2016 PTI Convention
Long Beach, California

Technical Session 2

Bridge Design and Construction

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FHWA DTFH6114D00048-Task 5009

DEVELOPMENT OF FHWA GUIDANCE FOR MONITORABLE, REPLACEABLE AND ASSESSABLE PT TENDONS

Presented by:

Trey Hamilton, P.E., Ph.D, University of Florida
Tony Ledesma, P.E., WSP|Parsons Brinckerhoff
Ian Hubbard, P.E., WSP|Parsons Brinckerhoff

April 25, 2016

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Presentation Goals:

Background

- Recent improvements have been made in the design, construction and inspection practices of post-tensioned (PT) bridges in the US. However, our industry should continue to develop new methods and tools to advance the state of practice for PT bridges to ensure they meet their intended service life.
- This research project will bring new technologies to US practices such as EIT monitoring, replaceable external PT, and provide a critical assessment of the current construction practices to further improve the existing US practices.

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Presentation Outline

1. Introduction
2. Sub-Task 2 : Monitorable PT Tendons
3. Sub-Task 3: Replaceable PT Tendons
4. Sub-Task 4: Assessable PT Tendons

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PRINCIPAL-IN-CHARGE
Barton Newton, PE

PROJECT MANAGER
Joe Tse, PE

PROJECT OPERATIONS MANAGER / TECHNICAL OPERATIONS MANAGER
Pepe Garcia, PE

TECHNICAL WORKING GROUP
Teddy Theryo, PE
(Former PB now with FDOT)

TASK LEADS
Piotr Paczkowski, PhD, PE
Trey Hamilton, PE, PhD (UF)

TECHNICAL ADVISOR
Hans Ganz, PhD (GC)

SUB-TASK 1: KICK-OFF MEETING
TWG Coordinator
Piotr Paczkowski, PE, PhD
Management & Admin Support
Pepe Garcia, PE

SUB-TASK 2: MONITORABLE PT TENDONS
Markus Büchler, PhD (SGK)
Ueli Angst, PhD (SGK)
Trey Hamilton, PE, PhD (UF)
Piotr Paczkowski, PhD

SUB-TASK 3: REPLACEABLE PT TENDONS
Antonio Ledesma, PE
Victor Ryzikov, SE, PE

SUB-TASK 4: ASSESSABLE PT TENDONS
Ian Hubbard, PE
Trey Hamilton, PE, PhD (UF)
Greg Hunsicker, PE (VSL)
Orlando Colon

SUB-TASK 5: QUARTERLY REPORTING
John Chow, AICP
Sylvia Lui (Admin Support)
Piotr Paczkowski, PE, PhD

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Technical Working Group (TWG) Rosters

NO.	Name	Affiliation
Government / DOT		
1	Reggie Holt	FHWA
2	Michael Sprinkler	VDOT
3	Claude Napier	VDOT
4	Robert Robertson	FDOT
5	Dan Hurtado	FDOT
6	Bijan Khaleghi	WSDOT
7	Leon Flournoy	TxDOT
8	Courtney Holle	TxDOT
9	Susan Hida	Caltrans
10	Craig Knapp	Caltrans
11	Nancy Daubenberger	MnDOT
12	Dustin Thomas	MnDOT
13	Jim Ma	Caltrans
Industry / Manufacturers		
1	Ted Neff	PTI
2	Randy Cox	ASBI
3	Guido Schwager	Schwager Davis, Inc.
4	Drew Micklus	Freyssinet
Consultants		
1	John Corven	Corven Eng
2	Brian Merrill	WJE
3	Brett Pielstick	Eisman & Russo
4	Jerry Pfuntner	Finley Engineering Group, Inc.

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Goals and Objectives of the Research

- Advance the ability to monitor, replace and evaluate future Post-tensioned bridges
- Improve durability of future PT bridges using monitoring and installation validation technologies.
- Improve quality of future PT bridges through a better construction inspection and material testing procedure
- Develop specification language for Sub-Tasks 2 and 3 to be included in the PTI/ASBI M-50 “Guide Specification for Grouted Post-tensioning”
- Develop manual / guidance for Bridge Owners
- Develop outreach and educational materials

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Sub-Task 2: Monitorable PT Tendons

Electrically Isolated Tendons (EIT) has been identified as a viable monitorable technology for grouted PT tendons

The research approach is divided into several phases of activities:

Phase 1: Review literatures of existing Swiss manuals and other countries (if available) for adoption to US application

Phase 2: Develop EIT manual / guidelines, included component requirement, installation, performance test, monitoring device, procedures and QA-QC for US implementation

Phase 3: Develop specification language plus texts for inclusion in the PTI/ASBI M-50 “Guide Specification for Grouted Post-Tensioning”

Phase 4: Develop a two-hour Power Point presentation plus texts

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Sub-Task 2: Monitorable PT Tendons

Status of Sub-Task 2

Research start date: January 2015

Submitted 1st draft: April 2015

Submitted 2nd draft: July 2015

Submitted 3rd draft: September 2015

Remaining work:

- Specification Language
- Two hours Power Point Presentation

Expected completion: Fall 2016

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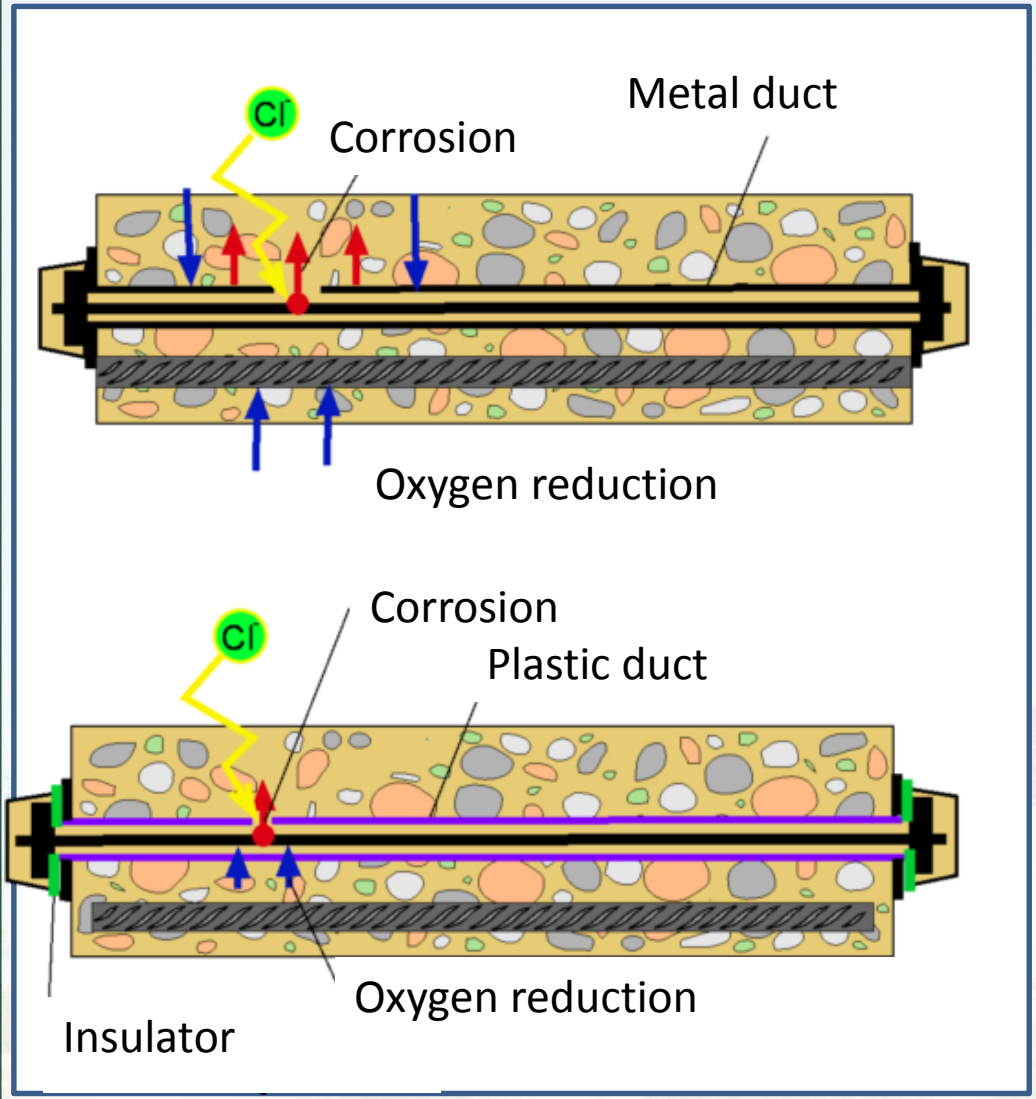
Sub-Task 2: Basic Principal of EIT



- Access of aggressive substances to the steel is blocked
- Efficiency of the insulation can be controlled
- Corrosion rate is decreased in case of activation

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Sub-Task 2: Swiss Experience

The Swiss experience on about 120 structures (mainly bridges) with EIT installed since 1993 shows

- On very long tendons (several 100 m (300 feet)) “learning effect” (workmanship, training)
- Instruction of persons working on site is very important (handling of plastic ducts, precautions)
- Qualification and certification of PT personnel is considered a key element to assure long term durability of PT systems
- Use of electrically isolated tendons has to be specified from the beginning of the project: design, construction, and quality control.

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Sub-Task 2: Monitorable PT Tendons

PTI/ASBI M50 "GUIDE SPEC. FOR GROUTED PT" PROTECTION LEVEL

- PL1A: duct with filling material providing durable corrosion protection.
- PL1B: PL1A plus engineered grout and permanent grout cap.
- PL2: PL1B plus an envelope, enclosing the tensile element bundle over its length, and providing a permanent leak tight barrier (encapsulation).
- PL3: PL2 (encapsulation) plus Electrical Isolation Tendon (EIT) to be monitorable or inspectable at any time.

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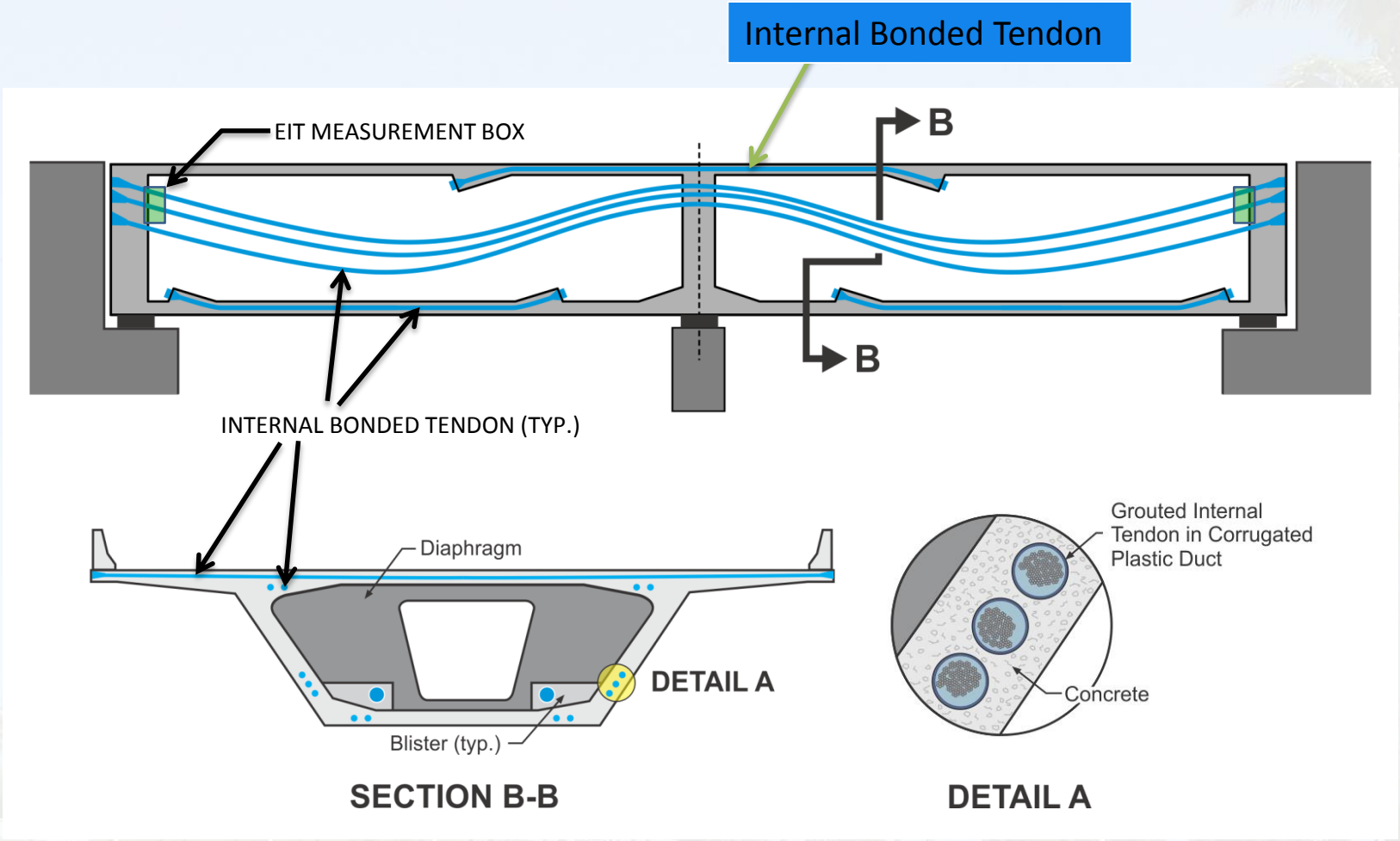
Sub-Task 2: Monitorable PT Tendons



Cast-in-place Bridge On Falsework (potential application)

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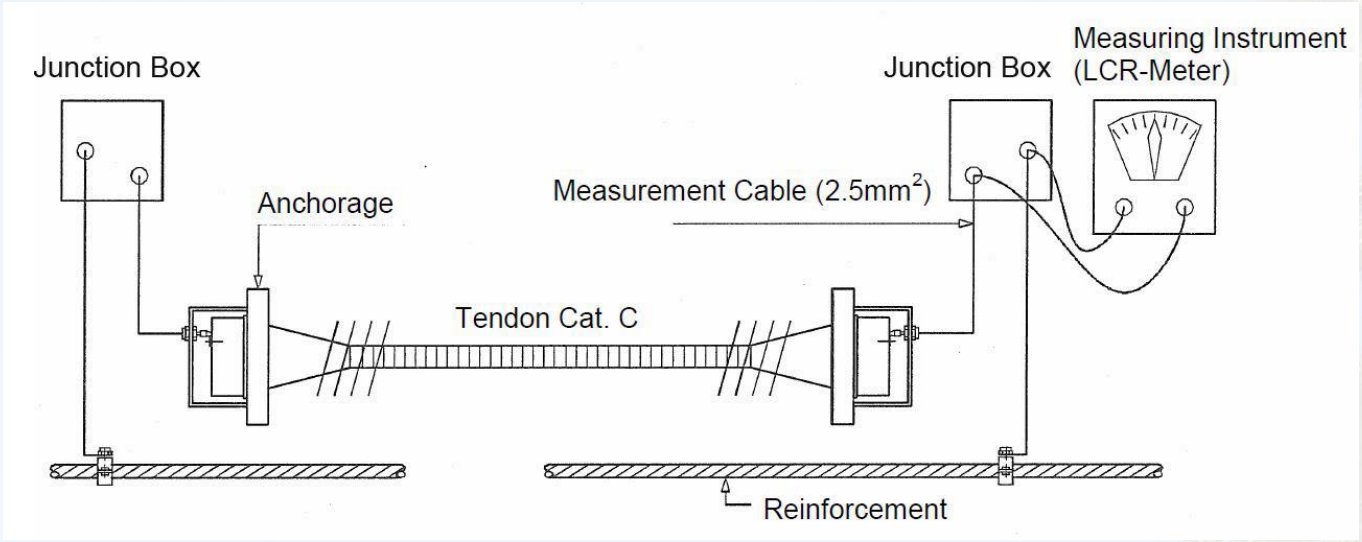
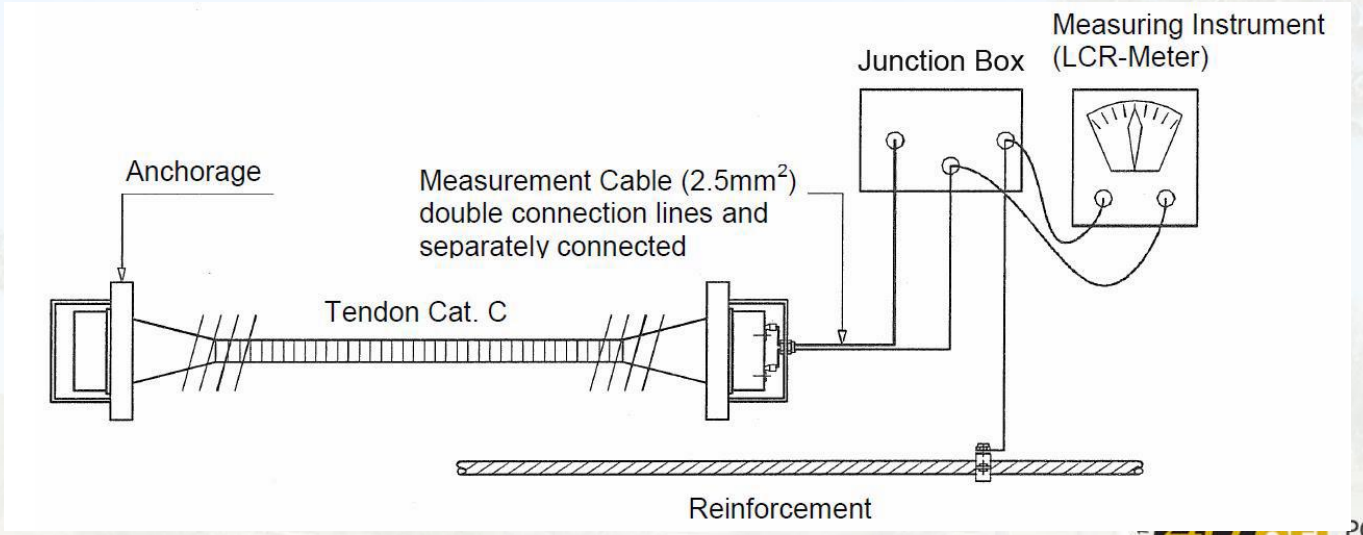
Sub-Task 2: Monitorable PT Tendons



Electrical connection to a tendon at both ends



Electrical connection to a tendon at one end only

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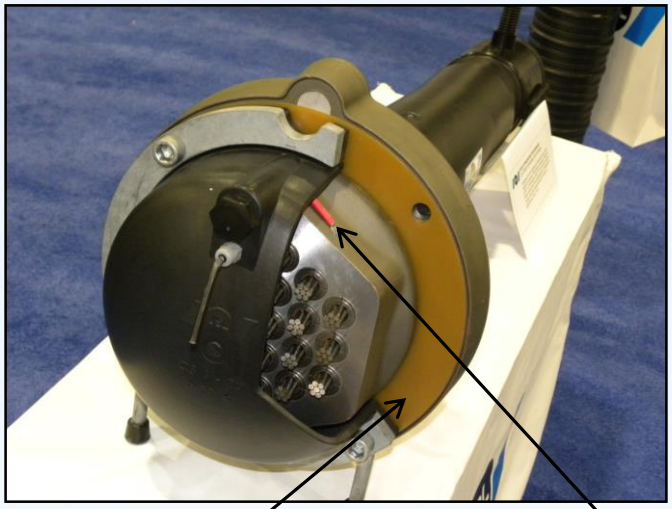
Sub-Task 2: Monitorable Internal PT Tendons

EIT cable, plate and LCM meter



EIT Plate

EIT Cable

LCM Meter

Sub-Task 2: Monitorable PT Tendons

Protective shell and plastic tie at duct support in the tight tendon curve zone

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Sub-Task 2: Monitorable PT Tendons

	Main criterion Monitoring	Fatigue	Stray current
Duct Ø	Specific resistance $R_l = R \cdot L$	Resistance R	Specific resistance $R_l = R \cdot L$
60 mm	>50 kΩm	>20 Ω	>250 kΩm
75 mm	>50 kΩm	>20 Ω	>200 kΩm
100 mm	>50 kΩm	>20 Ω	>150 kΩm
130 mm	>50 kΩm	>20 Ω	>125 kΩm
Max. tolerable failure rate	10%	0%	20%

Threshold for EIT, applicable 28 days after grouting (according to Swiss Guidelines)

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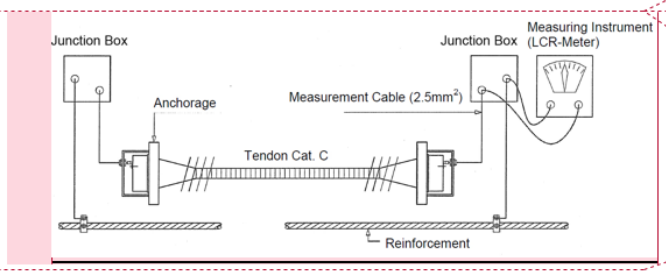
EIT Specifications

SPECIFICATIONS	COMMENTARY
4.3.13 – Electrical Components for PL-3 Wiring used for electrical measurements on PL-3 tendons shall be at least #12 AWG solid copper. Wiring shall have water-proof insulation. When cast into concrete, the insulation shall be resistant to alkaline environment in the concrete. Alternatively, wiring shall be permitted to be placed in non-conductive electrical conduit. Electrical contact to the tendon shall be located at the anchorage by means of a bolted cable strap. Galvanized conductors and contact bolts shall not be permitted. Protect bare metallic surfaces from corrosion to ensure unimpeded electrical contact. After installation of connections and cables, the electrical connections shall be checked for continuity by appropriate electrical measurements. A junction box with electrical terminals shall be installed at each anchorage. Junction boxes shall be provided with an	C4.3.13 – Electrical Components for PL-3 This minimizes the adverse effects of stray-currents, while maintaining the ability to perform electrical resistance measurements of the tendon. Junction boxes are required at each anchorage as shown in Figure 2. Electrical measurements can then be made independently from either anchorage. This ensures redundancy, for instance if one of the connections fails over time. In addition, having the possibility to electrically connect the tendon from both ends facilitates localizing defects in the duct.  **Figure 2. Schematic illustration of the installations needed for the electrical resistance measurements [2, 4].**

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Sub-Task 3: Replaceable PT Tendons

Technical Approach

The research approach will be divided into several phases of activities:

Phase 1:	**Review literature , test results, and standard practice in other countries**
Phase 2:	**Explore several replaceable external PT tendons concepts**
Phase 3:	**Geometric study of selected bridge projects with external PT tendons**
Phase 4:	**Develop standard details for fully replaceable external PT tendons**
Phase 5:	**Develop specification languages and commentary to be proposed to PTI/ASBI M-50 Committee for inclusion in the "Guide Specification for Grouted Post-Tensioning"**
Phase 6:	**Develop a two hour Power Point presentation for educational/training and outreach purposes, including speaker notes**

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Sub-Task 3: Replaceable PT Tendons

Status of Sub-Task 3

Research start date: January 2015

Submitted 1st draft: August 2015

Remaining work:

- 2nd draft is in progress
- Specification Language
- Two hours Power Point Presentation

Expected completion: Fall 2016

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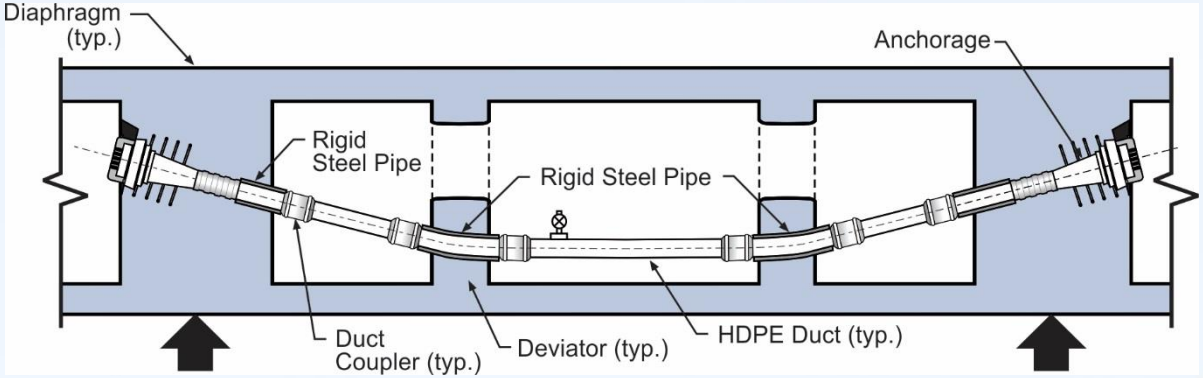
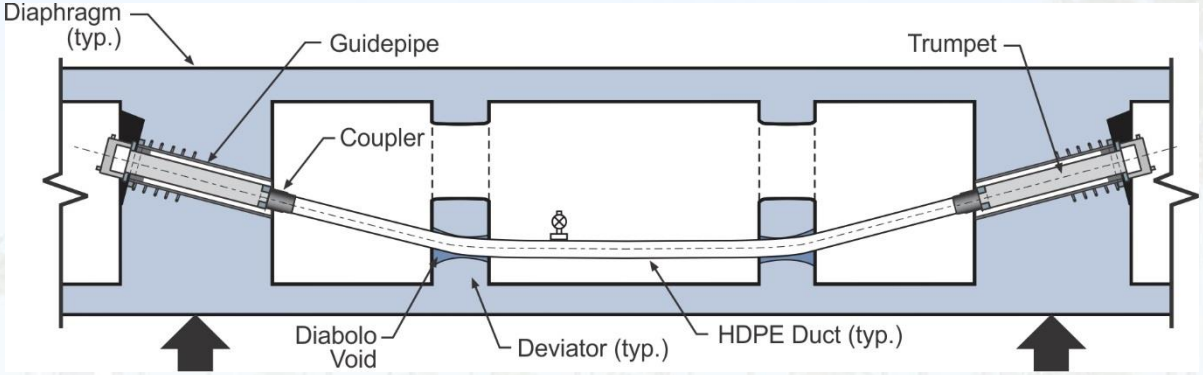
Sub-Task 3: Replaceable PT Tendons



Non Replaceable PT Tendon (US existing practice)



Replaceable PT Tendon (double envelope concept)

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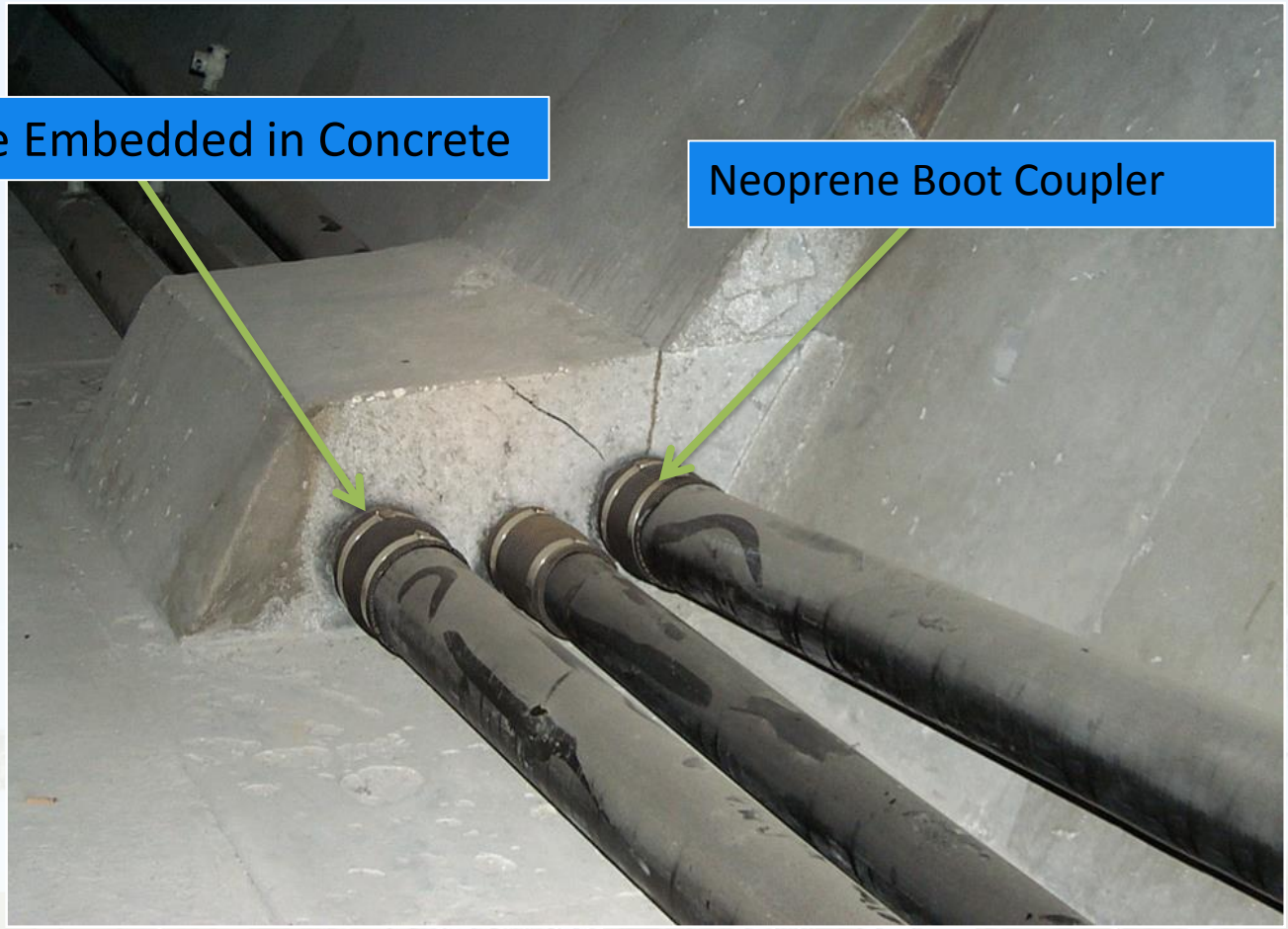
Sub-Task 3: Replaceable PT Tendons



Existing US Details in Deviator

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Sub-Task 3: Replaceable PT Tendons

STRATEGIES FOR FULLY REPLACEABLE EXTERNAL TENDONS AROUND THE WORLD

1. Implementation of flexible filler materials (grease and wax filler and bare strands). SETRA of France later prohibited grease and adopted wax instead)
2. Implementation of individually sheathed mono-strand. Can be greased or waxed (with grout)
3. Implementation of diablo forms (double envelope concept)
4. Combination of diablo forms with items 1 or 2.
5. Implementation of epoxy coated strands (no grout)

The study focuses on the development of guidance for replaceable grouted external PT tendons. The study concluded that diablo forms are a viable option for fully replaceable grouted external PT

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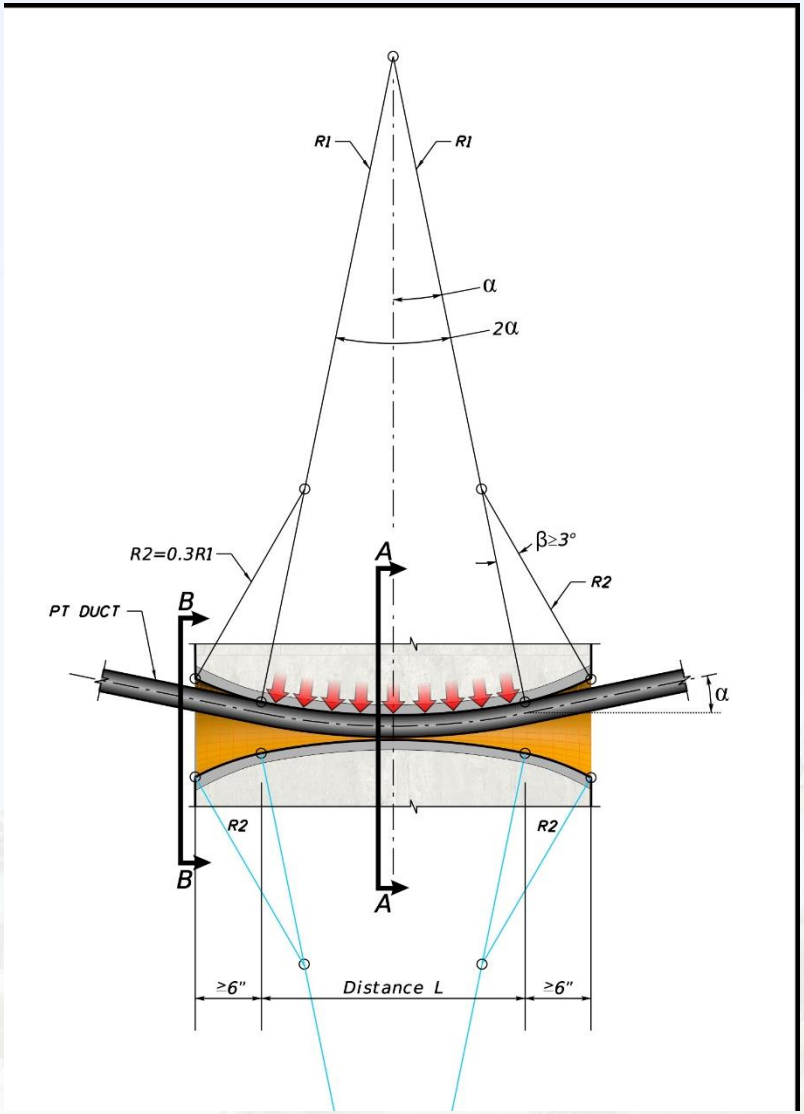
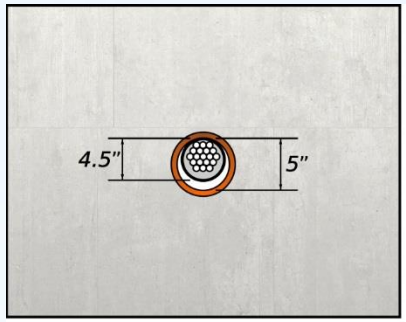
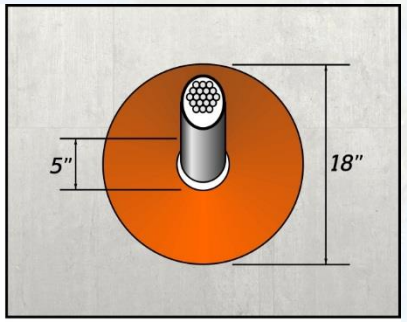
Sub-Task 3: Replaceable PT Tendons



Diablo - Basic Geometry 1



Section A-A
For 19-0.6" Tendon



Section B-B
For 19-0.6" Tendon

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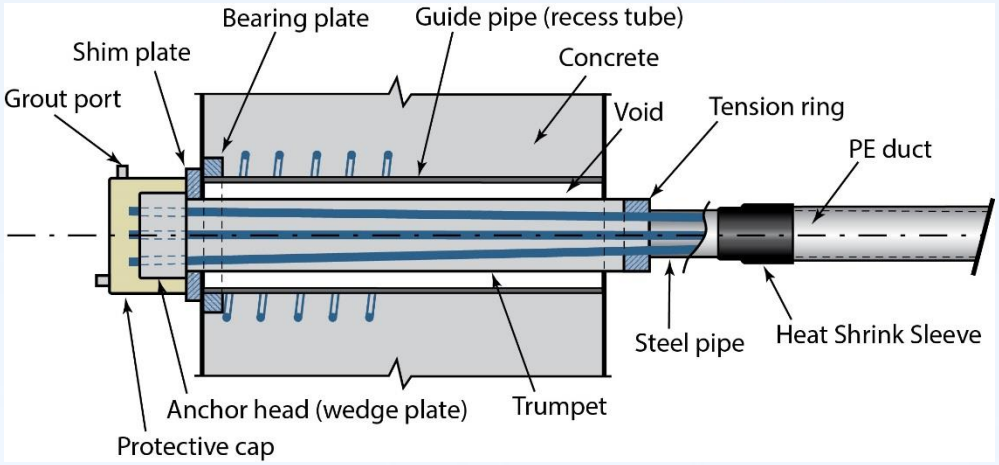
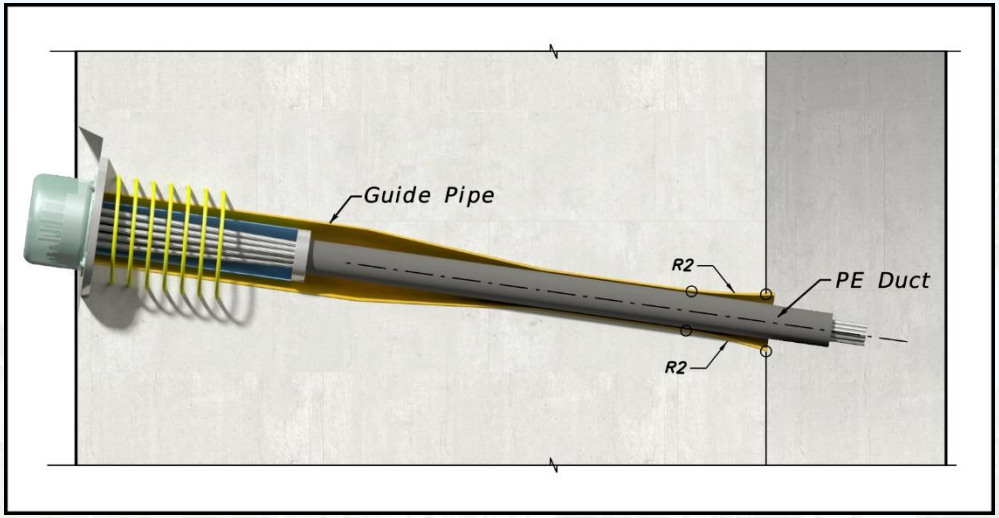
Sub-Task 3: Replaceable PT Tendons





Diablo Form Detail in Diaphragm

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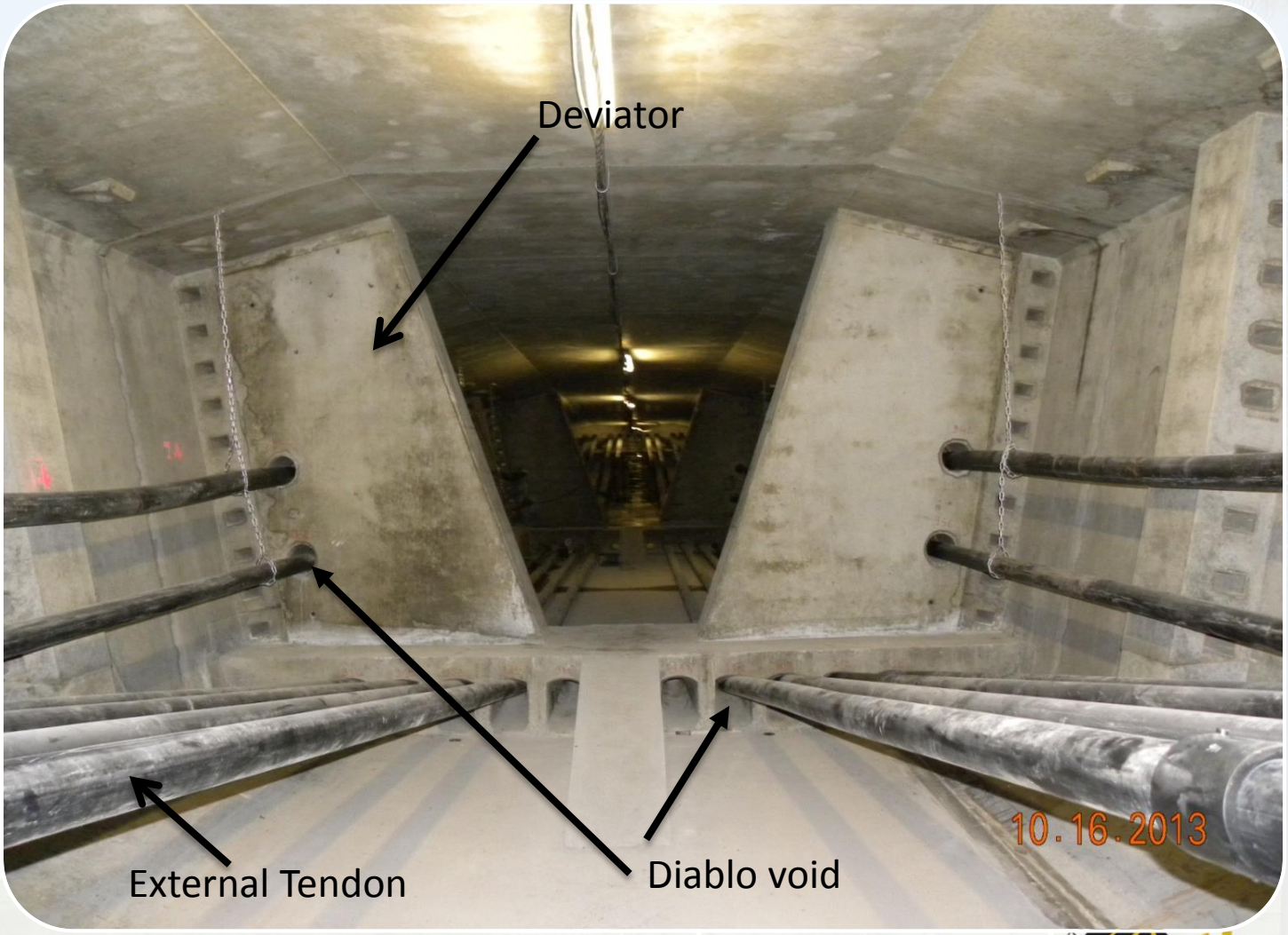
Sub-Task 3: Replaceable PT Tendons



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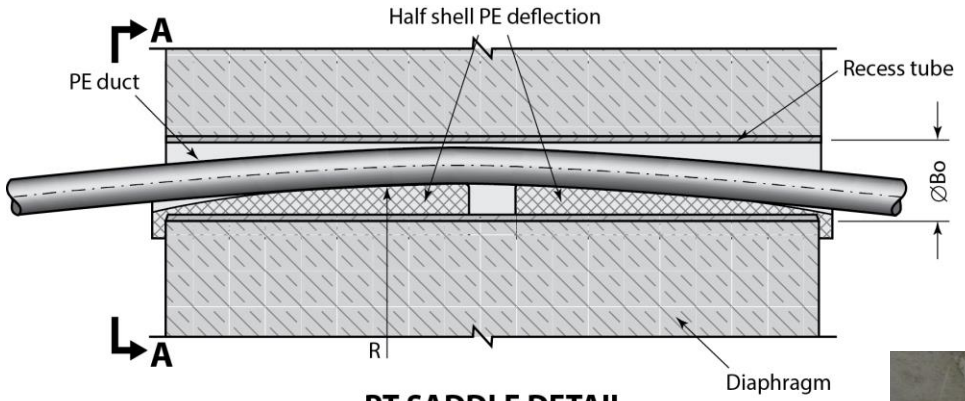
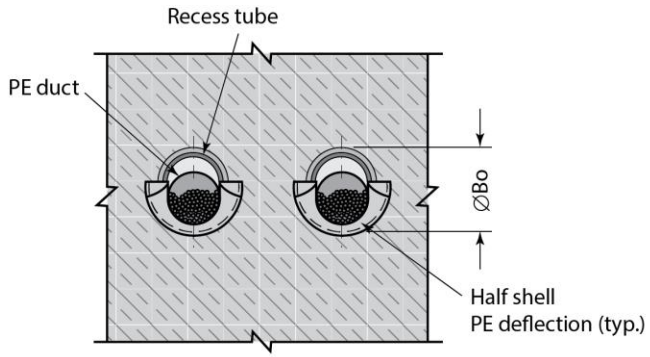
Sub-Task 3: Replaceable PT Tendons

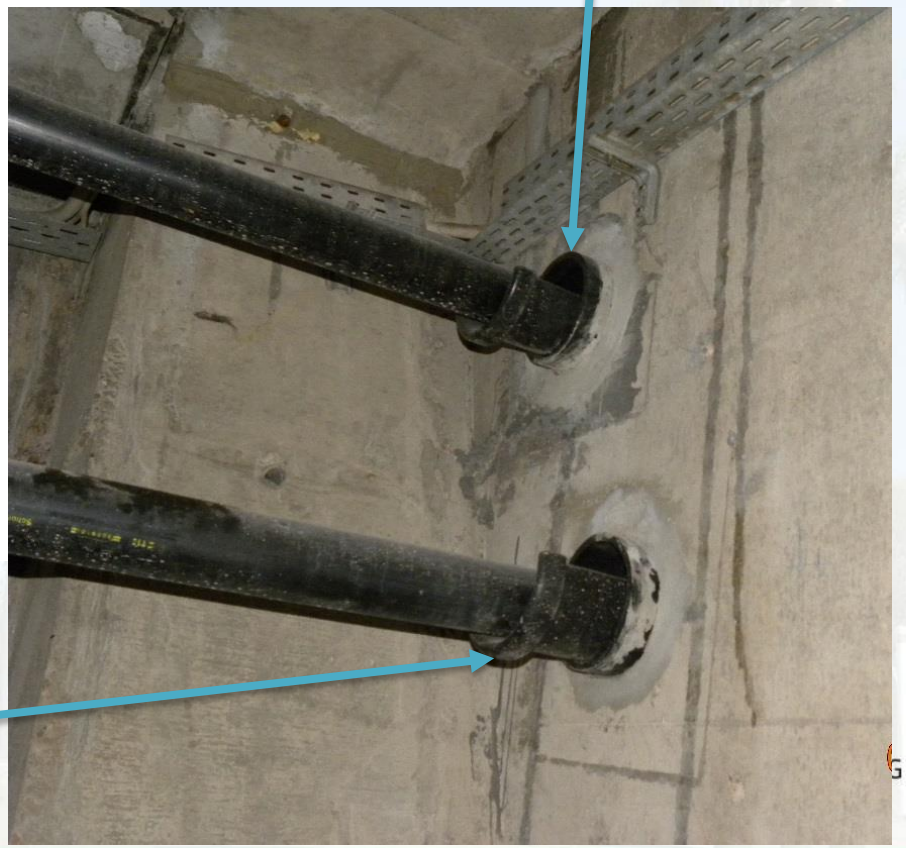


PT SADDLE DETAIL



SECTION A-A

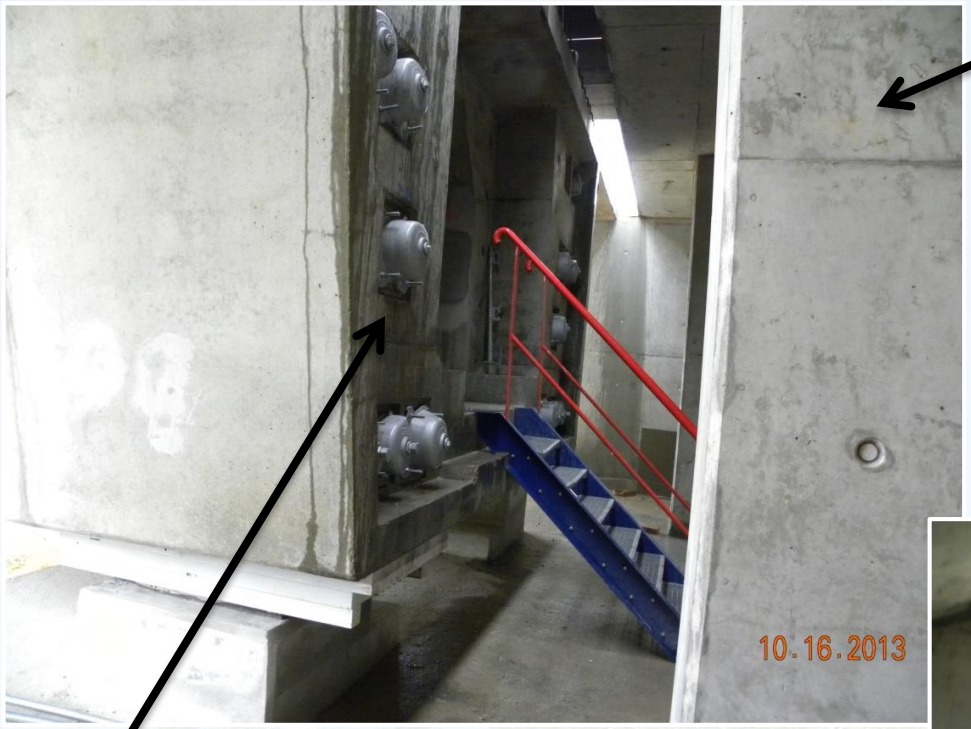
Plastic recess tube



Half shell PE deflector

Sub-Task 3: Replaceable PT Tendons

Abutment



Inspection and maintenance Gallery at abutment for fully replaceable external tendons

End Diaphragm

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Sub-Task 4: Assessable PT Tendons

- The scope of this Task is to assess how well our current PT construction inspection and testing procedures provide for evaluation of material performance, quality of construction and long term performance risks.

- And to Explore the question “To what extent are we providing a level of certainty that our PT systems will meet their intended service life and the design life of the structure?”

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Sub-Task 4: Assessable PT Tendons

Technical Approach

Phase 1: Data Collection

Phase 2: Data Analysis

Phase 3: Identification of Critical Risks

Phase 4: Comparison Inspection and Testing Procedures

Phase 5: Recommendations for Providing an Initial Bill of Health or "Birth Certificate" to document and archive pertinent data

Phase 6: Recommendations for improved Inspection and Testing Procedures, Possible Spec Revisions and identification of any new Promising Developments

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Sub-Task 4: Assessable PT Tendons

Phase 1 Data Collection

Sample DOTs - Thirteen States with a history of and/or active bridge construction programs that include post-tensioning elements contacted and sent a List of Questions.
Texas, Florida, California, Colorado, Virginia, Utah, Washington, Minnesota, Ohio, New York, Maine, Oregon, Massachusetts.

Then we asked similar questions to sample of:
Consultants, Contractors, PT Suppliers and some specialty questions for the Grout Suppliers to get Industry wide perspective.

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Sub-Task 4: Assessable PT Tendons

Phase 1 cont'd - Broad Range of Questions asked

Project Specifications knowledge and use of PTI/ASBI

- Construction inspection and testing methods
- Minimum Experience and Training requirements
- QC & QA roles
- Job records to include material certs, field tests conducted, sampling frequency of testing and Pass/Fail rates, Laboratory (acceptance) testing vs Field (production) testing
- PT Problems, Follow up and Close out Documentation

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Sub-Task 4: Assessable PT Tendons

Phase 2 – Data Analysis

- Comparison of State DOT Specifications & Requirements
- Materials Qualification
- QA/QC Procedures and references
- Construction inspection and testing practices
- Test procedures
- Visual inspections
- NDT test methods
- Destructive testing
- Corrective actions taken and results

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Sub-Task 4: Assessable PT Tendons

Phase 3 – Identification of Critical Risk Elements

- Identify most critical work elements
- Create ranking system and assigned importance category
- Use rankings to prioritize inspection effort
- Develop durability rating based on the inspection and testing especially for high ranking items.

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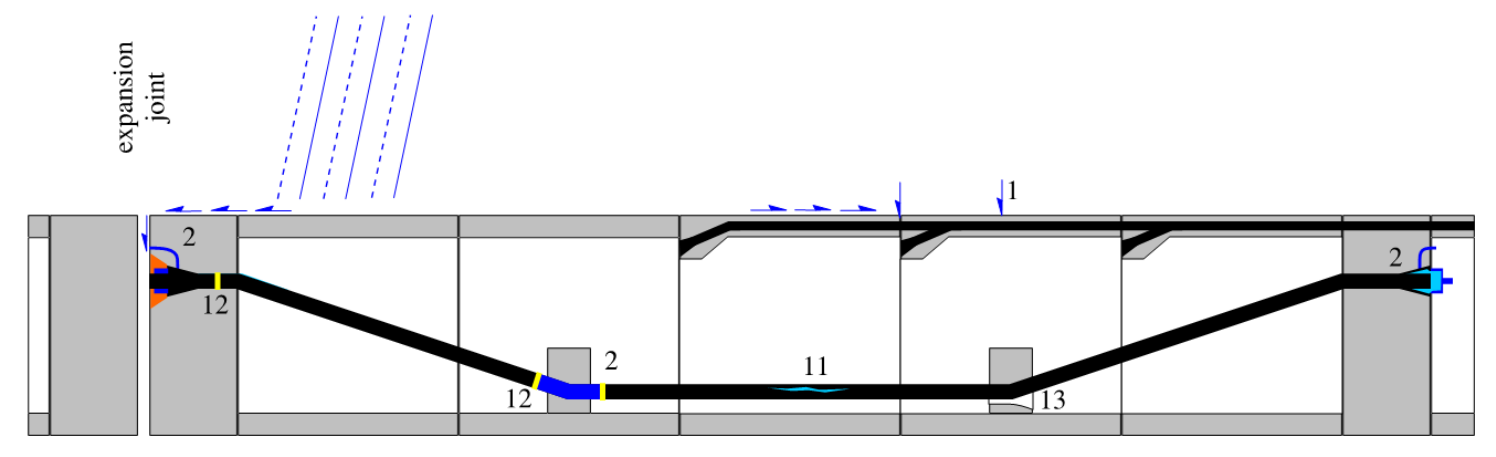
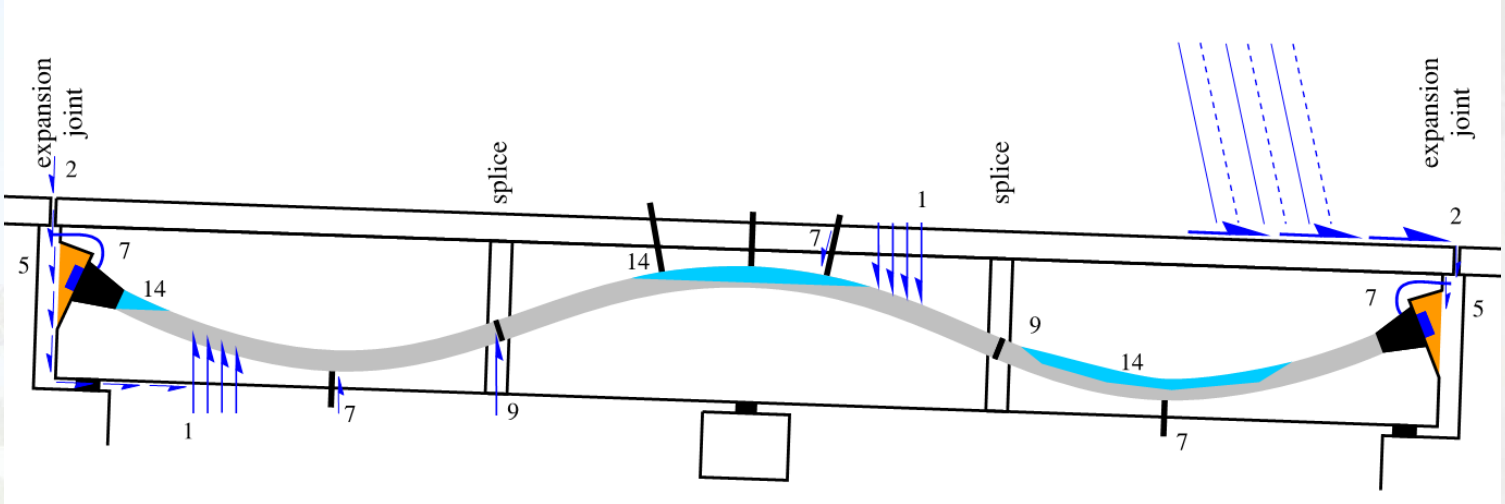
Phase 3 – Identification of Critical Risk Elements



Box Girder



Continuous I-Girder

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Phase 3 – Identification of Critical Risk Elements

Duct					
Element	**M50 Spec**	**ASTM**	**Possible deficiencies**	**Risk Category**	**Risk Rating**
Minimum Cross-sectional Area	4.3.5	*	none	G	3
Corrugated metal duct material	4.3.5.1	A653	Corrosion and duct breach	M	2
Seam construction of metal duct	4.3.5.1	*	Paste leakage and formation of duct blockage	M	2
Wall thickness of metal duct	4.3.5.1	*	Corrosion and duct breach	M	2
Corrugated polypropylene (cell classification range of PP0340B44541 to PP0340B67884)	4.3.5.2	D4101	Oxidation and duct breach	M	2
Cold weather (-22 to 32F) Corrugated polypropylene (cell classification range of PP0340B44531 to PP0340B67884)	4.3.5.2	D4101	Oxidation, strength reduction, duct breach	M	2
Corrugated polyethylene (cell classification range PE344434D to PE445574D)	4.3.5.2	D3350	Oxidation, strength reduction, duct breach	M	2
Cold weather (-22 to 32F)					

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Sub-Task 4: Assessable PT Tendons

Phase 4 – Comparison of Testing and Inspection Effort

- PT Tendons are critical to safety and serviceability.
- Compare "Level of Effort" between post-tensioning and other bridge components and other types of bridges.
- Review problems encountered on completed projects and relate those critical risks.

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Sub-Task 4: Assessable PT Tendons

Phase 5 – Recommendations for Providing an Initial Bill of Health or “Birth Certificate” for the PT elements

- Sample Documents for the Initial Bill of Health
- Provides both design and construction information
- Allow future assessment of PT system
- Valuable resource for assessment, repair, or replacement of critical PT elements.

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Sub-Task 4: Assessable PT Tendons

Phase 6 – Recommendations of changes to current Construction Inspection and Testing Procedures.

- From the data collected and our own assessment we are in process of preparing recommendations for changes or additions to current Construction Inspection and Testing Procedures for consideration by industry committees such as PTI/ASBI M50 and PTI M55.
- In addition we are on the lookout to report on promising PT field inspection and testing methods found during research for possible future research adoption.

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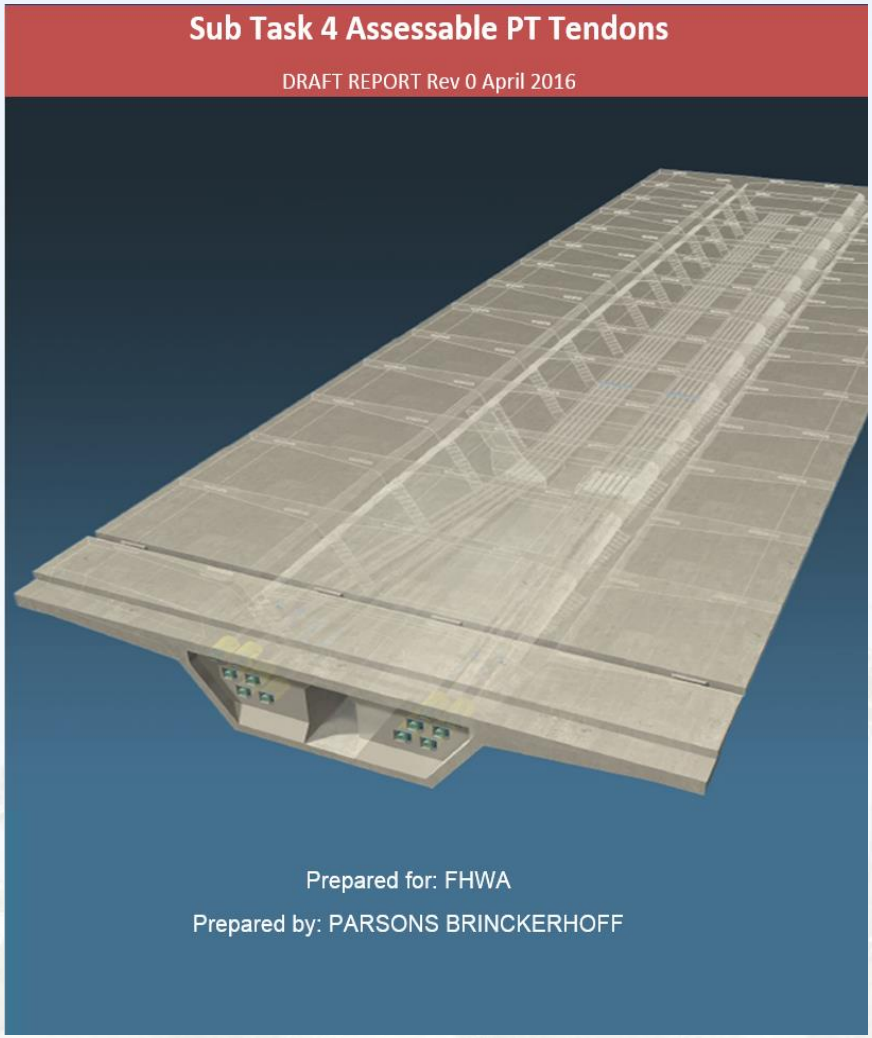
Sub-Task 4: Assessable PT Tendons



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Sub-Task 4: Assessable PT Tendons

Some sample Conclusions and Recommendations

- The industry in general considers we have come a long way to providing high quality product but there is still room for improvement.
- There is much interest by Owners (DOTs) in means and methods to evaluate existing structures. NDT methods to date provide limited quantitative assessment.
- There is much variation in Specification requirements between Owners and still much to do to get to national adoption of PTI/ASBI guideline specs.
- Project documentation and archiving needs to be improved.

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Sub-Task 4: Assessable PT Tendons

Conclusions and Recommendations cont'd

- There is general consensus for National PT System approval.
- The PTI and ASBI training courses are well perceived but should be updated and could go into more depth.
- There is a shift away from using metal ducts particularly in top slab tendons of highway bridges subject to deicing salts.
- Light rail projects require special consideration of stray currents.
- Grout producers believe that most grout problems are related to oversight and inspection issues in the field. Mock ups add value. Shelf life is addressed by producers in varying ways complicated by lack of uniform specification requirements which in some cases are imposed without fully understanding the implications.

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Sub-Task 4: Assessable PT Tendons

Status of Sub-Task 4

Schedule

Research effort started: January 2015

Reporting Quarterly to FHWA

Progress Report Fall 2015

Draft Report in progress April 2016

Final Report expected Fall 2016

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Thank You!

Questions ?

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FHWA DTFH6114D00048-Task 5009

DEVELOPMENT OF FHWA GUIDANCE FOR MONITORABLE, REPLACEABLE AND ASSESSABLE PT TENDONS

Presented by:

Trey Hamilton, P.E., Ph.D, University of Florida
Tony Ledesma, P.E., WSP|Parsons Brinckerhoff
Ian Hubbard, P.E., WSP|Parsons Brinckerhoff

April 25, 2016

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2016 PTI Convention
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