13	4.28	3.71	3.51	3.00
9"	-3"	6.44	6.87	6.03	5.19	4.40	3.82	3.47	3.20

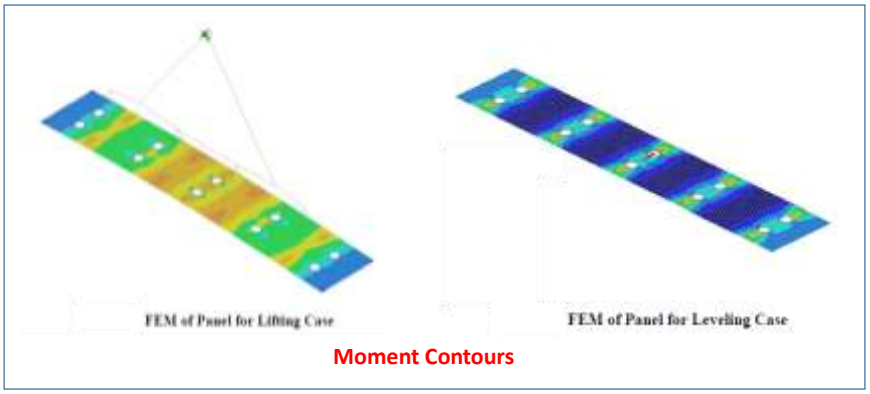


- OVERHANG DESIGN – FDOT Structures Design Guidelines
  - Minimum Area of Steel

*Modeling was done using LUSAS and checked using RISA

Design & Design Methods

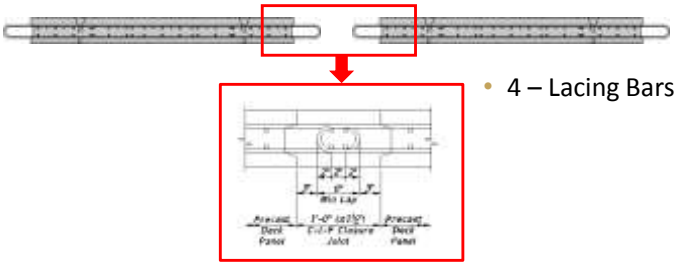
- DESIGN – CONSTRUCTION



Moment Contours

*Modeling was done using LUSAS and checked using RISA

Design & Design Methods



- 4 – Lacing Bars

Hoop Bar Details

Min. Pin Diameter

Note: The main steel is the inside layer so distance from extreme compression fiber to the centroid of the tensile reinforcement (d) gets smaller → Moment Capacity decreases

Design & Design Methods

Reinforced Panels

DESIGN FINAL

Panel Type		Reinforcement for Final Design	Reinforcement for Lifting Design	Reinforcement Provided on Plans
Type A	Typical Span	#5 @ 6.5″ T #5 @ 6.5″ B	Add (10) #4 T	(10) #4 & (15) #5 T (15) #5 B
8′-0″	OH	#5 @ 3.25″ T #5 @ 6.5″ B	NA	(25) #5 T (19) #5 B
Type B	Typical Span	#6 @ 7″ T #6 @ 4″ B	Add (2) #6 T	(18) #6 T (25) #6 B
7′-6″	OH	#6 @ 3.5″ T #6 @ 4″ B	NA	(20) #6 T (23) #6 B
Type C	Typical Span	#6 @ 7″ T #6 @ 4″ B	Add (6) #6 T	(15) #6 T (17) #6 B
5′-0″	OH	#6 @ 3.5″ T #6 @ 4″ B	NA	(15) #6 T (15) #6 B

Design & Design Methods

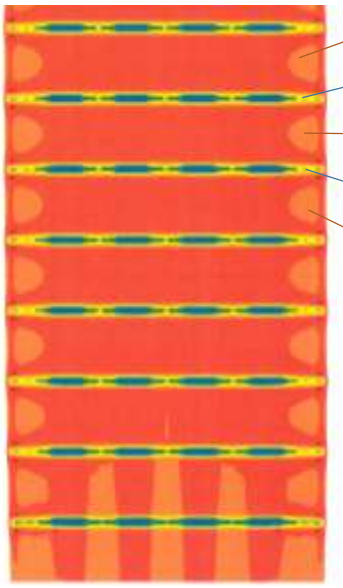
Prestressed Panels

FINAL

Panel Type		Mild Reinforcement	Prestressed Steel Design	Total Area of Prestressed Steel	Area of Concrete	Area of Strands/Area of Concrete
Type D	Typical Span	(12) #4 T (12) #4 B	(5) 0.5″ Dia. T (5) 0.5″ Dia. B	10 x 0.153 = 1.53 in^2	**8″** x 8′-0″ = 5.33 SF	1.53/5.33 = **0.29 in^2/SF**
8′-0″	OH	(18) #5 T (14) #5 B				
Type E	Typical Span	(12) #7 T (12) #7 B	(6) 0.5″ Dia. T (6) 0.5″ Dia. B	12 x 0.153 = 1.84 in^2	**10″** x 7′-6″ = 6.25 SF	1.84/6.25 = **0.29 in^2/SF**
7′-6″	OH	(12) #7 T (18) #7 B				
Type F	Typical Span	(7) #7 T (7) #7 B	(4) 0.5″ Dia. T (4) 0.5″ Dia. B	8 x 0.153 = 1.22 in^2	**10″** x 5′-0″ = 4.17 SF	1.22/4.17 = **0.29 in^2/SF**
5′-0″	OH	(8) #7 T (13) #7 B				

Design & Design Methods

Prestressed Panels



Accounting for Differential Creep:
- Panels → Prestressed
- Closure Joints →Mild Reinf

Specification Section DEV404:

Precast Deck Panel (non-prestressed)	Move from casting bed to storage	9 days
	Ship and/or Erect	28 days
	Grouting Operation	28 days
Precast Deck Panel (pretensioned)	Move from casting bed to storage	9 days
	Ship and/or Erect	28 days
	Grouting Operation	60 days

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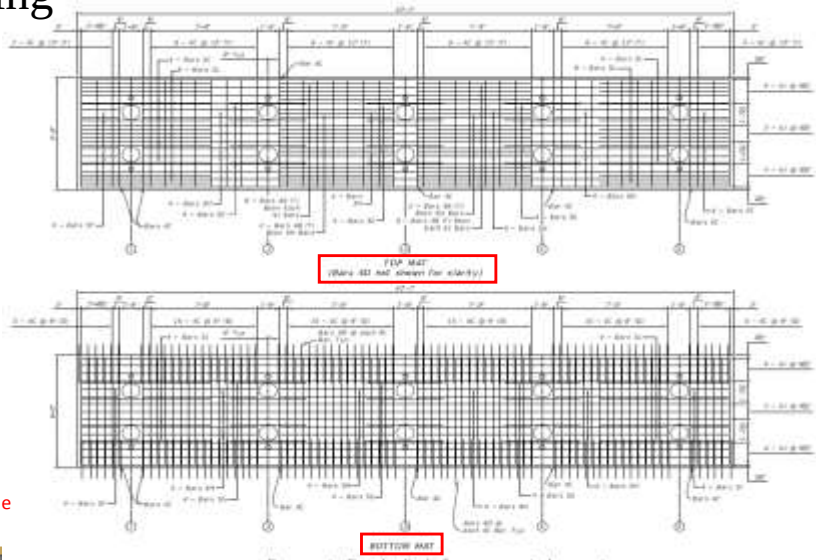
Detailing



Does not include Barrier Steel

Precast Deck Reinforcement Layout

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Detailing - Reinforcement Challenges

- Voids in the Panel
  - Shear Pockets
  - Leveling Device
  - Lifting Inserts
  - Keyway (Cover)
  - Scuppers in Closure Joint
- Barrier Steel
- Additional Steel for Lifting
- Accommodate for Future Widening
- Develop Prestress Strands at Panel Ends
- Temperature & Shrinkage Steel Requirements
- Hoop Bars & Lacing Bars for Closure Joint
- Longitudinal Steel → Outermost Layer of Steel
- End Panel(s) (aka Thickened Slab End in SDG)

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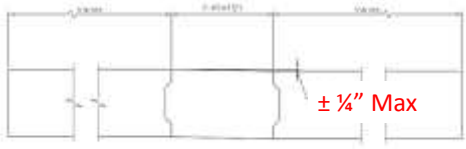
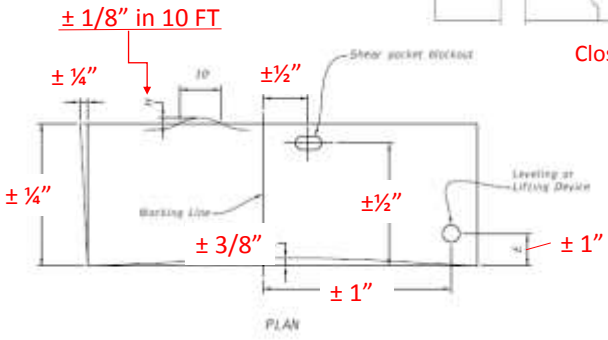
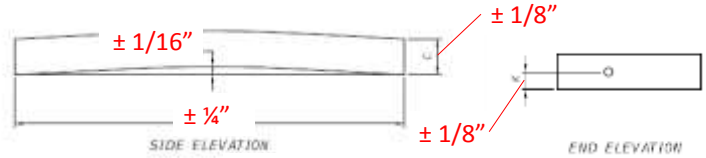
Detailing – Tolerances

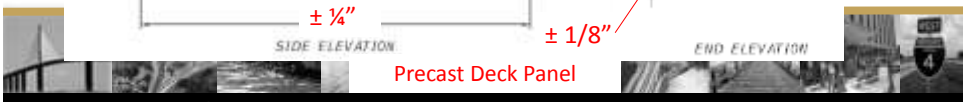


Closure Joint





Precast Deck Panel



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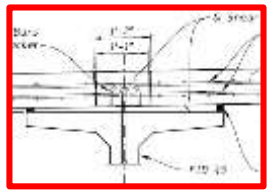
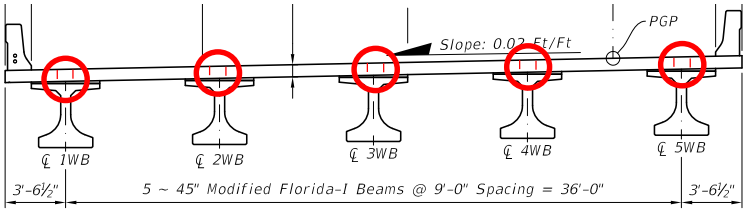
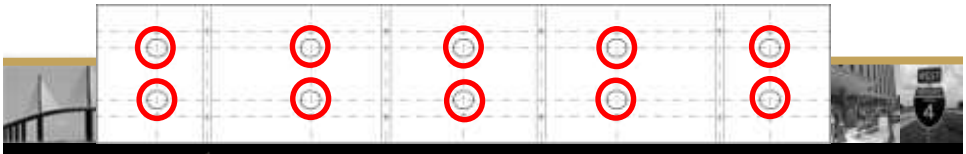
Shear Pocket Details

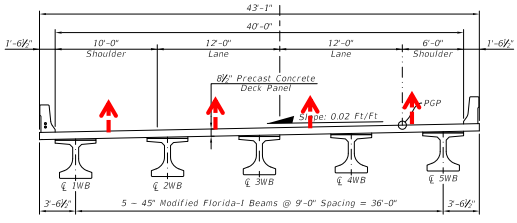


Shear Pockets (full depth)

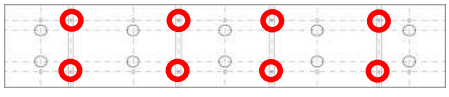




Lifting



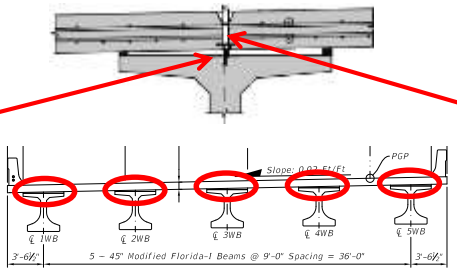
Lifting Points for handling & erection



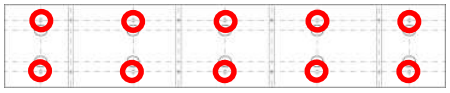
- Designed for 8-point lifting points (all panels)
- Reinforced Panels (Type A, B & C)
  - Dead Load w/ IM = 1.5
  - Limit reinforcing steel stress to 32 ksi
- Prestressed Panels (Type D, E & F)
  - Dead Load w/
    - IM = 1.3 for yard lifting and handling
    - IM = 1.5 for transport and erection

Leveling

Cast Into Beam: Steel Plate on the Top of Girders placed at Leveling Bolt locations



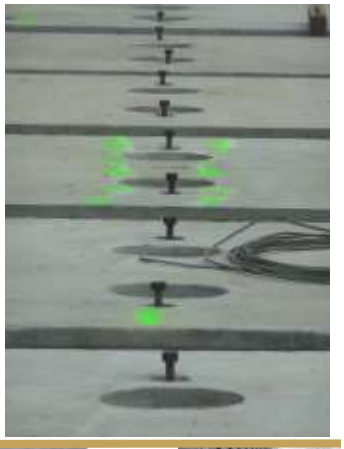
Leveling Devices



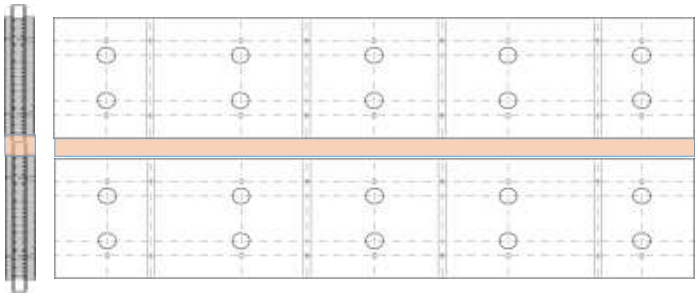
Cast Into Panel: Square Washer, Pipe, & Nuts

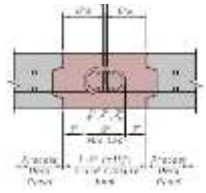
Leveling – What exactly do we mean by **leveling**?

- Steps:
  - Survey top of beam elevations
  - Preset Leveling Bolts to anticipated height
  - Erect Panels within a span
  - Adjust leveling devices to bring them to grade
  - Survey top of beam after all panels have been placed & leveled.
  - Submit information to Engineer for review
  - If survey data does not produce required dead load distribution → reset all panels with the span, resurvey and resubmit to the Engineer for review



Closure Joints





- **1'-0" Cast in Place Closure Joints filled with Class II (Bridge Deck) w/ SRA Concrete on Site**
- **Type A Epoxy on Keyway to bond fresh concrete to hardened concrete**

PDP = Precast Deck Panel
SRA = Shrinkage Reducing Admixture

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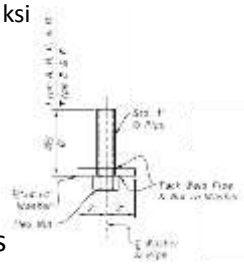
Specifications & Materials

- Plans & Plan Notes:
  - Concrete Strength
    - PDP Class II (Bridge Deck) = 4.5 ksi (Mild Reinforcement)
    - PDP Class IV = 5.5 ksi, 4.4 ksi Release (Prestressed)
    - C.I.P. Closure Joints Class II (Bridge Deck) w/ SRA = 4.5 ksi
  - Structural Steel for Leveling Bolts
    - Bolt → A193 B7 or F1554 Grade 55
    - Pipe → A53 Gr. B
    - Washer → A36 & Nut → For A193 Bolt – A194 Grade 2H For F1554 Bolt – A194 Grade 2H or A563 Grade A Hex
  - Reinforcement → 60 ksi
  - PT → 0.5" Dia. Grade 270 Low Relaxation Strands



PDP = Precast Deck Panel
SRA = Shrinkage Reducing Admixture

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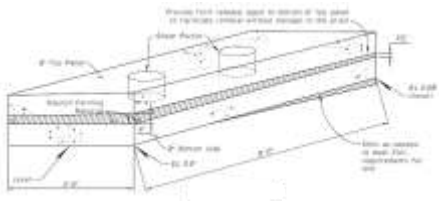
Grouting Demonstration Test



Objective of Test:

- Demonstrate Grout Properties
- Adequacy of Equipment
- Forming Material
- Familiarize Job Site Personnel with Grouting Procedure

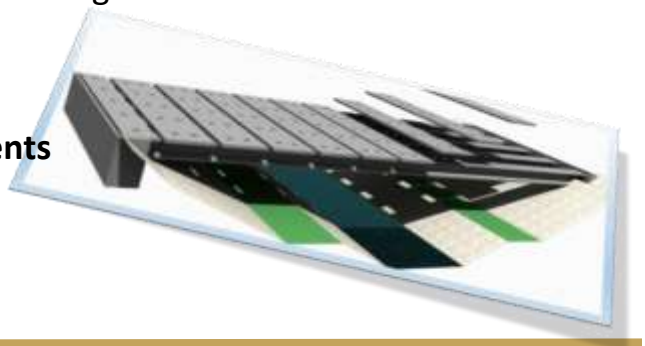
Conclusion:

- Maintain the Grout at 70 degrees F to meet the efflux requirements and to ensure a flowable /fluid mix
- Use 4 grout tubes (1 at each corner) for each haunch area.
  - Previous plan was only for 2 at high point.
- Total percentage of voids → 6%
  - The largest void was 2% of the total area.
- The haunch foam was hard to remove after the test → Use less glue in the field.

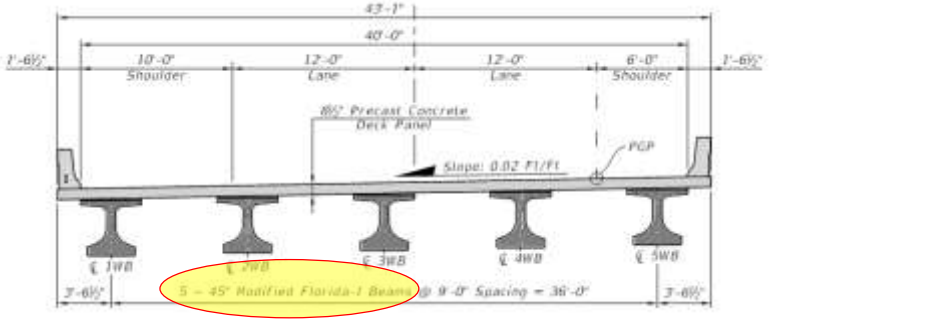
Panels Installed

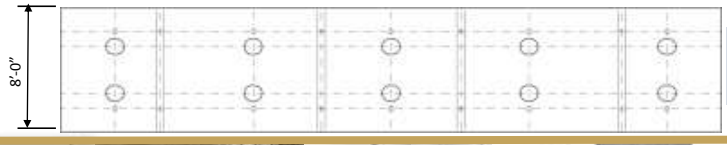
Agenda - Continued

- Introduction to EDC, ABC & PBES
- Pilot Project
- Precast Deck Panel Design
- **Beam Design**
- **SRC Mock-Up**
- **Contract Documents**
- **Construction**
- **IBRD**



Beam Design
Superstructure Typical Section





Reinforced or
Prestressed
8'-0" x 43'-1" (typ.)

Beam Design Methodology

AASHTO LRFD BDS (5th edition)

C5.8.4.1: "Composite section design utilizing full-depth precast deck panels is not addressed by these provisions. Design specifications for such systems should be established by, or coordinated with, the Owner."

(Changed at the 2013 AASHTO SCOBS Annual Meeting)

Methods for Interface Shear Design

Equilibrium Forces	Global Moment Capacity	Classical (elastic) Strength of Materials Method
AASHTO LRFD 5.8.4	AASHTO 6.10.10.4	VQ/I
CIP Deck on PS Beams	CIP Deck on Steel Girders	

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Limit States

Strength I Load Combination

Cohesion and Steel

Strength II Load Combination

Consider only cohesion no slip under normal loading conditions
Use HL-93 live load

Cohesion and Friction Factors

Shear pocket and closure pour areas

CIP concrete slab on clean concrete girder surfaces, free of laitance with surface roughened to an amplitude of 0.25 in.

Other area based on a clean unroughened surface

K1 and K2 are also conservatively based on a clean unroughened surface.

Shear Pocket Spacing

AASHTO 5.8.4.2 limit of 24"

NCHRP Report 584

PCI journal article 'Composite Behavior of Precast Concrete Bridge Deck-Panel Systems' equation for the shear pocket spacing resulted in a maximum of 45 inches

Design Exception approved (changed in 2013)

Minimum Reinforcing

Due to wide flange of FIB

AASHTO 5.8.4.4 not met

Design satisfied two methodologies

Design Exception approved

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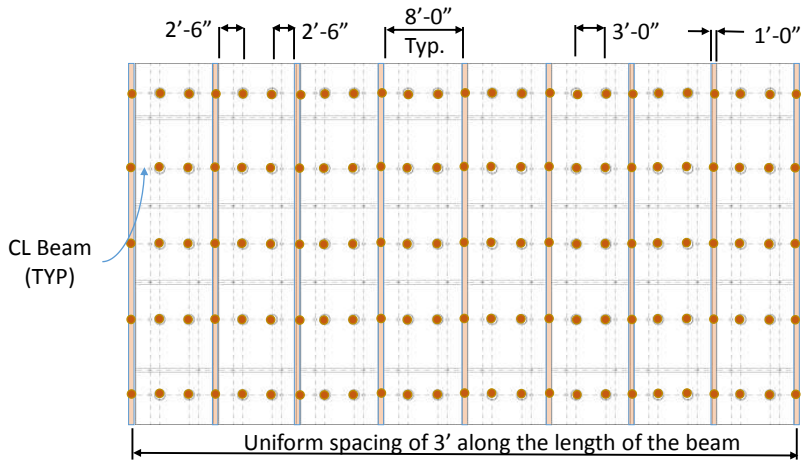
Horizontal Shear Reinforcing Layout



Strength I
Shear Resistance

Strength II
Shear Resistance

Everywhere else

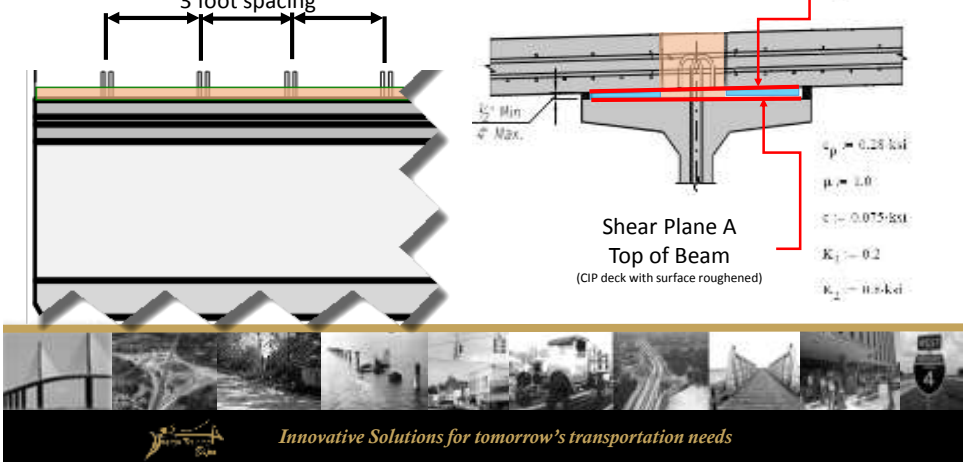
Shear Pocket and
Closure Joint

3 foot spacing

AASHTO 5.8.4.1-3

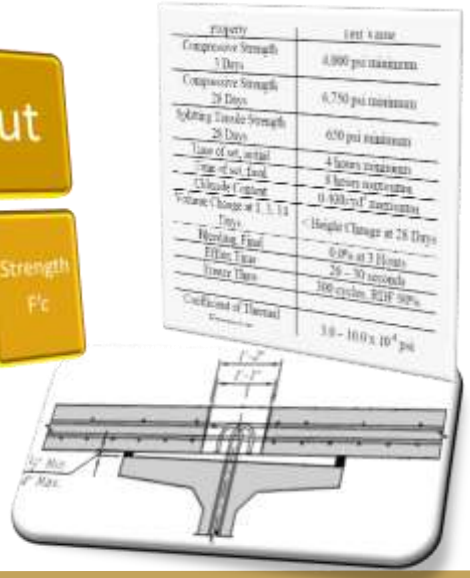
Shear Plane B
Bottom of PDP
(normal weight concrete placed
monolithically)

Shear Plane A
Top of Beam
(CIP deck with surface roughened)



Precision Grout

- Non-Shrink
- Fluid
- Extended Working Time
- Strength F'c



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SRC Mock-up

Reinforcement Challenges	Evaluate Products	Lifting and Leveling	Construction Methods
Shear Pockets	Grout	8 lifting points	Grouting
Lifting Devices	Haunch Form Material	10 leveling points	Transverse Closure Joint • Epoxy and • Concrete w/ SRA
Leveling Inserts	Concrete w/ SRA	Strain Gages to measure stresses	
Hoop Bars	Lifting Inserts		
Transverse Closure Joints	Leveling Device		

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Shear Pocket Blockout Forms
Leveling Device
Haunch Forming Material
PDP Forming
PDP Lifting
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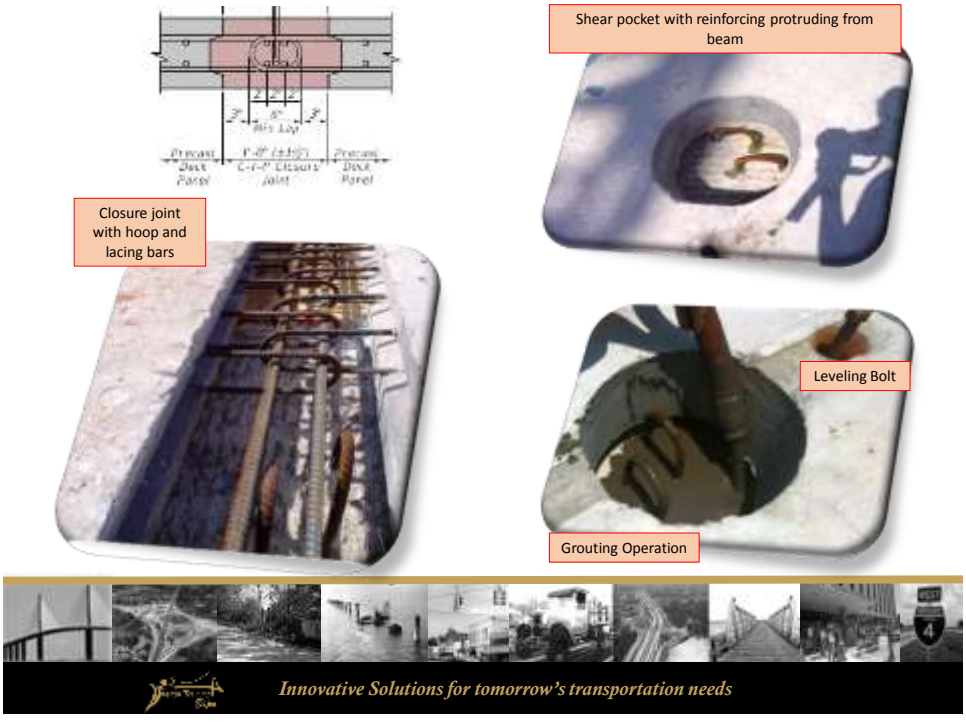
Shear pocket with reinforcing protruding from beam
Closure joint with hoop and lacing bars
Leveling Bolt
Grouting Operation
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Contract Documents

Plans

Specifications

Special Provisions

Developmental

Supplemental

Standard

Developmental Specifications 404
Precast Concrete Elements for Bridge Construction

Precast elements - fabricate, handle, store, ship and erect precast concrete bent caps and deck panels

Connections – attaching or joining precast elements with cast-in-place closure joints or grouted connections with details shown on the plans and in accordance with this Section

Fabricate precast elements in a precast plant, forming and curing in accordance with this Section and Section 400.

Fabricate prestressed precast deck panels in accordance with Section 450. Handle, store, ship, erect and complete construction of prestressed precast deck panels as precast deck panels in accordance with this Section while maintaining handling requirements as specified in Section 450.

Developmental Specifications 404
Precast Concrete Elements for Bridge Construction

Contents

- 404-1 Description
- 404-2 Materials
- 404-3 General
  - (Precast Placement Plan)
  - (Grout Demonstration Test)
- 404-4 Precast Bent Caps
- 404-5 Precast Deck Panel
  - (Transverse Closure Joints)
- 404-6 Method of Measurement
- 404-7 Basis of Payment

Affected Specifications

Supplemental Specifications

- 400 Concrete Structures
- 450 Precast Prestressed Concrete Construction (prestressed PDP)
- 455 Structures Foundations
- 924 Admixtures for Concrete (SRA)
- 934 Non-Shrink Grout (Precision Grout)

404-7 Basis of Payment

Item No. 404-1 Precast Bent Caps – per cubic yard

Item No. 404-5 Precast Deck Panel – per square yard

Item No. 404-6 Grout for Precast Deck Panel – per cubic yard

Item No. 404-7 Closure Joint for Precast Deck Panel – per linear foot

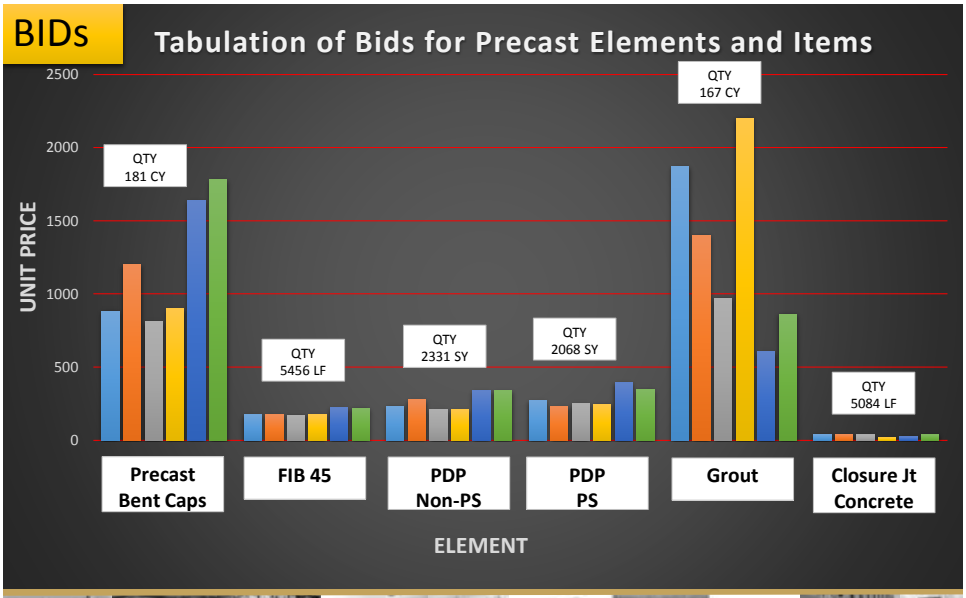
Construction

- BIDs
- FIB Fabrication
- PDP Fabrication
- Haunch Forming
- PDP Erection
- PDP/Haunch Grouting
- Transverse Closure Joint

BIDs

Contractor	Bid Total
Anderson Columbia Co., Inc.	$9,576,951.91
GLF Construction Corp.	$9,670,927.11
Sema Construction, Inc.	$10,161,111.00
Superior Construction Co. Southeast, Inc.	$10,294,502.23
Scott Bridge Co., Inc.	$10,420,342.13
Orion Marine Construction, Inc.	$12,622,164.98

BIDs



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FIB Fabrication

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PDP Fabrication

PDP Fabrication

- Engineering Analysis Report (EAR) →
  Cracking in the Precast Deck Panels – Non Prestressed

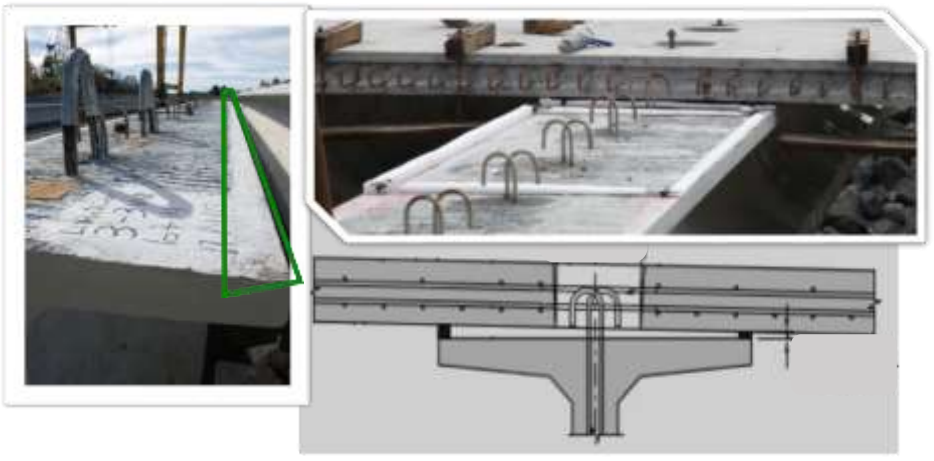
PANEL TYPE	A	B	C
No. of Panels	**54**	**2**	**8**
No Cracks	3	1	0
ISOLATED	44	0	6
OCCASIONAL	7	1	2

PANEL TYPE	WIDTH OF CRACK (in)			
	0.012	**0.014**	**0.016**	**0.018**
A	15	0	7	0
B	1	0	0	0
C	4	2	1	1

ISOLATED = Area of Cracking/Area of Panel < 0.0005%
OCCASIONAL = 0.017% > Area of Cracking/Area of Panel > 0.0005%

- Only 1 Panel required treatment
  - Epoxy Injection OR Methyl Methacrylate

Haunch Forming



PDP Erection

PDP/Haunch Grouting

Transverse Closure Joint

Completed Bridge

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Monitoring Project - IBRD

- Load testing pre-service
- Monitoring in service
- Annual BIR
- Load testing in-service

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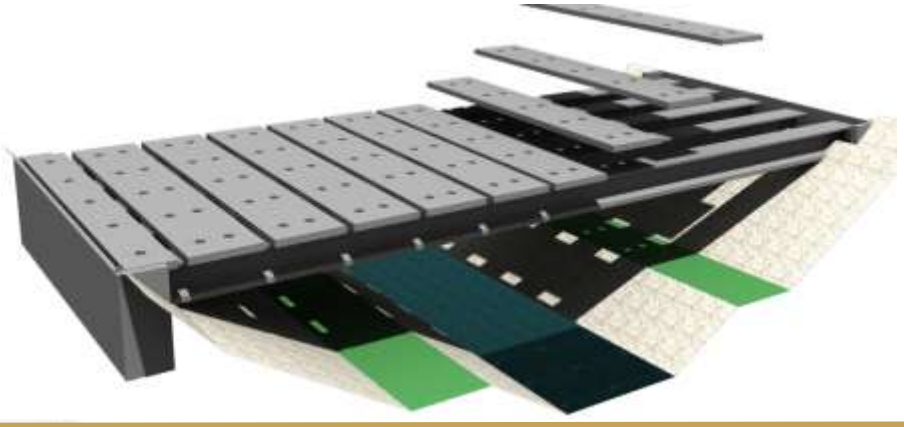
Thank You!

PBES – Full Depth Precast Deck Panel Development and Implementation

Vickie Abalo, PE
Dennis Golabek, PE
Structures Design Office



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