Use of Flexible Filler in Post-Tensioned Bridges

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Motivation

Prestressed Concrete

- Cost-effective method of bridge construction

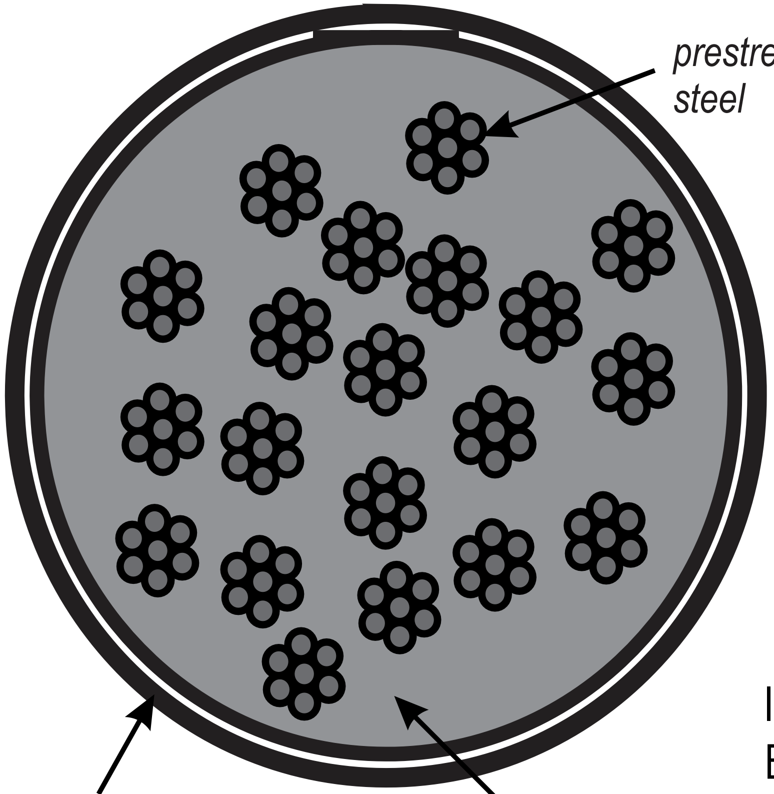
Durability Issues

- Poor grouting practice
- Poor material performance

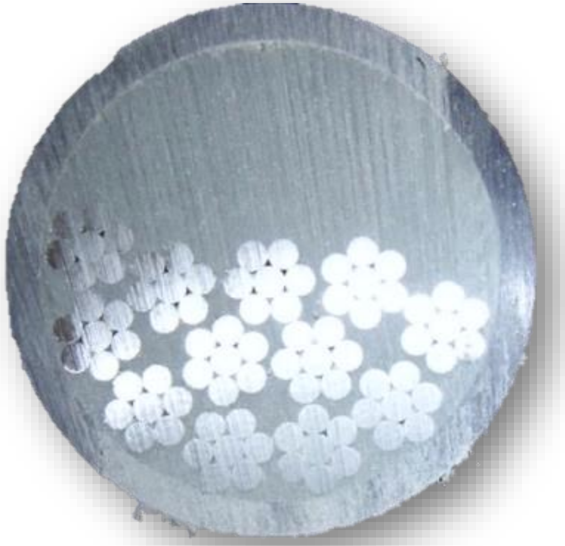
Flexible Fillers

- Structural implications
- Reevaluation of current design specifications

Post-tensioning Components



Grout



Internal Tendons designed as bonded.
External Tendons designed as unbonded.

Flexible Filler

All tendons unbonded.

Issues with grout

Soft Grout

Tendon Corrosion

Tendon Failure

Internal and External Tendons

Drop-in Girders
Internal Tendons

Segmental Box Girders
External Tendons

Research Status - Final Report Complete

- Literature review
- Filler injection
- Structural testing
  - ✓ Flexural strength
  - ✓ Fatigue at deviator and anchorage
- Wire break detection

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Replaceable Unbonded Tendons for Post-Tensioned Bridges

Extended Summary

This report is one of a four-part compilation published under separate covers as follows:
Extended Summary
Part I Mockup for Flexible Filler Injection
Part II Structural Testing
Part III Wire Break Detection

Final Report **December 2017**

Principal investigator:
H. R. Hamilton
Co-Principal investigator:
J. A. Rice

Research assistants:
A.B.M. Abdullah
Rahul Bhatia

COMPLETED

ida Department of Transportation (FDOT)
William Potter, P.E. – Project Manager
Rick W. Vallier, P.E. –Project Manager

Contract:
UF Project No. 000112216 & 000112218
FDOT Contract No. BDV31-977-15

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Engineering School of Sustainable Infrastructure and Environment
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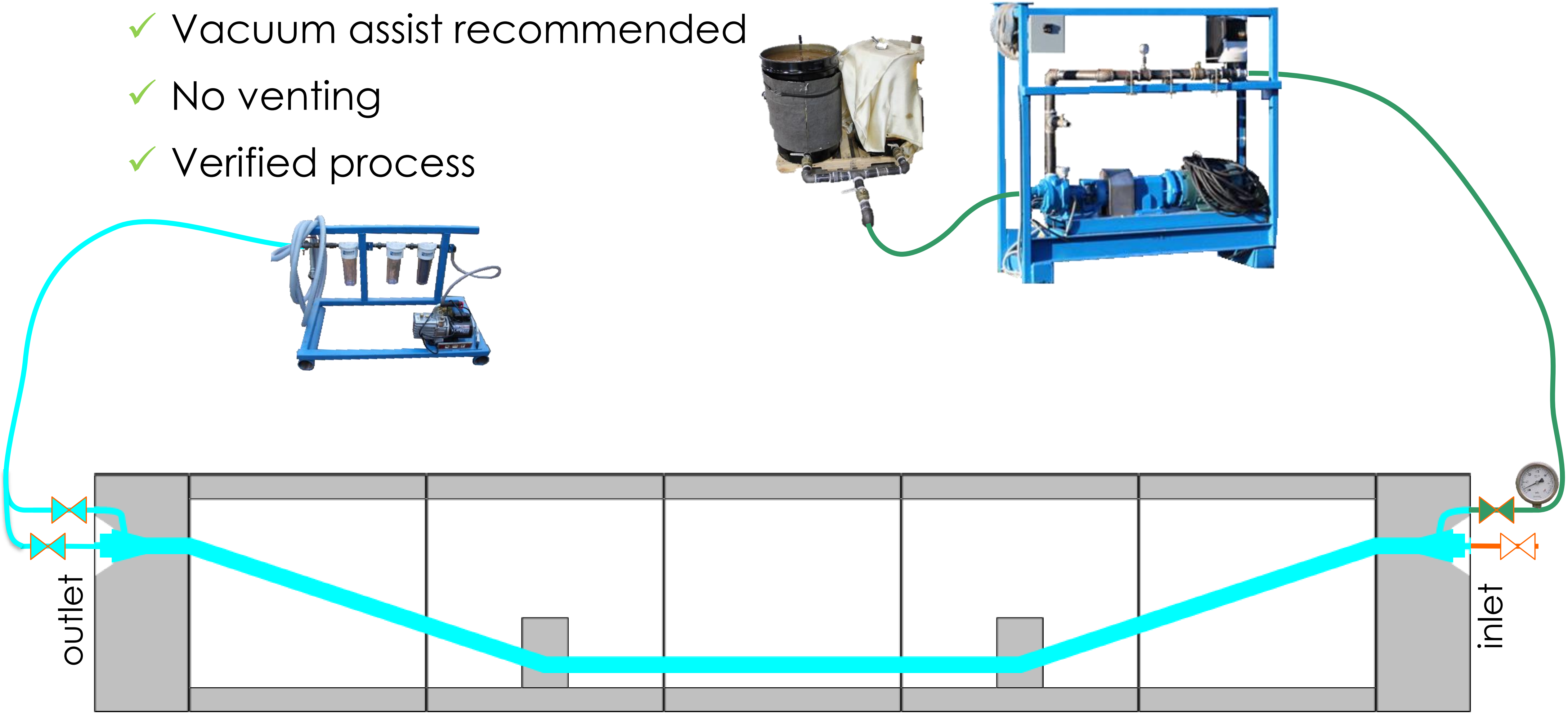
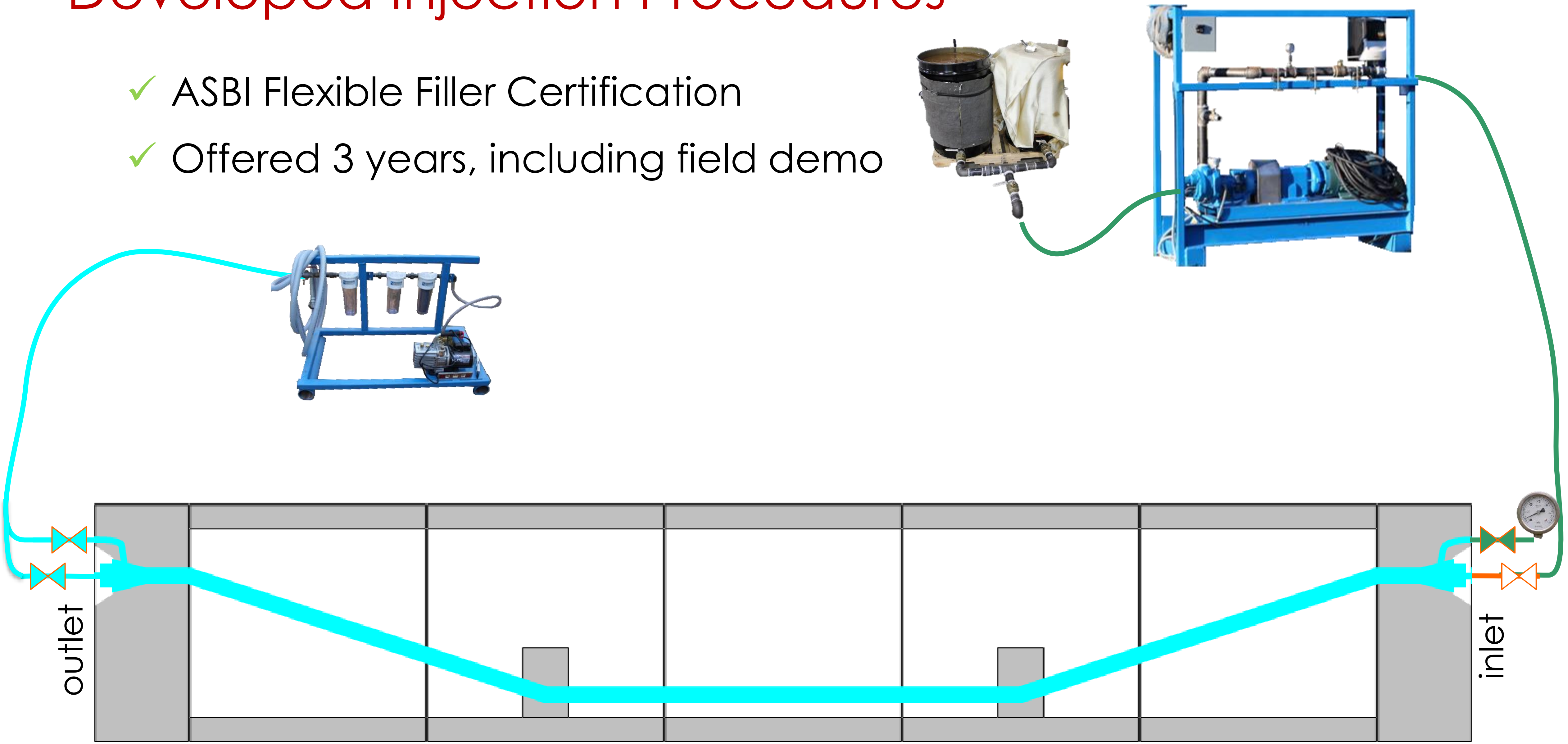
Developed Injection Procedures

- ✓ Vacuum assist recommended
- ✓ No venting
- ✓ Verified process



Developed Injection Procedures

- ✓ ASBI Flexible Filler Certification
- ✓ Offered 3 years, including field demo



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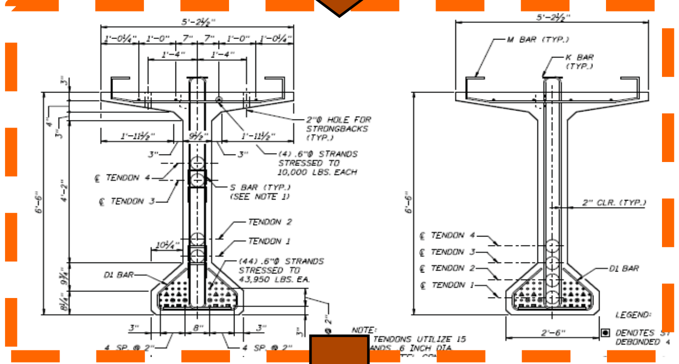
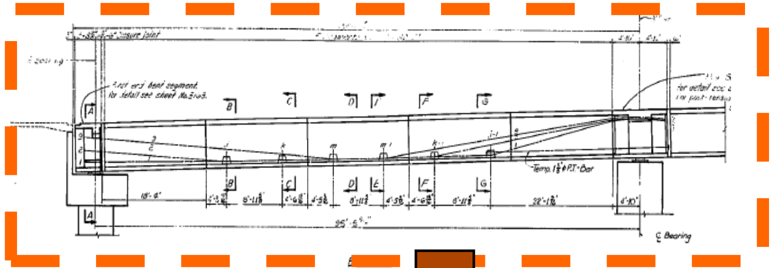
Structural Testing *Internal and External Tendons*

Drop-in Girders
Internal Tendons



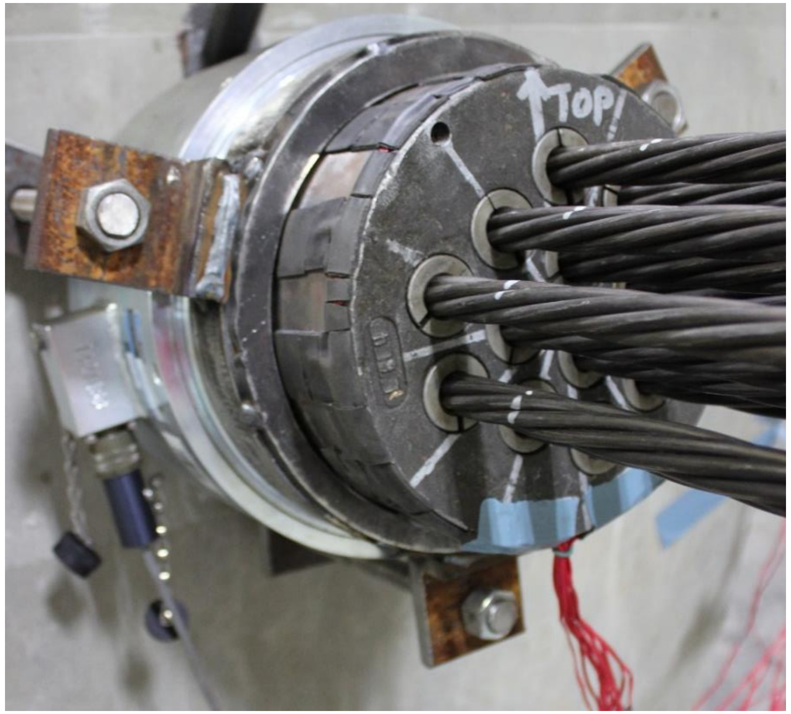
(3) Internal Tendon Specimens

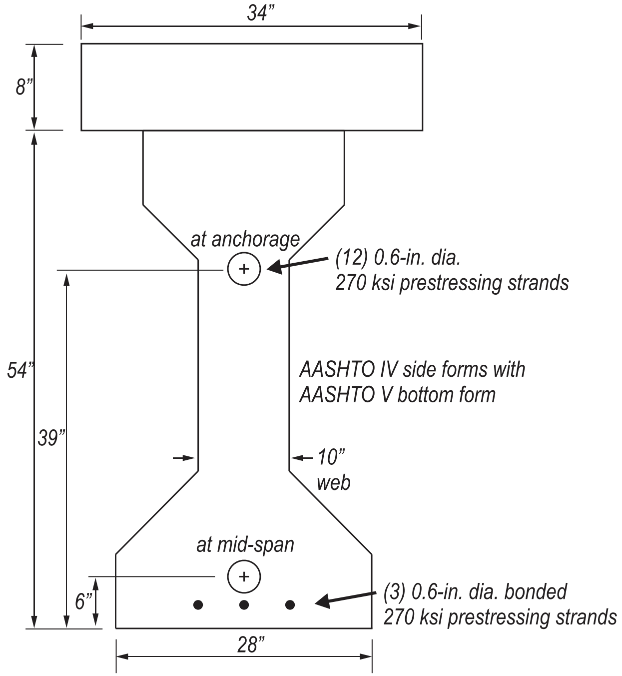
Segmental Box Girders
External Tendons



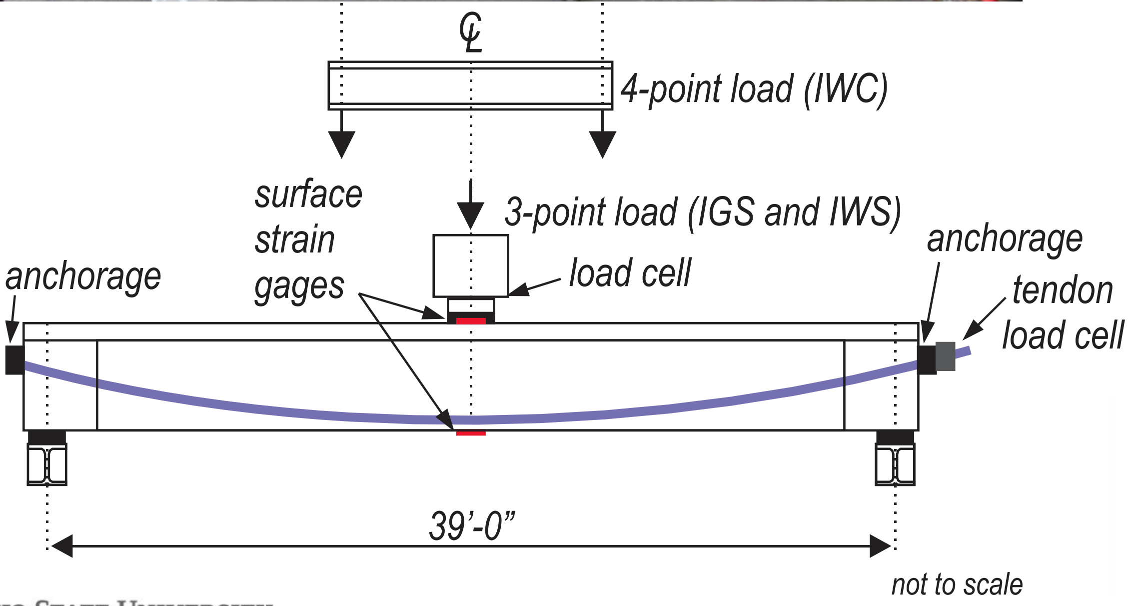
(2) External Tendon Specimens

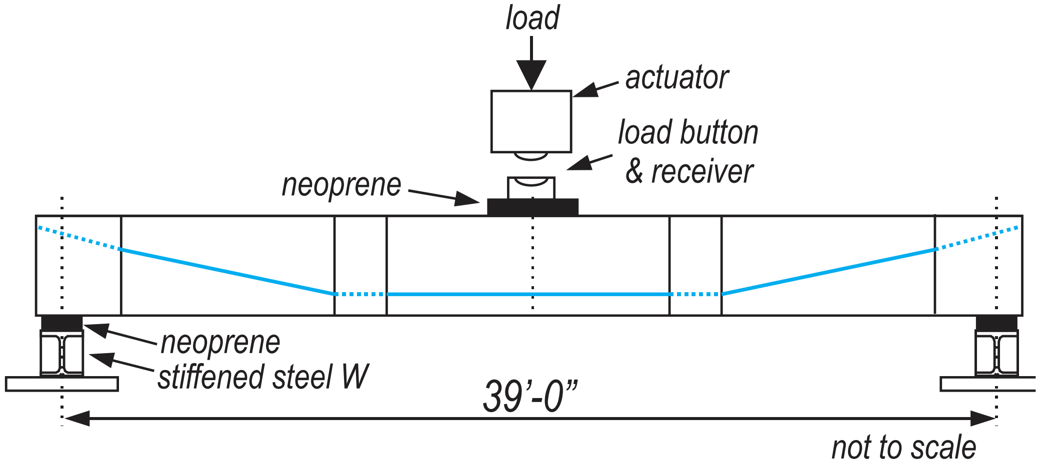
Test Specimens





Flexural Testing





Design Specifications: AASHTO-LRFD 2017

- ## Bonded Tendons

Article 5.6.3.1.1

- For rectangular or flanged sections subjected to flexure about one axis where the approximate stress distribution specified in Article 5.6.2.2 is used and for which f_{pe} is not less than 0.5 f_{pu}, the average stress in prestressing steel, f_{ps}, may be taken as:

$$f_{ps} = f_{pu}\left[1 - k\left(\frac{c}{d_p}\right)\right]$$

- ## Unbonded Tendons

Article 5.6.3.1.2

- For rectangular or flanged sections subjected to flexure about one axis and for biaxial flexure with axial load as specified in Article 5.6.4.5, where the approximate stress distribution specified in Article 5.6.2.2 is used, the average stress in unbonded prestressing steel may be taken as:

$$f_{ps} = f_{pe} + 900\left(\frac{d_p - c}{l_e}\right)$$

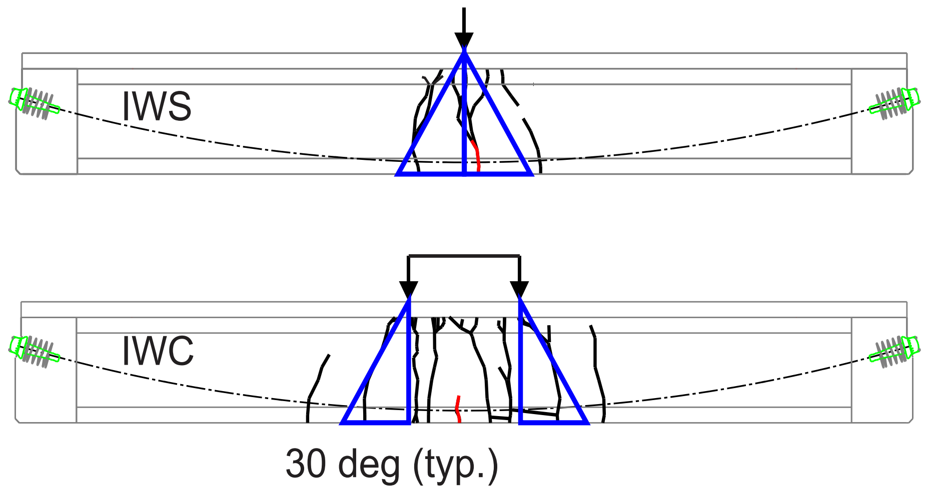
- ## Mixed Reinforcement Conditions

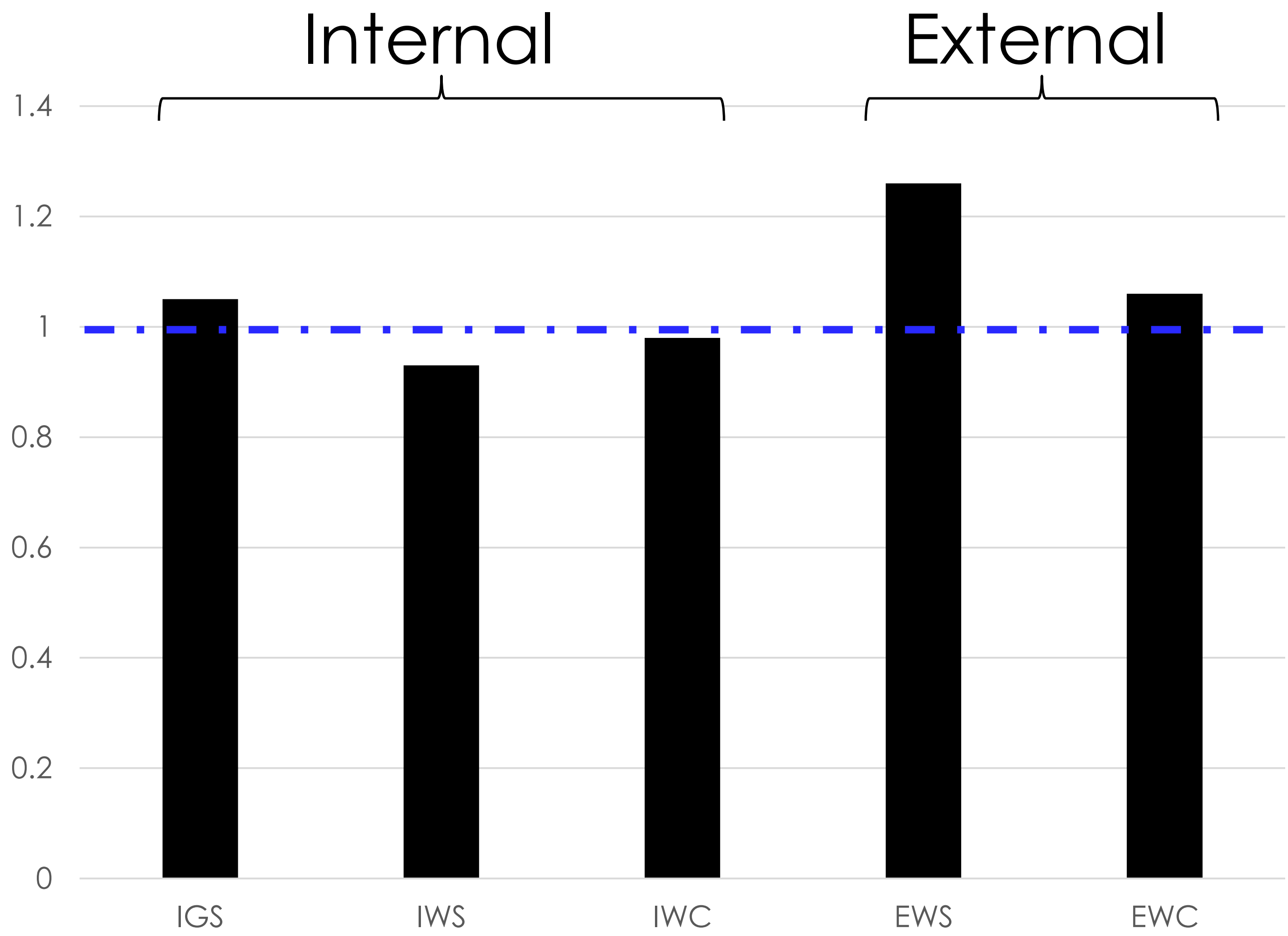
Article 5.6.3.1.3

- 5.6.3.1.3A – Detailed Analysis
- 5.6.3.1.3B – Simplified Analysis

Comparison with AASHTO-LRFD

- Using LRFD 5.7.3.1.3b simplified analysis for elements with bonded and unbonded tendons





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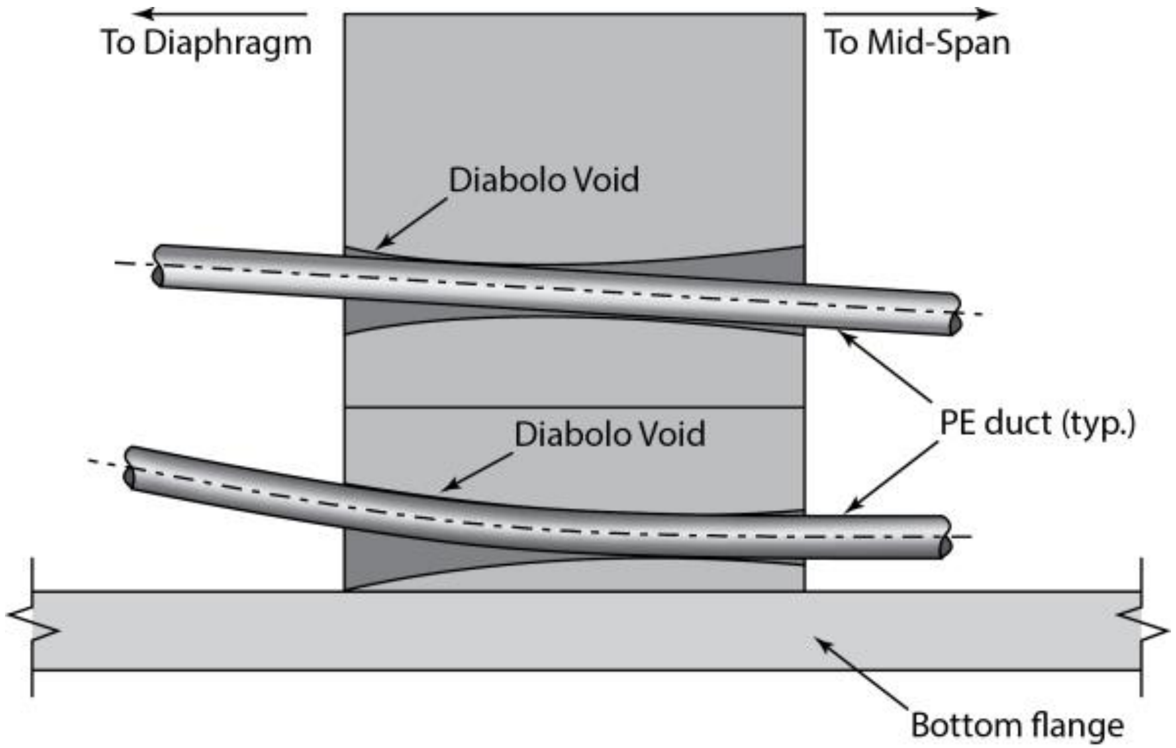
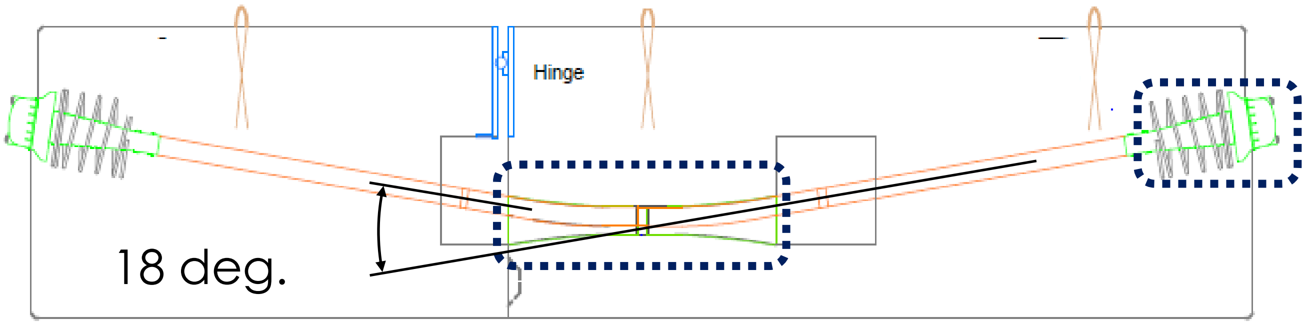
External Tendons – Deviation Points

- Effects of fatigue
- Diabolos



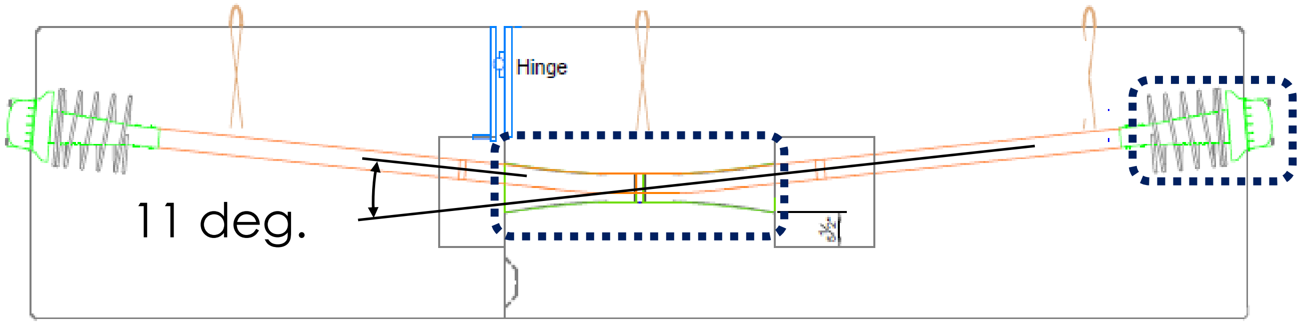
DEVIATOR @ QUARTER POINT

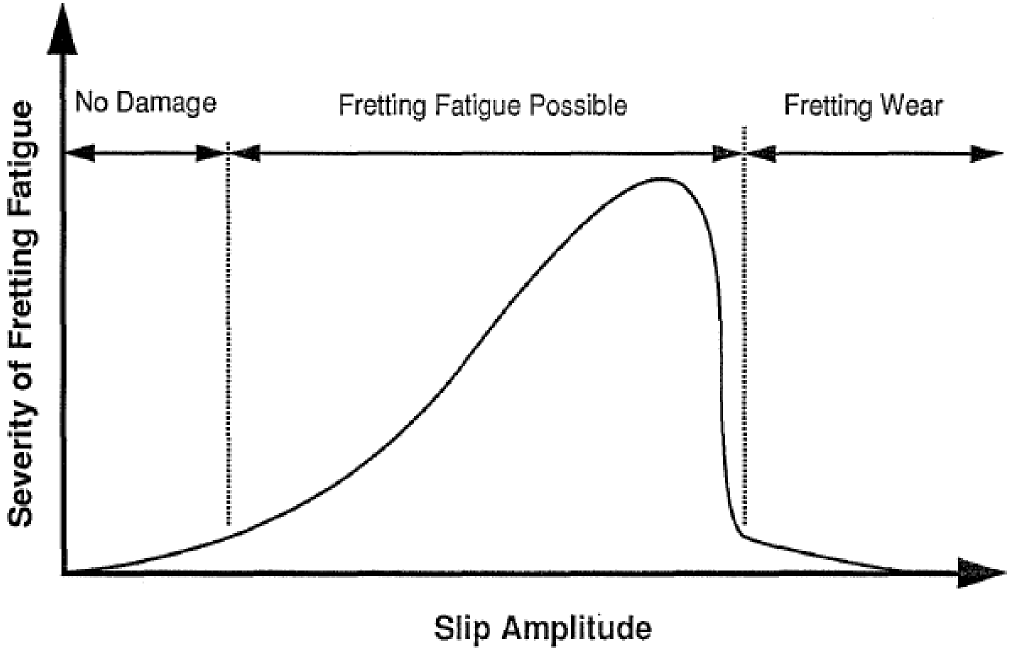
Reduced Beam Testing



Fretting fatigue
Duct damage

Anchor fatigue

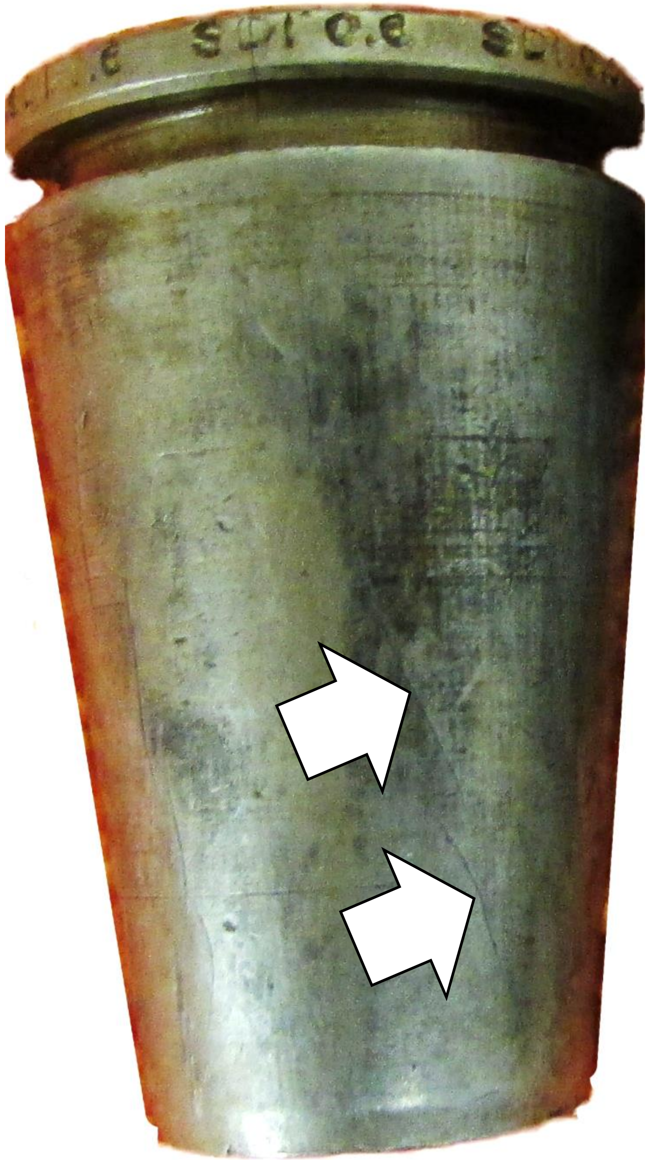


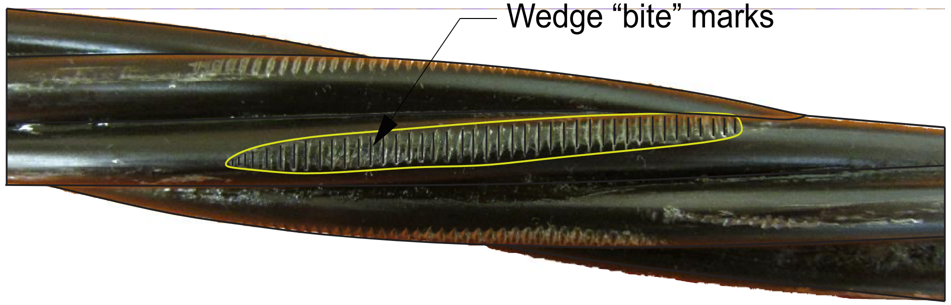


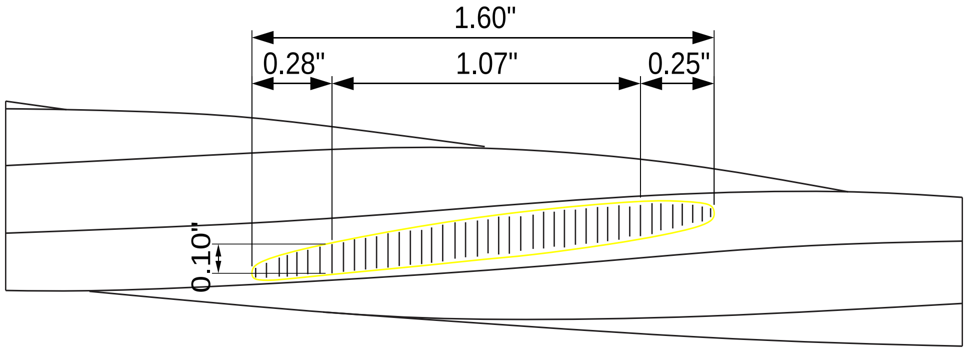
Post-cycling evaluation

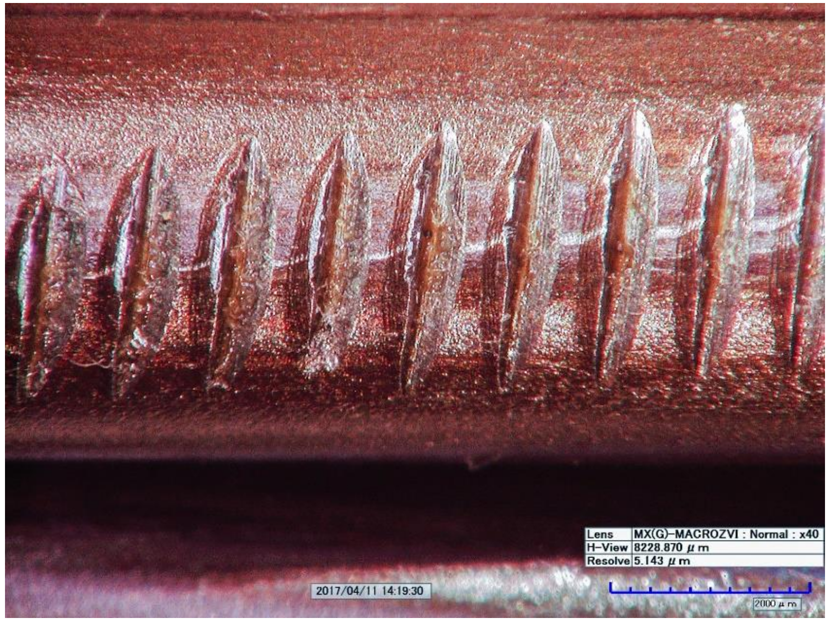
- Visual inspection of HDPE sections in diabolo
- Visual inspection of prestressing strand at wedges
- Ultimate tension tests of individual prestressing strands with diabolo in gage length

Anchorage



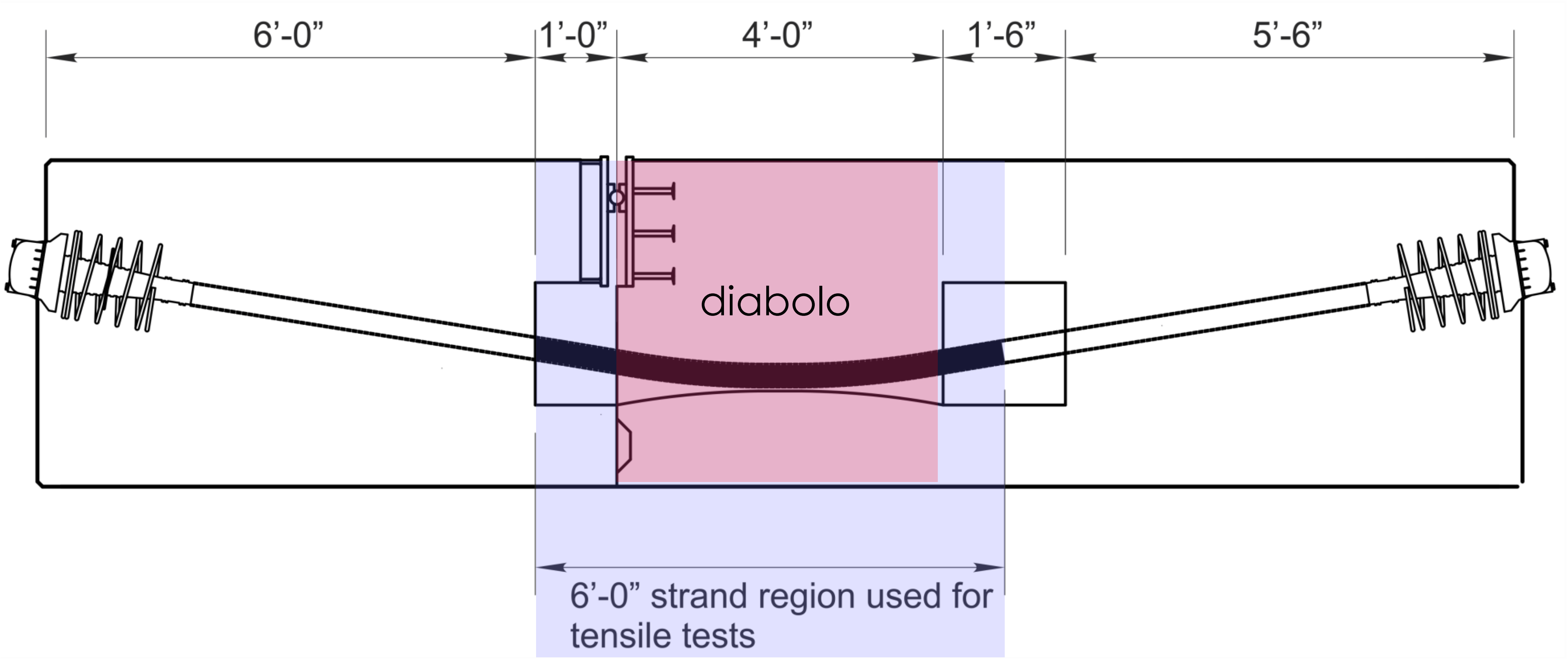

Wedge “bite” marks


1.60"
0.28"
1.07"
0.25"
0.10"


Lens MX(G)–MACROZVI : Normal : x40
H–View 8228.870 μm
Resolve 5.143 μm
2017/04/11 14:19:30
2000 μm

Tension Tests

Source: instron.com



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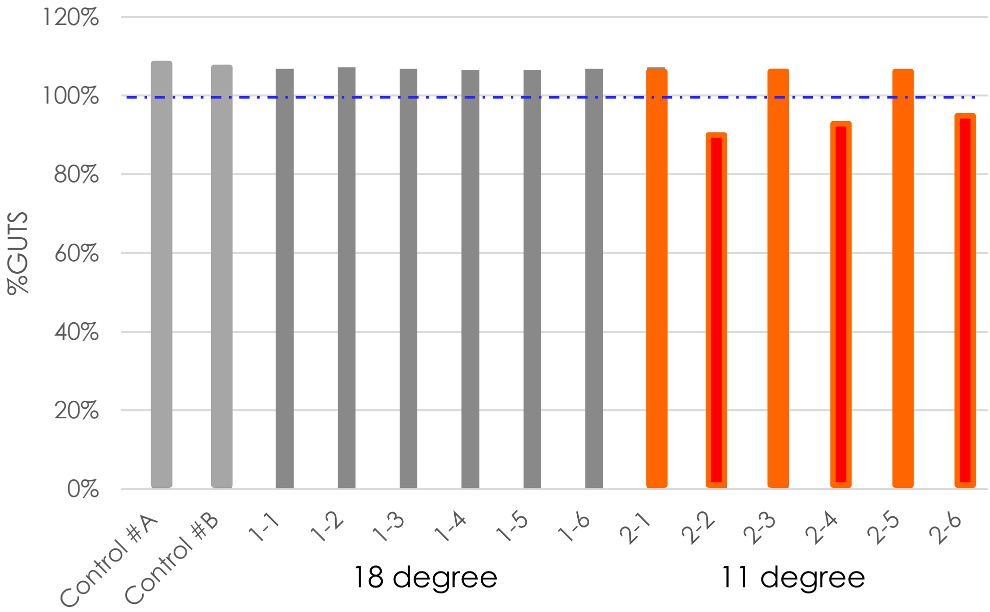
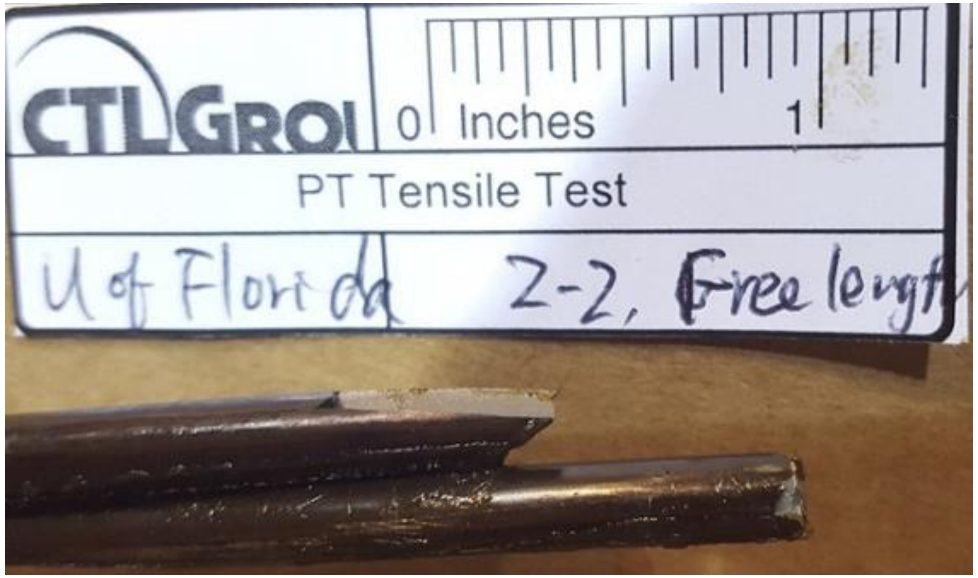
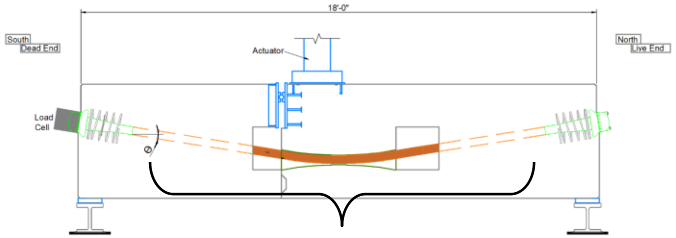
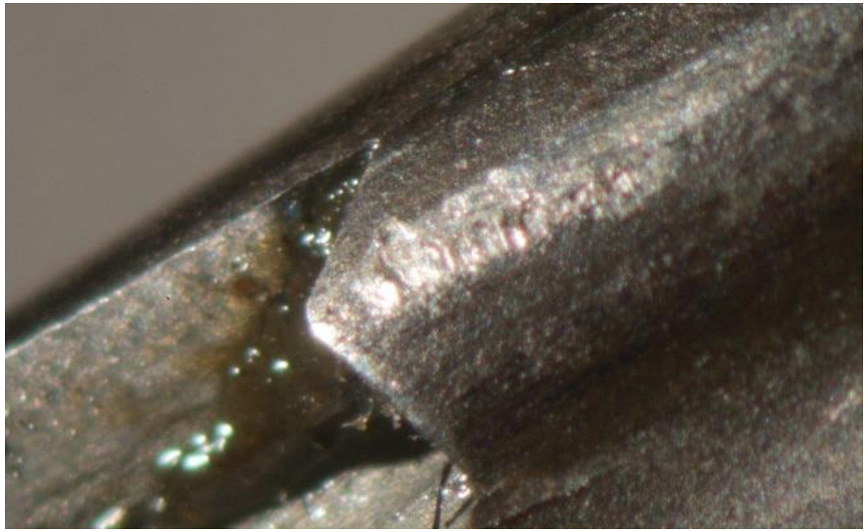


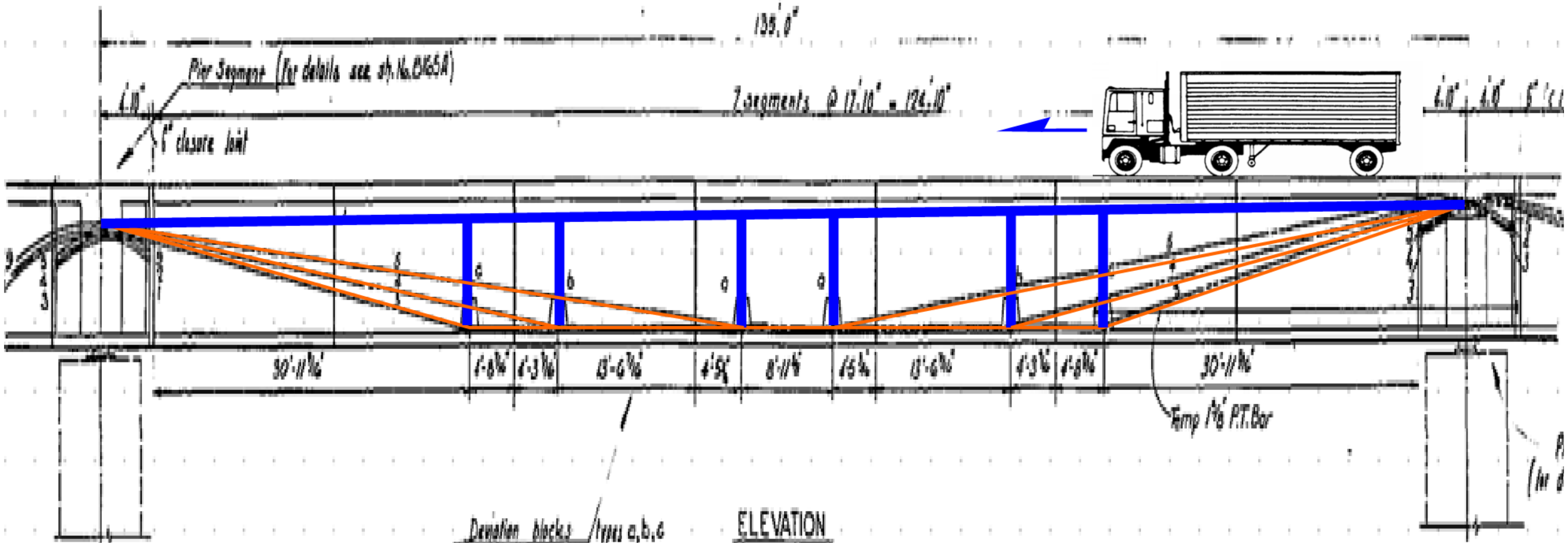




Strand sample



Channel 5 segmental bridge



Tendon force
difference at deviator

Outcomes and Implementation

- Injection procedures
- Developed heat transfer model for use in evaluating maximum length of tendon to inject
- Developed and delivered flexible filler training for engineers, contractors, and owners
- Evaluated AASHTO LRFD provisions for flexural design
- Evaluated fatigue resistance
- Evaluated diabolo geometry
- Developed prestressing strand breakage detection algorithm

Field Implementation

- Wekiva Parkway – Section 6
- Cast-in-place segmental
- Flexible filler used for external tendons and internal bottom continuity tendons

FINLEY Engineering Group

Field Implementation

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- Cast-in-place segmental
- Flexible filler used for external tendons and internal bottom continuity tendons

FINLEY Engineering Group

Field Implementation

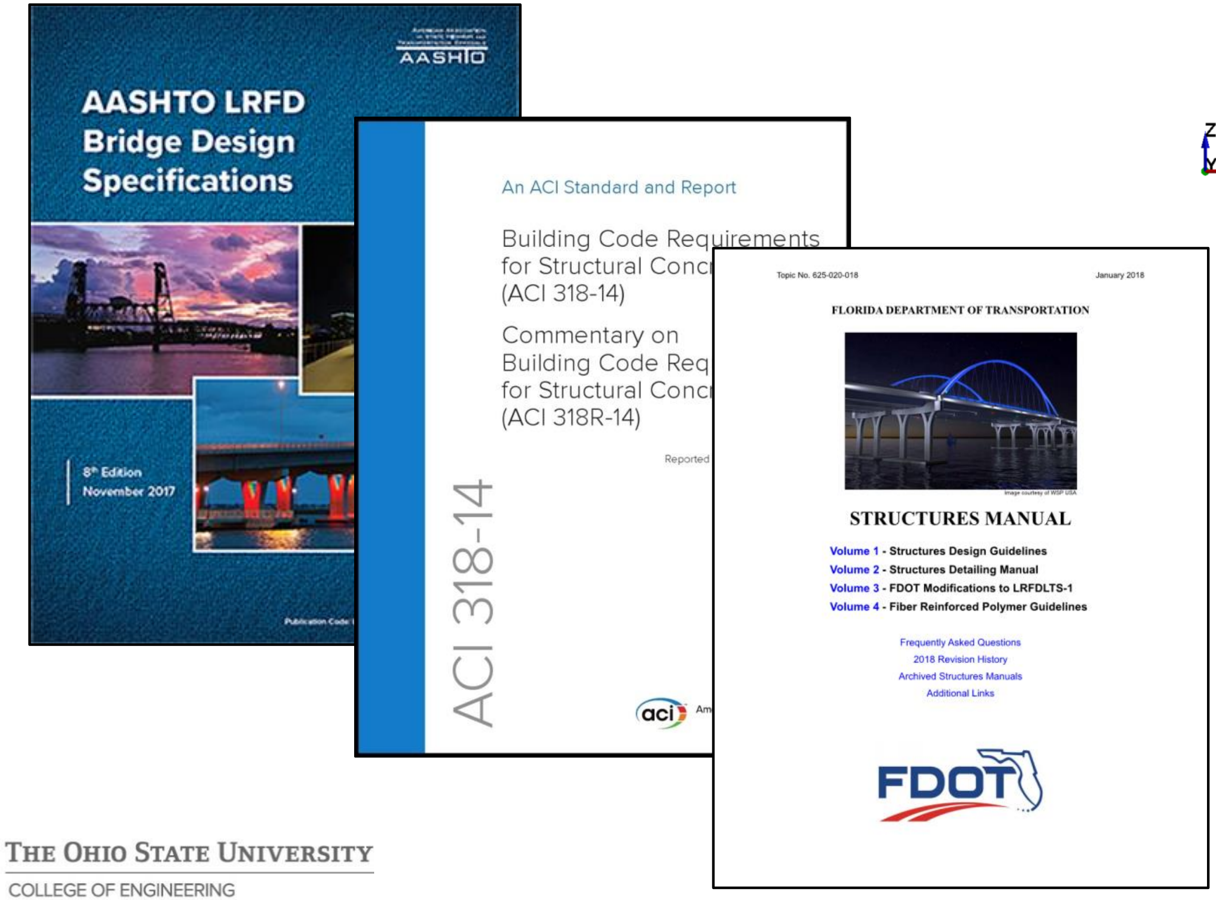
- First continuity tendons injected
- (3) 650 gallon internally-heated tanks
- Monitored flow and qty injected.

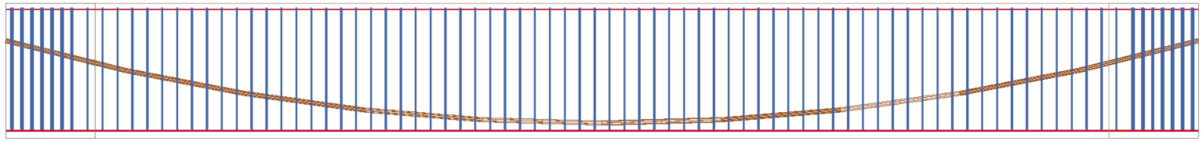
- Initial feedback from the field
- Vacuum-assist learning curve

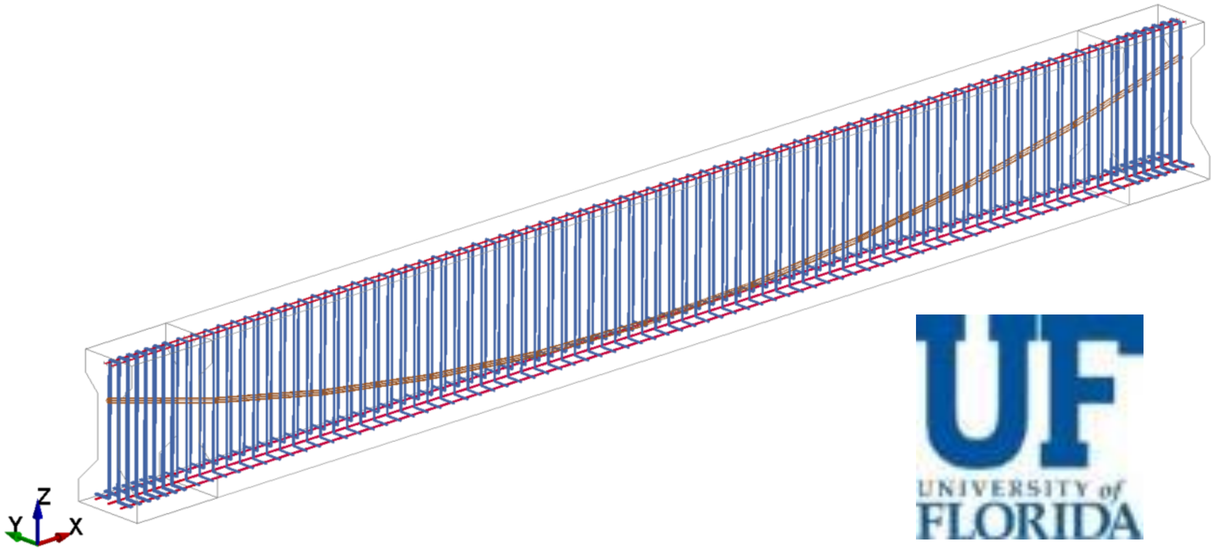
FINLEY Engineering Group

Current Research - **Flexural Capacity of Concrete Elements with Unbonded/Bonded Prestressing**

- Develop design guidelines and analysis procedures for bridge members with unbonded tendons with particular focus on a combination of unbonded tendons and bonded prestress and/or mild reinforcement.







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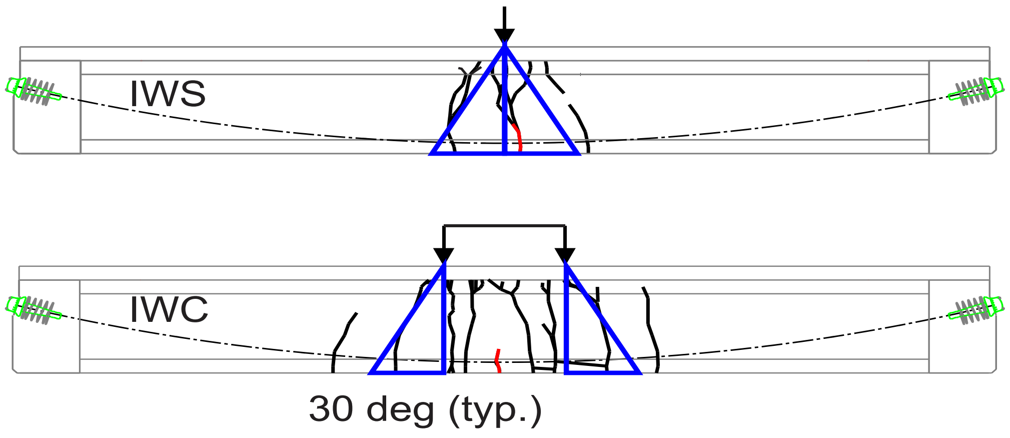
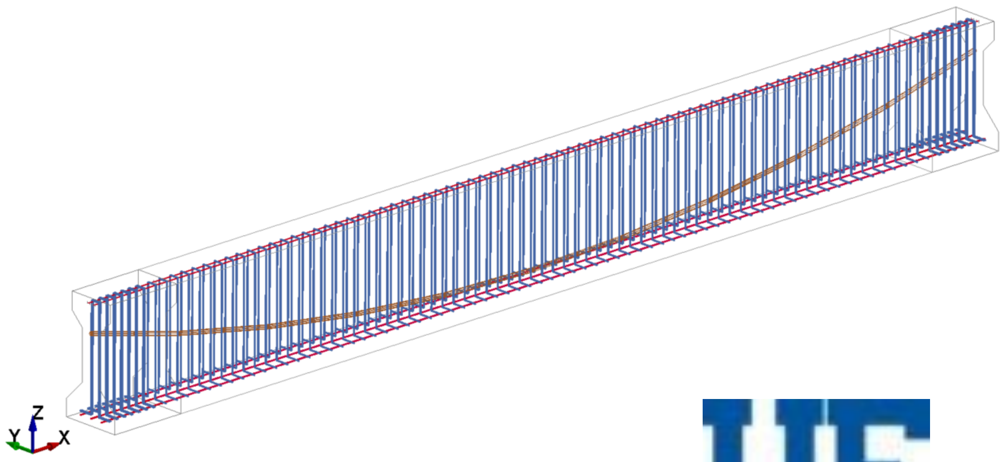
Phases of Project (BDV31-977-93)

- Development of analytical modeling procedures
- Preliminary analytical study
- Experimental testing
- Integration of experimental and analytical data
- Development of design and analysis guidelines





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- grc@ufl.edu / 352-294-7796

Acknowledgements

FDOT

Marcus H. Ansley Structures Research Center
CTL Labs and Dr. Gary Gan

DSI DYWIDAG-SYSTEMS INTERNATIONAL

TRENTON
ANTICORROSION MATERIALS

FREYSSINET
SUSTAINABLE TECHNOLOGY

AUGUST GÄHRINGER DUISBURG
FABRIK TECHNISCHER OELE+FETTE

SANCHEM, INC.
WORKING WITH TRUSTED BRANDS SINCE 1918

PILGRIM

SD
SCHWAGER DAVIS INC

sonneborn
REFINED PRODUCTS

VSL

Civetea
CIRES VASELINES ET TECHNIQUES APPLIQUEES

Test Design

- Modeled fatigue test after ETAG-013
- Minimum stress range of 11.6 ksi
- Maximum load of 65% of tensile element characteristic strength