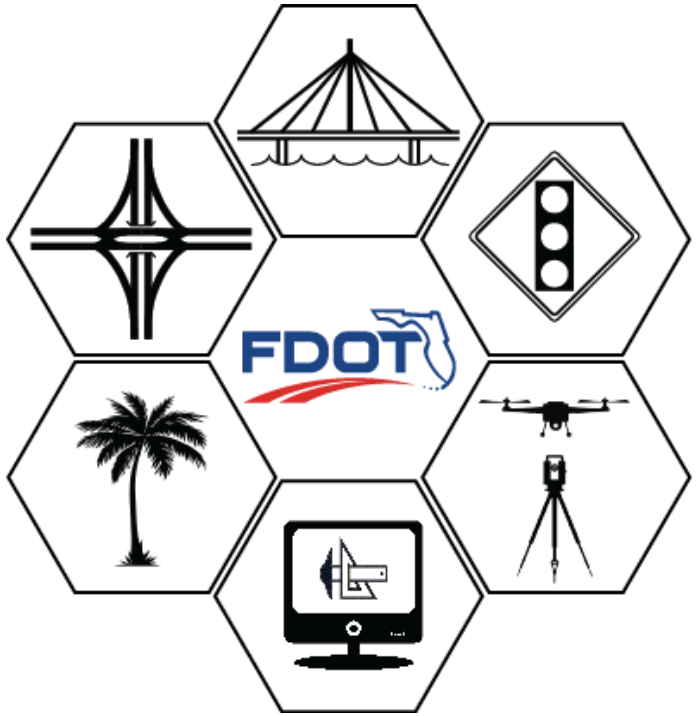


FDOT TRANSPORTATION SYMPOSIUM 2019

# PT System and Approval Process

Jacqueline Petrozzino-Roche and Scott Arnold

# Presentation Overview

- Post-Tensioning in Florida
  - Key projects
  - Corrosion
- A need for Improvement
  - Reevaluation of the Department's Policy
  - Flexible filler
- FDOT's Policy on Post-Tensioning
  - Structures Manual
  - Standard Plans
  - Specifications
- Post-Tensioning System Reviews
  - Requirements
  - Outcomes

# FDOT's History with Post-Tensioning

- 1954 – Sunshine Skyway Approaches
  - PT bars in the beams' bottom flange
- 1979 –Chipola Nursery Road Bridge
  - First draped tendons in girder web
- 1979- Long Key Bridge
  - First span-by-span segmental bridge
- 1984 –Ramp I over I-75
  - First balanced cantilever bridge in Florida
- Benefits of using Post-Tensioning:
  - Longer spans
  - Structures with greater curvature
  - More efficient structures

***Chipola Nursery Road Bridge over I-10***

***Ramp I over I-75***

Images from: *New Directions for Florida Post-Tensioned Bridges*

# Corrosion of Post-Tensioning

- Factors Contributing to Corrosion:
  - Insufficient concrete cover
  - Dry joints between segments
  - Insufficient material for the grout and ducts
- New Criteria for Post-Tensioned Bridges:
  - Improved post-tensioning hardware
  - Pre-bagged thixotropic grouts
  - Enhanced training for installers and inspectors

***Niles Channel Anchorage***

***Sunshine Skyway Bridge Piers***

Images from: *New Directions for Florida Post-Tensioned Bridges*

# Recent Issues with Grout Filler

- Inadequate quality control
- Uncontrolled pump pressures
- Improper or prolonged storage of prepackaged grout
- Excessive water added to mix
- Variable bag weights
- Insufficient mix time
- Grout sensitivity to environmental conditions
- Contamination with chlorides

# Presentation Overview

- Post-Tensioning in Florida
  - Key projects
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  - Standard Plans
  - Specifications
- Post-Tensioning System Reviews
  - Requirements
  - Outcomes

# New Policy

- Reevaluation of Policy
  - Tendon inspection
  - Experimentation- Structures Research Center
  - Post-tensioning advancements
    - Nuclear Industry
    - Bridges in Europe
- Outcomes- New Policies and Criteria
  - Implemented in 2016
  - Flexible filler
  - Post-tensioning system testing

*Soft- Chalky Grout (2001)*

*Soft- Wet Grout (2011)*

# Moving Forward- Flexible Filler

Microcrystalline Wax

- Stable and non-separating
- Nonflammable
- No environmental concerns or precautions
- Completely prepackaged

- Corrosion Resistant
- Allows the Tendon to be Fully Replaceable
  - Non-rigid: Material viscosity increases with temperature

# Presentation Overview

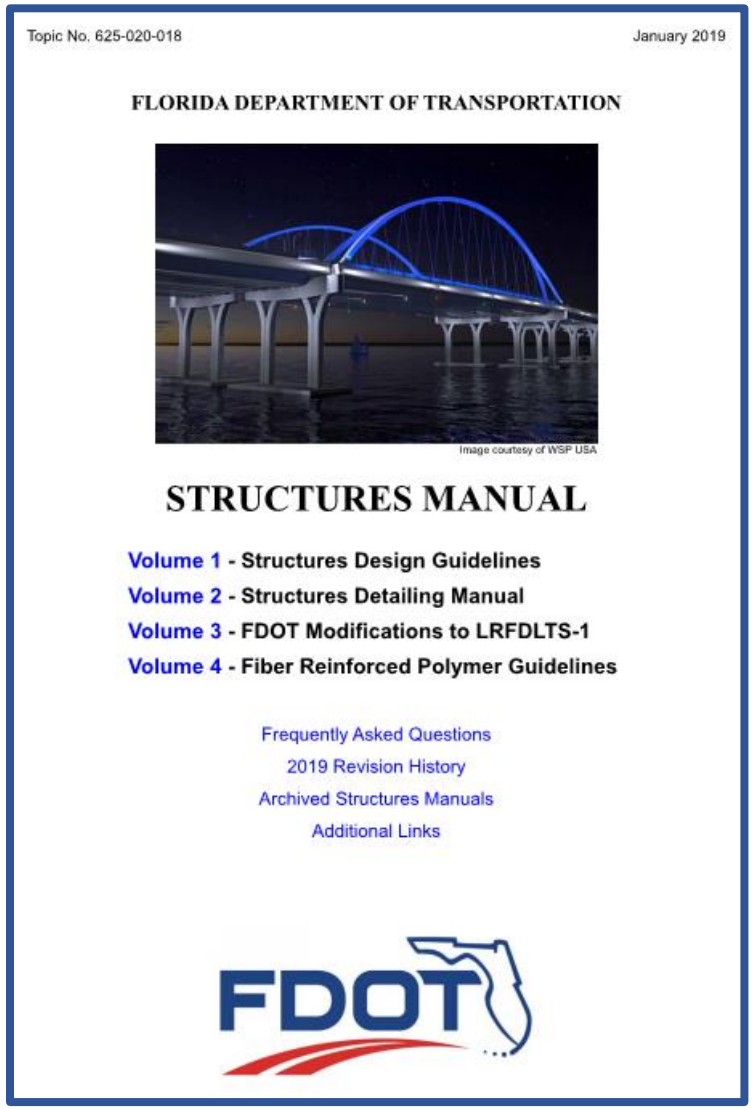
- Post-Tensioning in Florida
  - Key projects
  - Corrosion
- A need for Improvement
  - Reevaluation of the Department's Policy
  - Flexible filler
- FDOT's Policy on Post-Tensioning
  - Structures Manual
  - Standard Plans
  - Specifications
- Post-Tensioning System Reviews
  - Requirements
  - Outcomes

# Policy Documents

- Structures Manual
  - www.fdot.gov/structures/
- Standard Plans
  - www.fdot.gov/structures/
- The Standard Specifications for Road and Bridge Construction
  - www.fdot.gov/programmanagement/

# Structures Manual

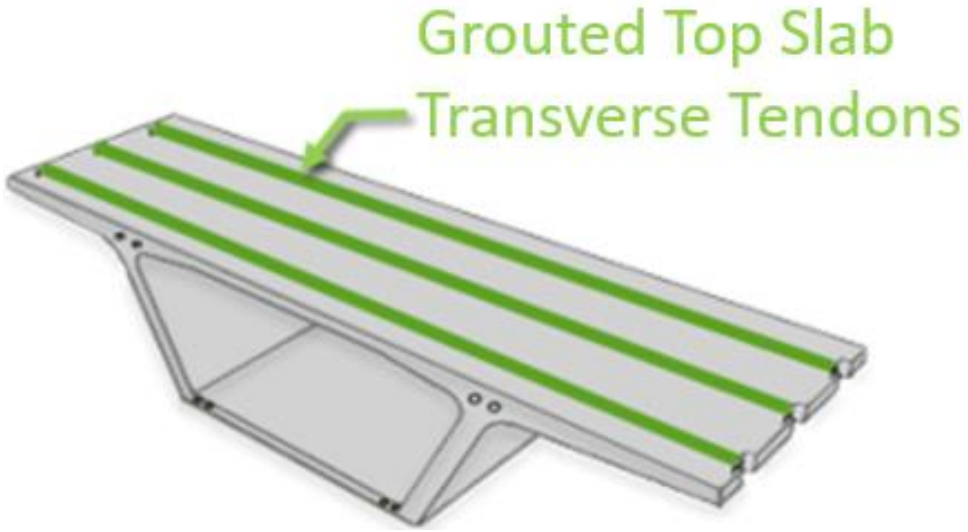
- Modifies the AASHTO LRFD Bridge Design Specifications to meet Florida's requirements
- Provides design and detailing criteria
- 4-Volume Manual
  - Volume 1- Structures Design Guidelines (SDG)
  - Volume 2- Structures Detailing Manual (SDM)

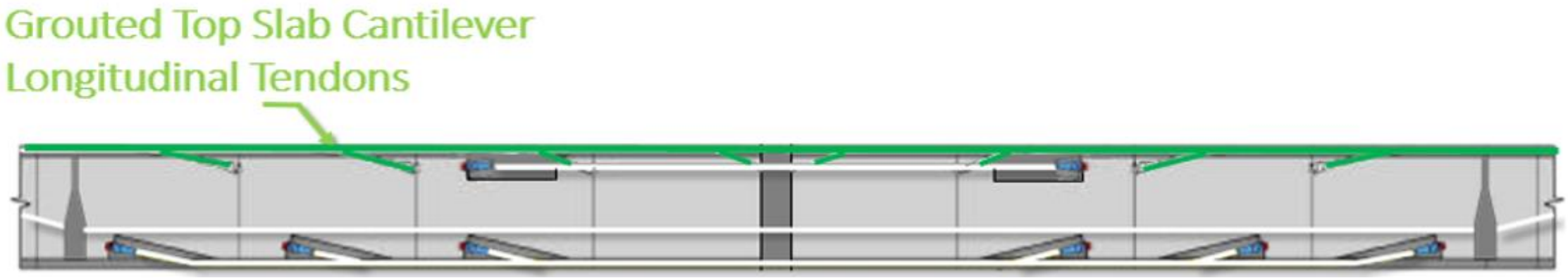


# Structures Manual- SDG 1.11.5 Tendon Design

## Bonded Tendons with Grout Filler:

- Segmental Box Girders
  - Top slab transverse tendons
  - Top slab cantilever longitudinal tendons
- Slab Type Superstructures
  - Tendons that are draped 2’-0” or less




Original images from: *New Directions for Florida Post-Tensioned Bridges*

# Structures Manual- SDG 1.11.5 Tendon Design

**Bonded Tendons with Grout or Unbonded Tendons with Flexible Filler:**

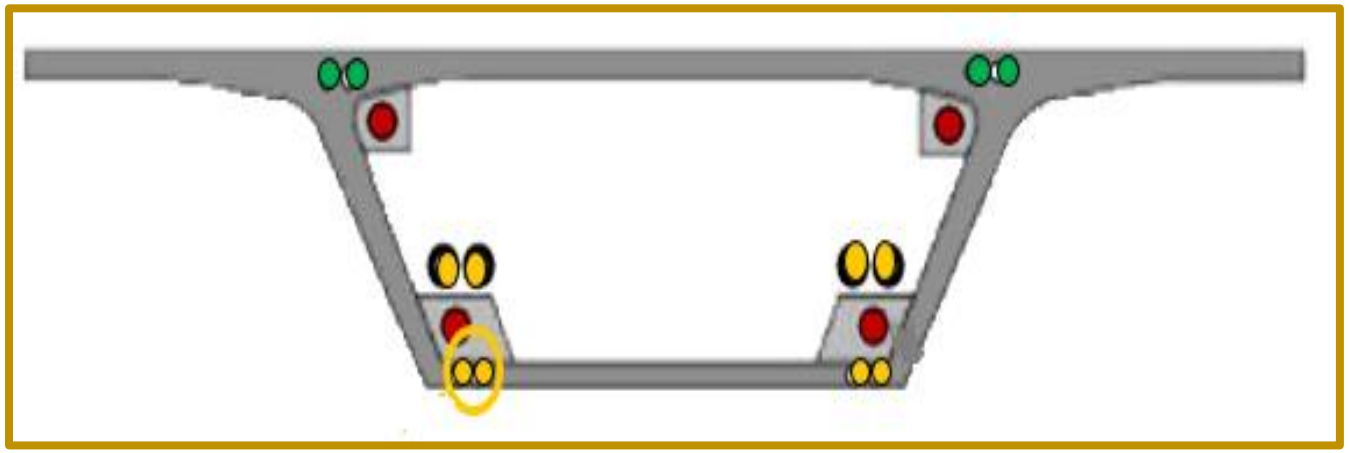
- Straight strand or parallel wire tendons other than continuity tendons in U-beams and girders.
- Bar tendons- horizontal or vertical

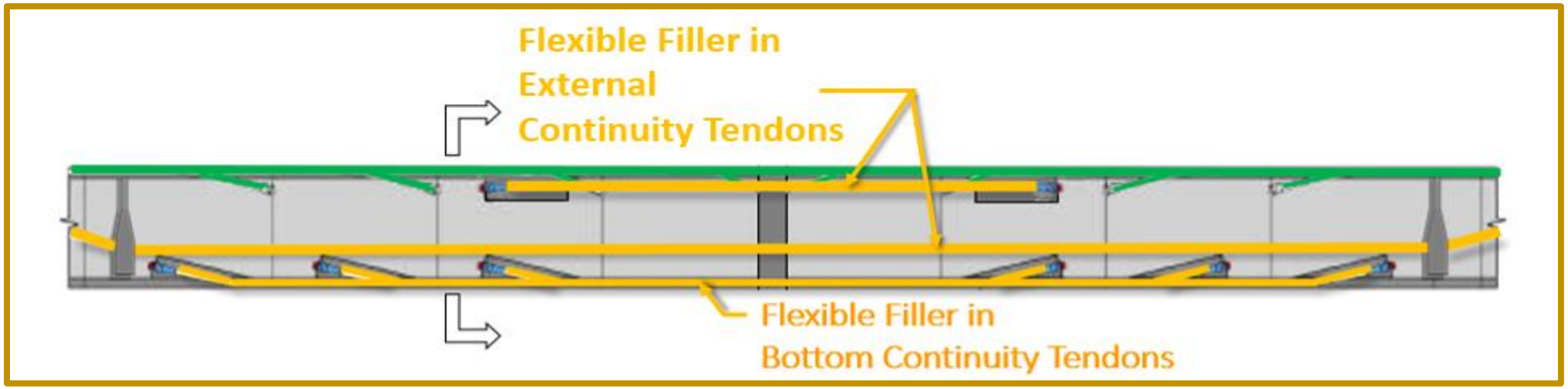
# Structures Manual- SDG 1.11.5 Tendon Design

## Unbonded Tendons with Flexible Filler:

Segmental Box Girders

- External tendons
- Continuity tendons

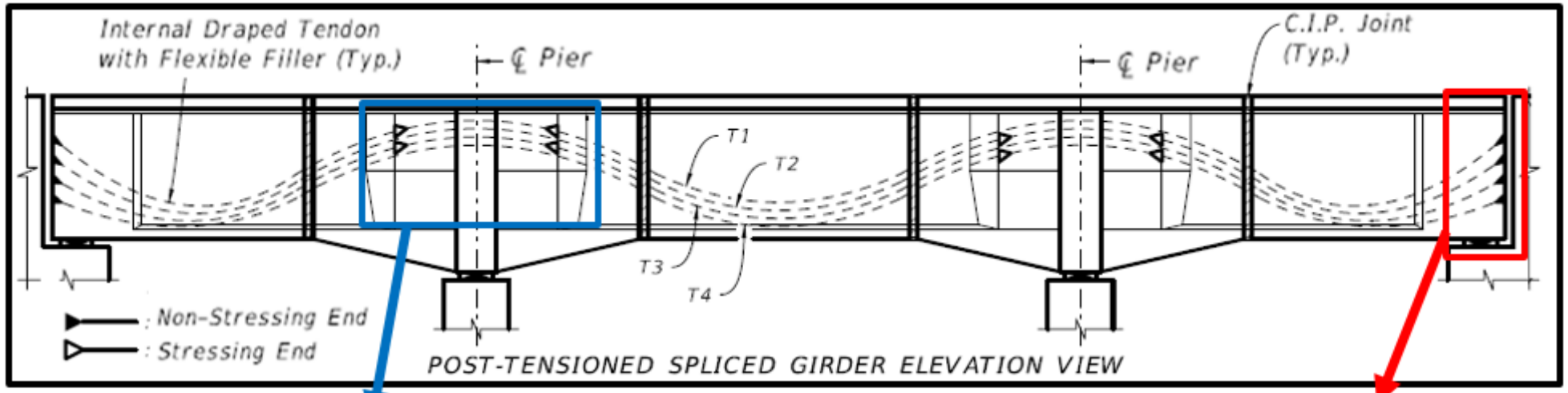


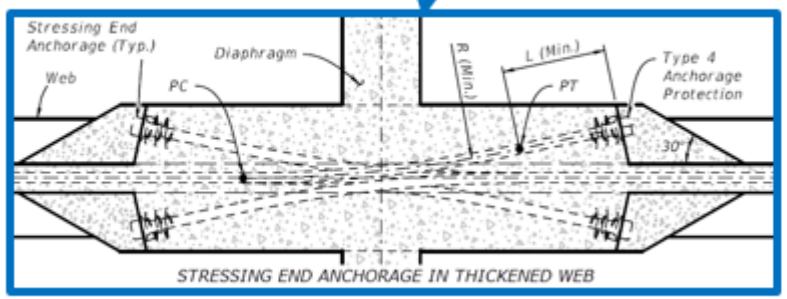



Original images from: *New Directions for Florida Post-Tensioned Bridges*

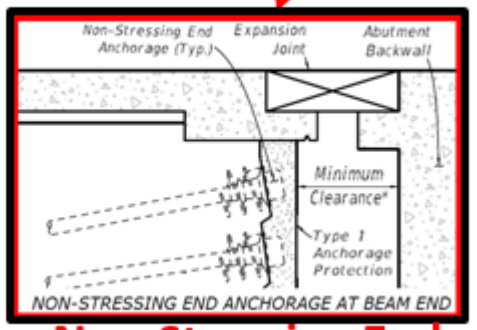
# Structures Manual – SDG 1.11.5 Tendon Design

- **Unbonded Tendons with Flexible Filler:**
- Spliced I-Girders




Stressing End



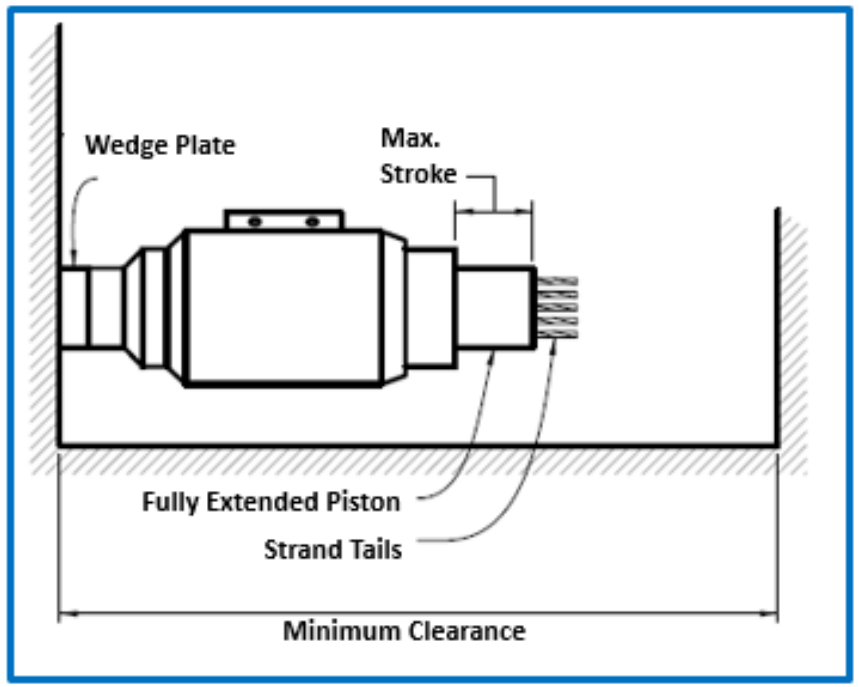

Non-Stressing End

FDOT TRANSPORTATION SYMPOSIUM

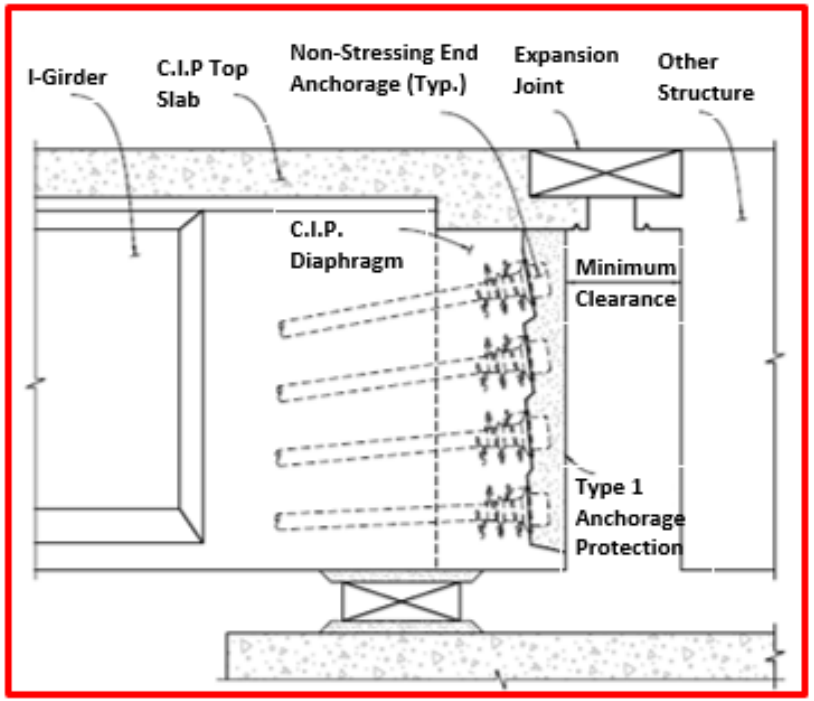
# Structures Manual

- **Structures Design Guidelines Table 1.11.1-1:** Minimum Clearance Requirements at Anchorages for Replaceable Strand and Wire Tendons

**Stressing End Anchorage**

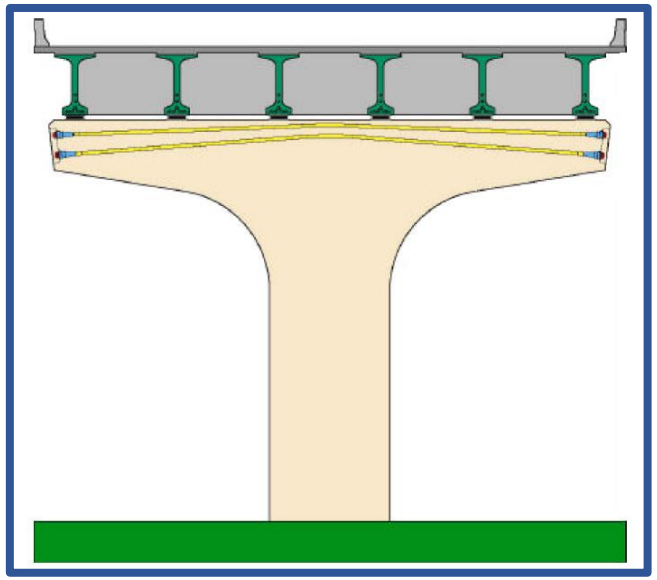



**Non-Stressing End Anchorage**

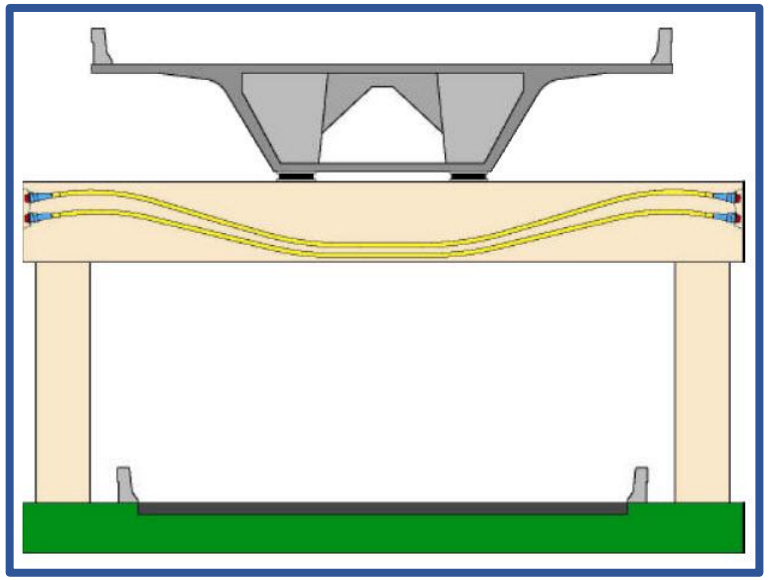


# Structures Manual- SDG 1.11.5 Tendon Design

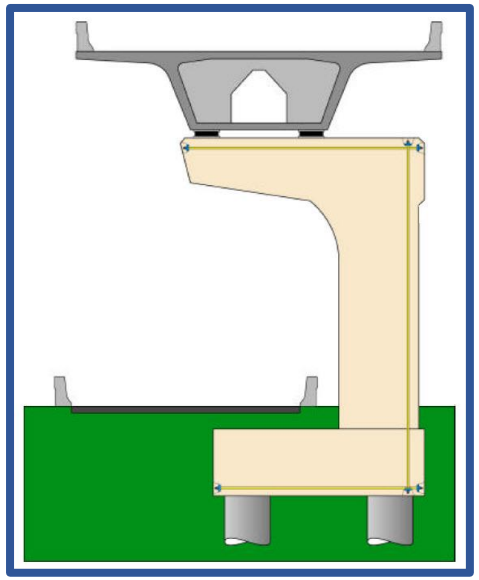
- **Unbonded with Flexible Filler:**
- All substructure strand tendons



Hammerhead Pier



Straddle Bent

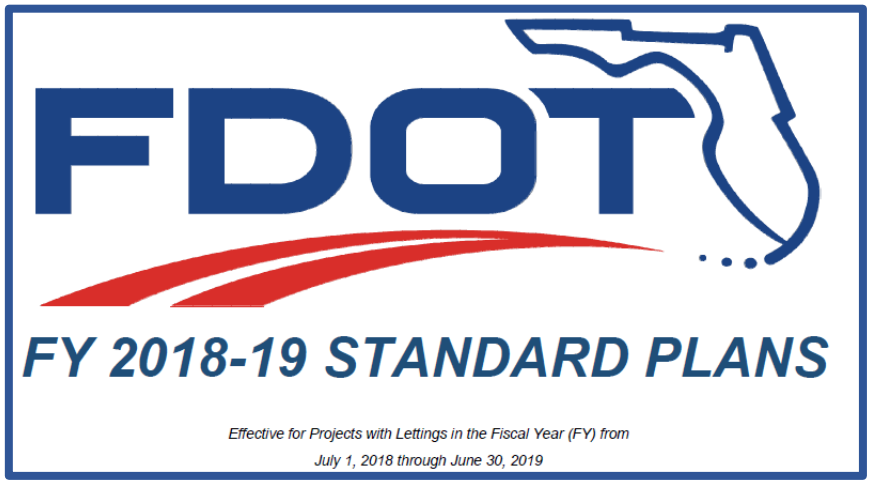


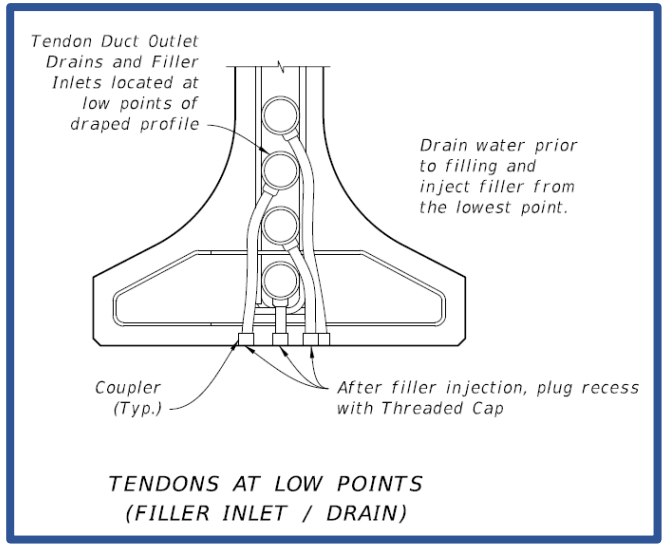
C-Pier

Images from: *New Directions for Florida Post-Tensioned Bridges*

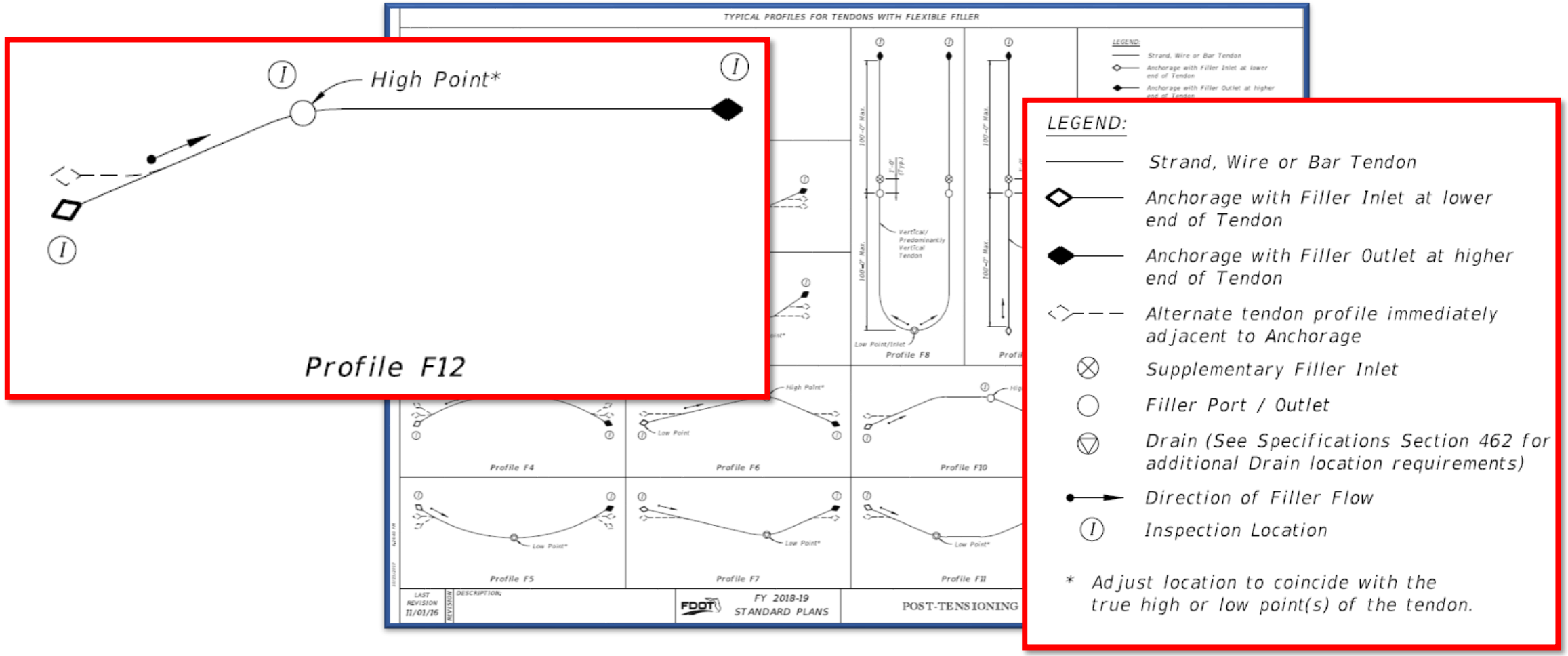
# Standard Plans

- Uniform Standards
- 462 Series- Post Tensioning
  - 462-001: Post-Tensioning Vertical Profiles
  - 462-002: Post- Tensioning Anchorage Protection
  - 462-003: Post- Tensioning Anchorage and Tendon Filling Details
  - Standard Plans Instructions



# Standard Plans 462-001: Post-Tensioning Vertical Profiles

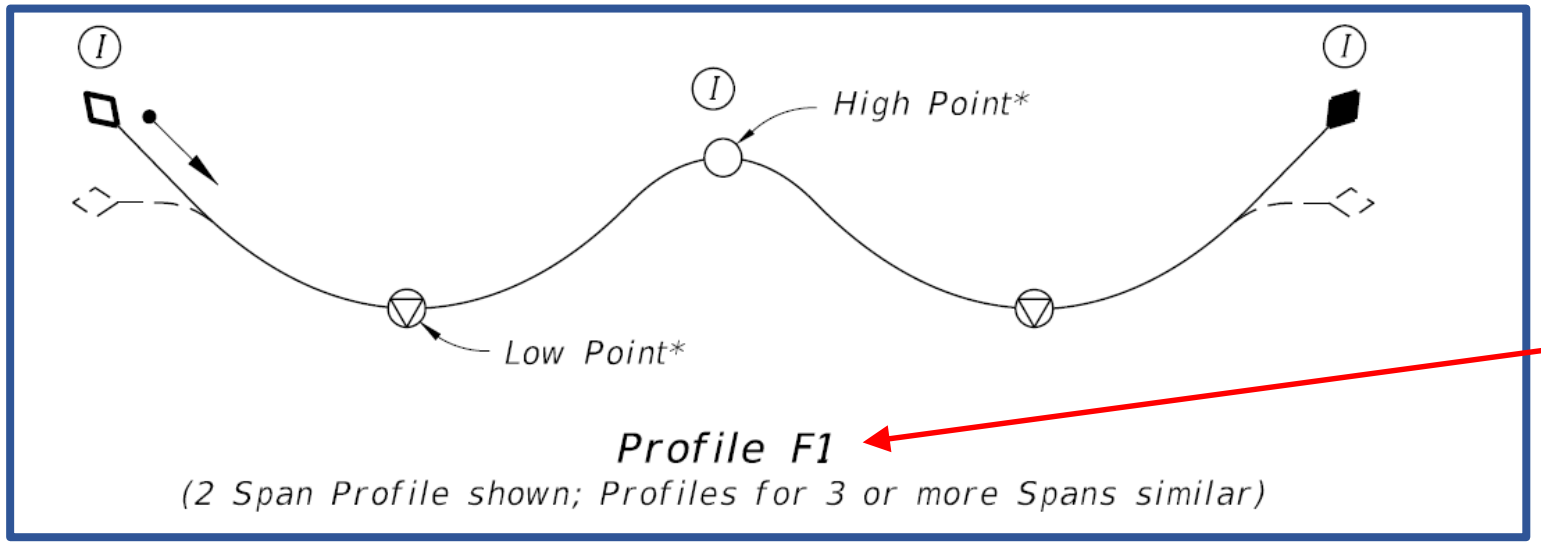


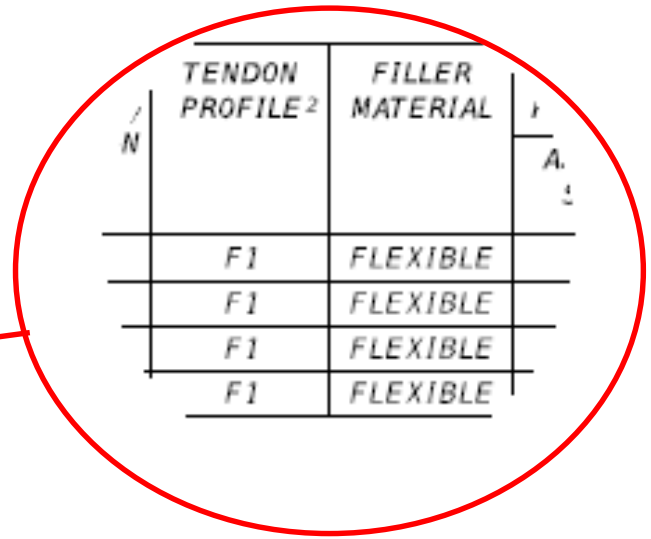

FDOT TRANSPORTATION SYMPOSIUM

# Post-Tensioning Tendon Data Table

**POST-TENSIONING STRAND TENDON DATA TABLE** — Table Date 07-01-16

| TENDON DESIGNATION | NO. REQUIRED | TENDON SIZE | TENDON LENGTH (Ft-in) | AHEAD-STATION STRESSING FORCE PER TENDON (kips) | BACK-STATION STRESSING FORCE PER TENDON (kips) | FORCE @ AHEAD-STATION END AFTER ANCHOR SET (kips) | FORCE @ BACK-STATION END AFTER ANCHOR SET (kips) | STRESSING END [1] | THEORETICAL ELONGATION @ AHEAD-STATION END (in) | THEORETICAL ELONGATION @ BACK-STATION END (in) | TENDON PROFILE [2] | FILLER MATERIAL | ANCHORAGE PROTECTION TYPE [3] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | AHEAD STA. | BACK STA. |
| 1 | 6 | 12-0.6 | 650'-0⅞" | 562.5 | 562.5 | 454.9 | 468.9 | Alt. (back/ahead) | 10.9 | 32.2 | F1 | FLEXIBLE | 1 | 1 |
| 2 | 6 | 12-0.6 | 650'-1¾" | 562.5 | 562.5 | 456.3 | 456.3 | Alt. (back/ahead) | 10.8 | 31.6 | F1 | FLEXIBLE | 1 | 1 |
| 3 | 6 | 12-0.6 | 650'-3⅝" | 562.5 | 562.5 | 458.4 | 459.8 | Alt. (back/ahead) | 10.6 | 31.0 | F1 | FLEXIBLE | 1 | 1 |
| 4 | 6 | 12-0.6 | 650'-6¼" | 562.5 | 562.5 | 465.4 | 465.4 | Alt. (back/ahead) | 10.6 | 30.3 | F1 | FLEXIBLE | 1 | 1 |



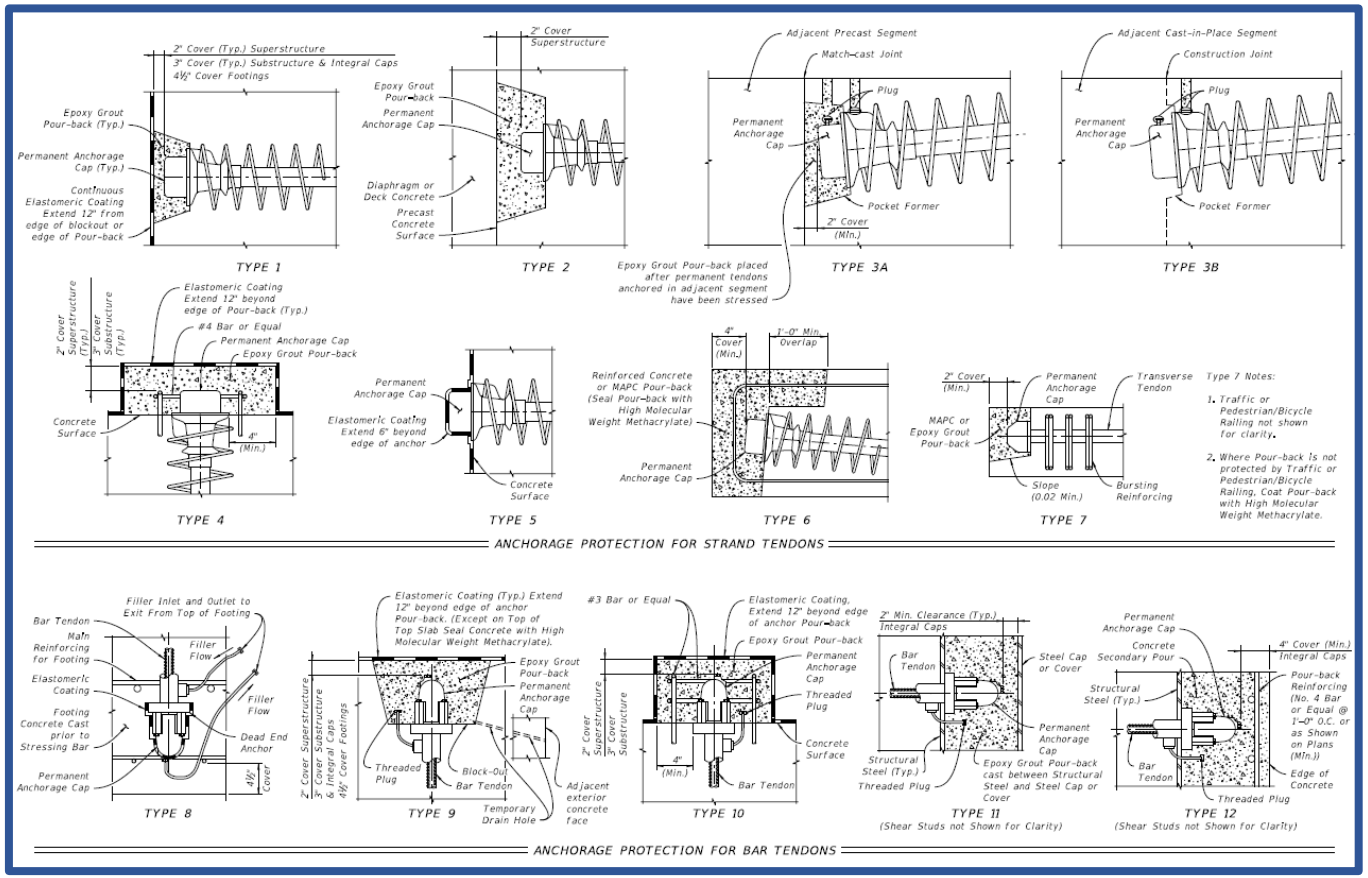




Index 462-001

# Standard Plans 462-002: Post-Tensioning Anchorage Protection

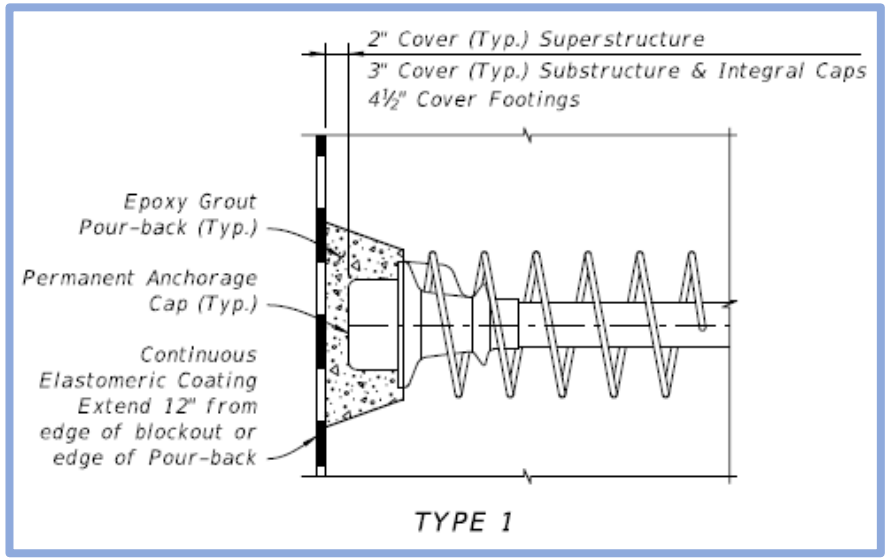
Structures Design Guidelines
1.11.2- Corrosion Protection

- Four levels of corrosion protection are required at the anchorages
  - Filler in the cap
  - Permanent anchorage cap
  - Concrete structure for interior surfaces or pour-back for exterior surfaces
  - Seal coat



# Standard Plans 462-002: Post-Tensioning Anchorage Protection

- Transverse Tendons:
  - Ahead Station →Left Anchorage
  - Back Station → Right Anchorage
- Vertical Tendons
  - Ahead Station → Top of Tendon
  - Back Station → Bottom of Tendon




POST-TENSIONING STRAND TENDON DATA TABLE

Table Date 07-01-16

| TENDON DESIGNATION | NO. REQUIRED | TENDON SIZE | TENDON LENGTH (Ft-in) | AHEAD-STATION STRESSING FORCE PER TENDON (kips) | BACK-STATION STRESSING FORCE PER TENDON (kips) | FORCE @ AHEAD-STATION END AFTER ANCHOR SET (kips) | FORCE @ BACK-STATION END AFTER ANCHOR SET (kips) | STRESSING END [1] | THEORETICAL ELONGATION @ AHEAD-STATION END (in) | THEORETICAL ELONGATION @ BACK-STATION END (in) | TENDON PROFILE [2] | FILLER MATERIAL | ANCHORAGE PROTECTION TYPE [3] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | AHEAD STA. | BACK STA. |
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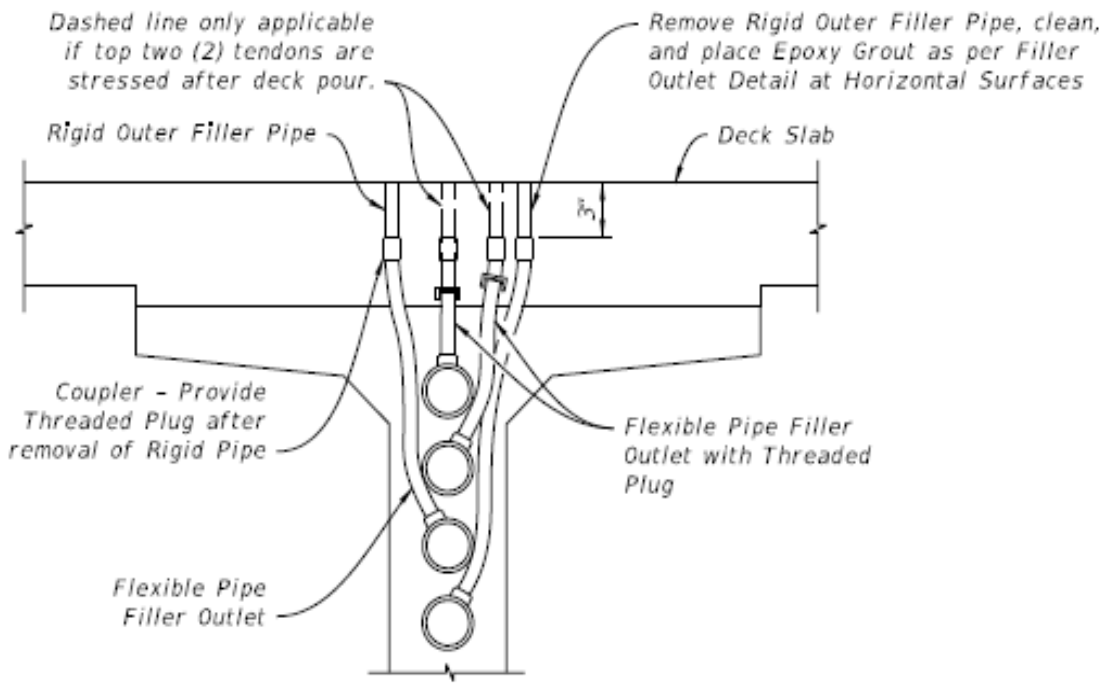
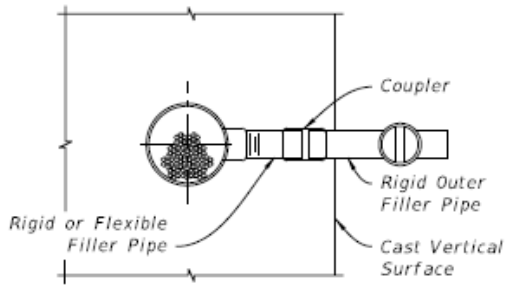
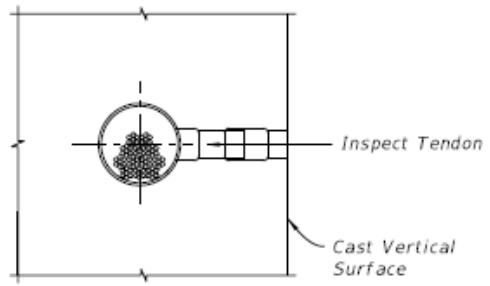
# Standard Plans 462-003: Post-Tensioning Anchorage and Tendon Filling Details



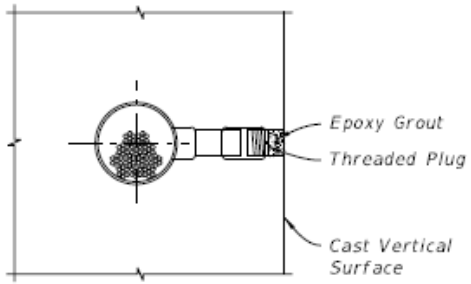

TENDONS AT HIGH POINTS AND 3' FROM HIGH POINTS (FILLER OUTLET)




1 FILLER OUTLET CONNECTION TO TENDON




2 POCKET PREPARATION




3 FILLING POCKET

PROCEDURE:

1. Remove Rigid Filler Pipe or drill Grout in flexible pipe.
2. Inspect tendon for voids.
3. Vacuum inject as required. If grout is used, allow grout to cure. If flexible filler is used, replace filler displaced by inspection. Remove pipe used for vacuum injecting.
4. Install Threaded Plug into Outlet to form a tight fit.
5. Over-ream hole (¼" Ø over-ream). Clean and roughen sides.
6. Fill pocket with epoxy grout.

FILLER OUTLET DETAIL AT VERTICAL SURFACES

FDOT TRANSPORTATION SYMPOSIUM

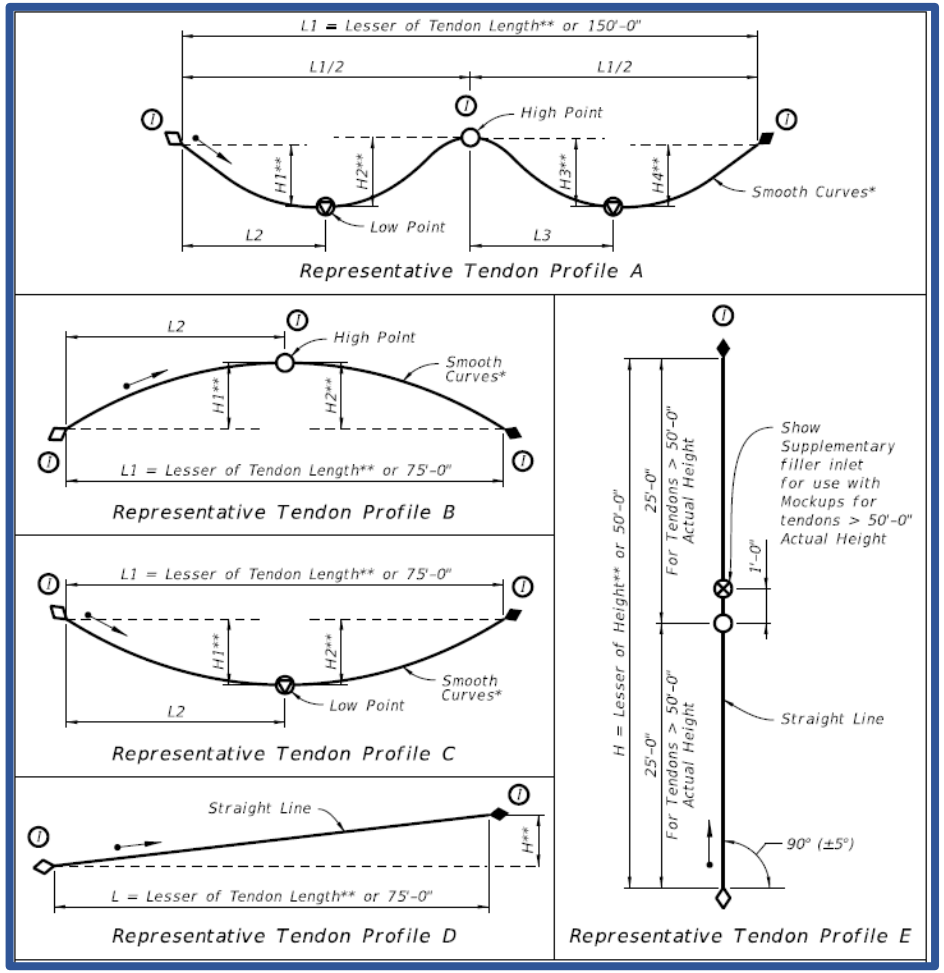
# Tendon Mockups

- Successful demonstration of the Contractor's means and methods
  - Duct dissection
  - Inspection at all ports
- Mockups components to be identical to production injection components with the exception of:
  - Segmental duct couplers
  - Corrugated plastic duct
  - Steel pipe

# Standard Plans Instructions for the 462 Series

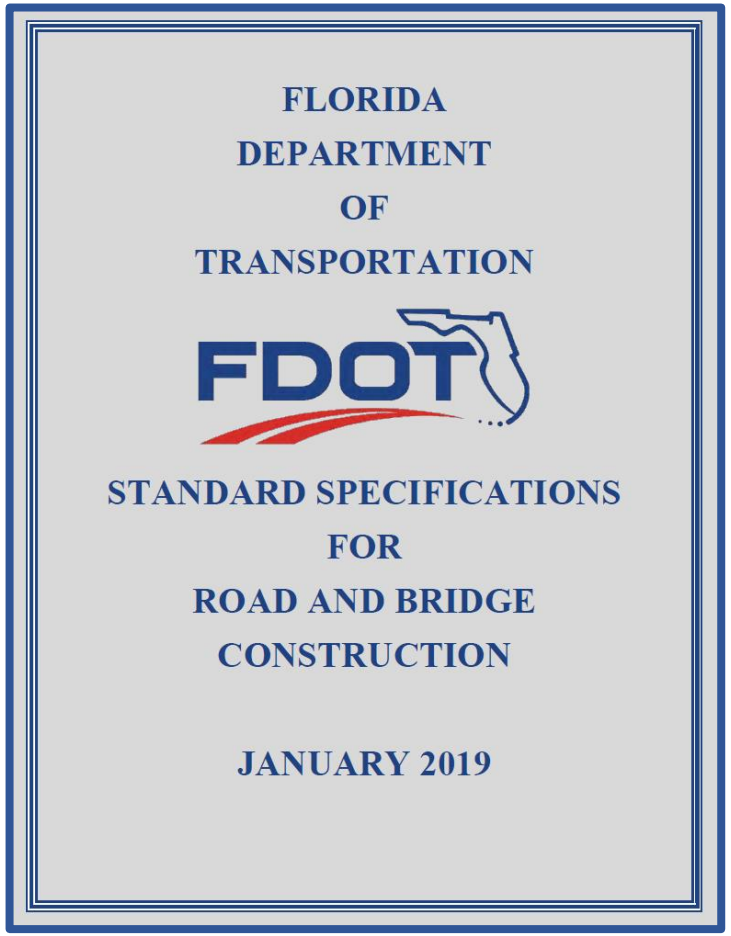
- Mockup Profiles
- Reduce the number of mockups by grouping tendons with similar geometry

| Actual Tendon Profile (See Index 462-001) | Representative Tendon Profile |
|---|---|
| F1, F2 and F3 | A |
| F4, F6 and F10 | B |
| F5, F7 and F11 | C |
| F8 and F9 | E |
| F12, F13 and F14 | D |
| G1 | A |
| G3 | B |
| G4 | C |
| G5 | D |
| G6 | E |



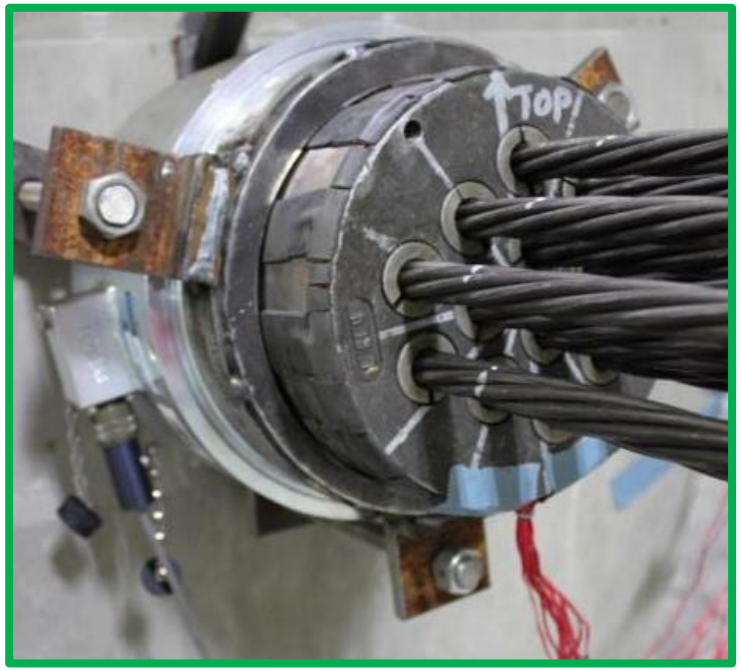
# The Standard Specifications for Road and Bridge Construction

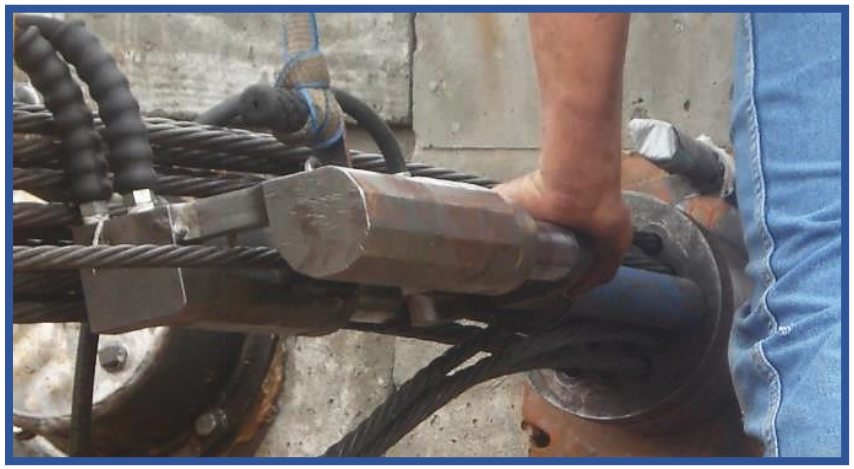
- Organized into Three Divisions
  - Division I: General Requirements and Covenants
  - Division II: Construction Details
  - Division III: Materials
- Sections Pertaining to Post-Tensioning
  - 462: Post-Tensioning
  - 938: Duct Filler for Post-Tensioned Structures
  - 960: Post-Tensioned Components



# 462- Post-Tensioning

- 462-1: Description
- 462-2: Materials
- 462-3: Alternate PT System Designs
- 462-4: Qualifications
- 462-5: Submittals



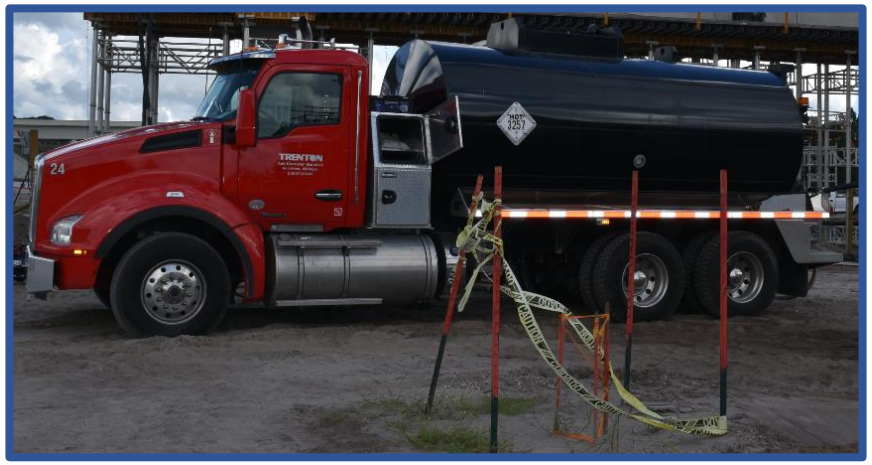
- 462-6: Transport, Handling and Storage
- 462-7: Construction
- 462-8: Acceptance and Testing
- 462-9: Method of Measurement
- 462-10: Basis of Payment

# 462 Post- Tensioning

- 462-1 Description
  - Furnish all post-tensioning system components from a single supplier
  - System must be approved and meet the requirements of Section 960
    - Posted to the Department's Approved Post-Tensioning Systems Webpage
- 462-2 Materials
  - Grout and flexible filler must be approved and meet the requirements of Section 938
    - Posted to the Department's Approved Products List (APL)
  - Do not combine different grout or flexible filler products

# 462 Post- Tensioning

- 462-4 Qualifications: Refer to Section 105
  - Minimum requirements for the foreman, technicians and Inspector
- 462-6 Transportation, Handling and Storage
  - Storage in the open must be on a raised and covered platform
    - Grout filler: 1 week
    - Flexible filler: Up to the manufacturer's expiration date
  - Product Use:
    - Grout filler: 6 months from the production date
    - Flexible filler: Up to the manufacturer's expiration date



# 462 Post-Tensioning

- 462-7 Construction:
  - Time limit between Post-tensioning steel installation and filler injection:
    - PT bars in the superstructure and all strand: 14-days
    - PT bars in the substructure: 21-days
  - Inject according to the approved injection plan
  - Conduct all injection operations in the presence of the Engineer.

# 462-7 Construction

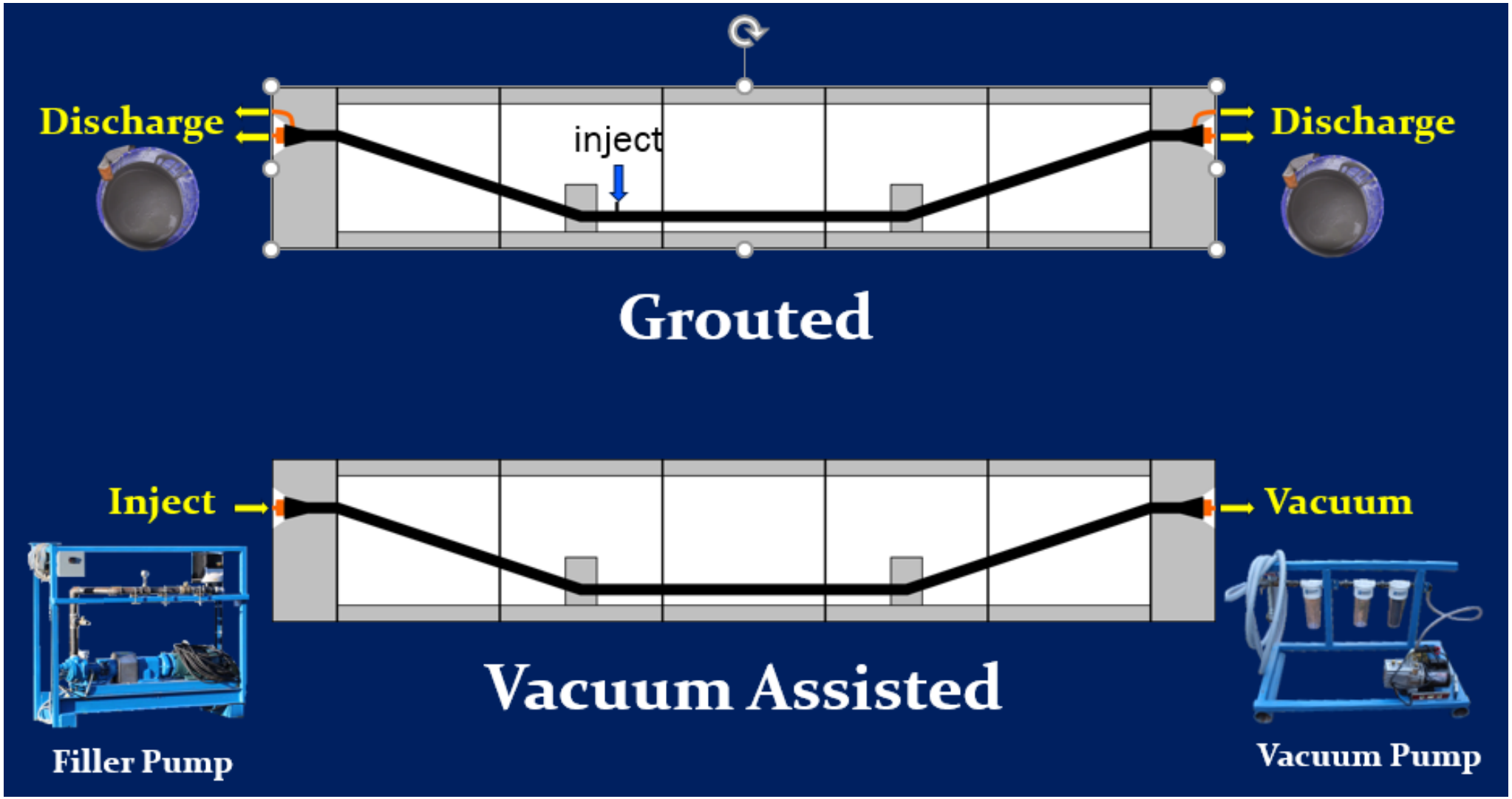
## Grout

- **Injection Velocity:** Ducts must be filled and vented in not more than 30 minutes without interruption
  - Typically 15-50ft./min.
- **Pressure:**
  - 10-50 psi at the inlet
  - 145 psi maximum anywhere in the system
  - 75 psi maximum for flat ducts
- **Temperature:** 90°F maximum

## Flexible Filler

- **Injection Velocity:** 40-70 ft./min.
- **Pressure:**
  - 75 psi maximum at the inlet
  - 145 psi maximum at the pump
- **Temperature:** 212°F-240°F

# 462-7 Construction




Slide Credit: Will Potter, Structures Research Center and Dr. Trey Hamilton, University of Florida

# 462-7 Construction

- **Vertical** or predominately vertical profiles **may** utilize vacuum assisted injection.
- **Horizontal** profiles **must** utilize vacuum assisted injection.

# 462-8 Acceptance and Testing

## Post-Filler Injection Operations

### Grouted Tendons:

- Allow grout to cure for a minimum of 24 hours
- Complete inspection within 1 hour of opening ports
- Drill into ports at all high points and anchorage ports
- Inspect using a borescope
- Fill all voids detected within 4 days from grouting
- Fill all voids due to inspection within 4 hours

### Flexible Filler Tendons:

- Allow wax to cool for a minimum of 24 hours
- Complete inspection within 1 hour of opening ports
- Visually inspect all high and low points and ports at anchorages, remove anchorage caps
- Sound external ducts with a rubber mallet
- Repair all voids deeper than ½” or if strands are exposed and uncoated
- Fill all voids within 4 days from filler injection
- Fill all due to inspection within 4 hours

# 938 Duct Filler for Post-Tensioned Structures

- 938-1 Description
- 938-2 Approved Product List
  - Submit the following to Program Management for Inclusion on the APL:
    - Product Evaluation Application including test reports, material certifications, written certification from the manufacturer
  - Any changes to the material or material source requires new testing and certification
- 938-3 General Requirements

# 938 Duct Filler for Post-Tensioned Structures

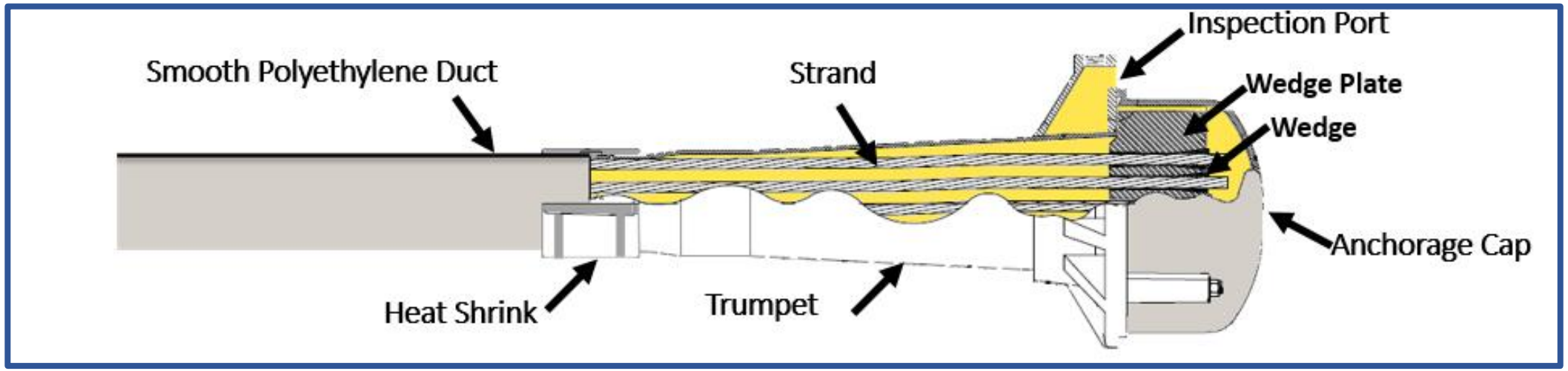
- 938-4 Grout
  - Thixotropic properties
  - Prepackaged in moisture proof containers
- 938-5 Flexible Filler- Microcrystalline Wax
  - Petroleum based microcrystalline

# Presentation Overview

- Post-Tensioning in Florida
  - Key projects
  - Corrosion
- A need for Improvement
  - Reevaluation of the Department's Policy
  - Flexible filler
- FDOT's Policy on Post-Tensioning
  - Structures Manual
  - Standard Plans
  - Specifications
- Post-Tensioning System Reviews
  - Requirements
  - Outcomes

# 960 Post -Tensioning Components

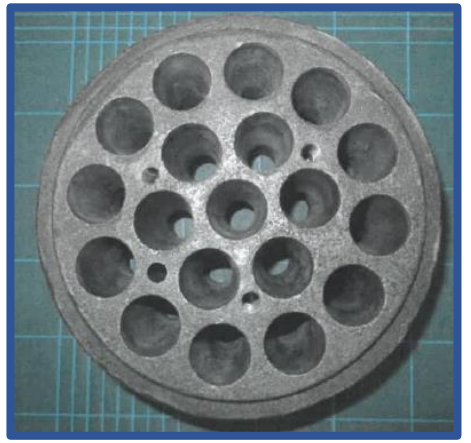
- 960-1 Description
- 960-2 Component Standards
  - Material properties for system components
- 960-3 System Pre-Approval Requirements
  - Pressure tests for components and assemblies
  - Fully detailed drawings



# 960- Post- Tensioning Components

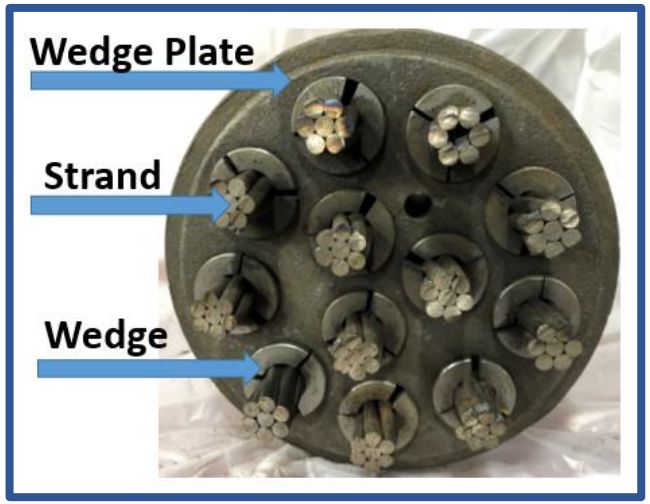
The following components are identical for systems using grout or flexible filler:

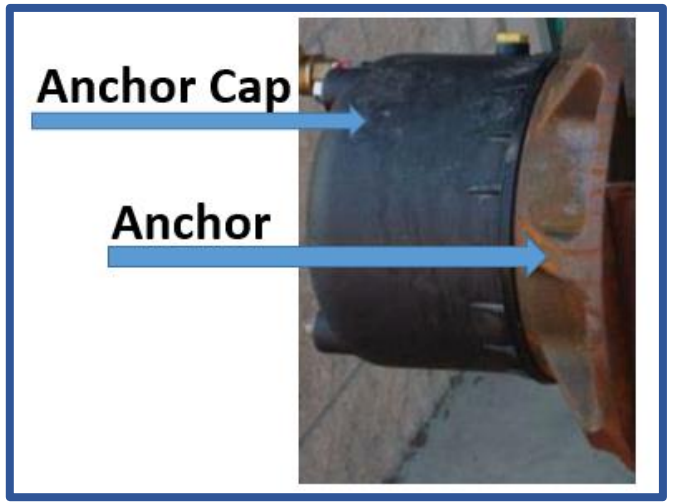
- Wedge
  - Grips the strand
- Wedge Plate
  - Seats the wedge
- Anchor cap
  - Contains the filler around the anchorage



**Wedge Plate**

**Wedge**

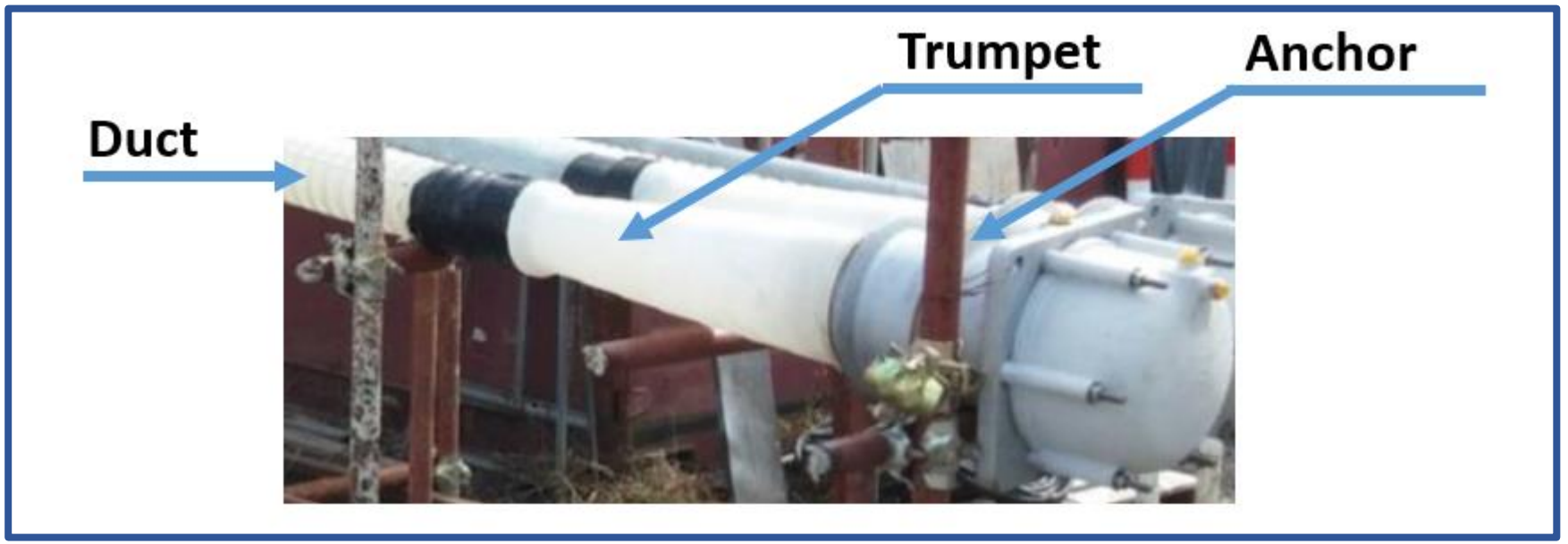


# 960- Post- Tensioning Components

The following components are identical for systems using grout or flexible filler:

- Anchorage
  - Transfers the prestressing force to the concrete
- Trumpet
  - Used to deviate the strand from the anchor to duct



# 960 Post-Tensioning Components

- Conduit
  - Grouted: Polypropylene corrugated duct
  - Flexible Filler: Smooth high density polyethylene pipe
- Connections
  - Grouted: Heat welding, duct couplers with gaskets or heat shrink
  - Flexible Filler: Heat welding, Electrofusion couplers

**Corrugated Duct**

**HDPE Pipe with Electrofusion Coupler**

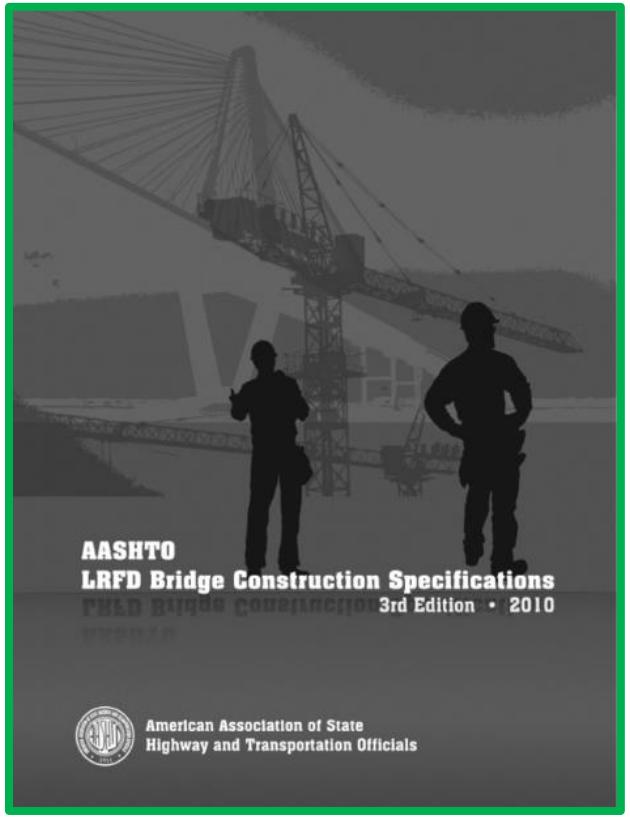
# 960 Post-Tensioning Components

- Injection Hoses and Ball Valves
  - Grouted: Plastic components
  - Flexible Filler: Metallic components
    - Compatible with high heat and pressure
- Heat Shrink
  - Grouted: CANUSA PLA
  - Flexible Filler: CANUSA KLNN
    - Higher pipeline temperature
  - Heat shrink may only be used for connections encased in concrete

# 960 Post-Tensioning

Required Testing- Conducted or witnessed by an independent lab

- Anchorage
  - AASHTO LRFD Bridge Construction Specifications
    - Anchorage shall develop 96% of PT steel AUTS
  - AASHTO LRFD Bridge Construction Specifications Load Transfer Test
    - Prestressing force transferred to the concrete with acceptable crack widths
  - European Assessment Document 16004-00-0301 Fatigue Test
    - 2-million cycle load test
    - Ensures that the strands will not break as they deviate from the wedge to the duct.




# 960 Post-Tensioning

Required Testing- Conducted or witnessed by an independent lab

- Materials
  - Physical properties defined by ASTMs for:
    - Polypropylene
    - Polyethylene
    - Nylon
    - Rubber
    - Steel

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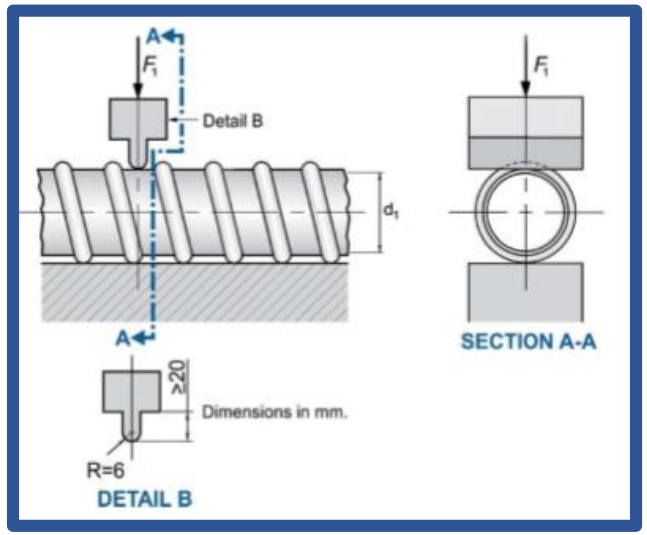
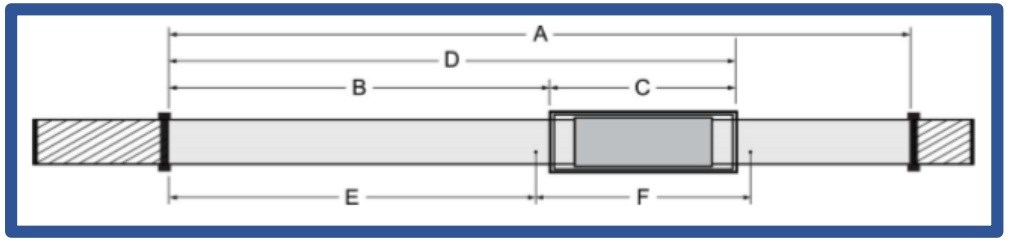
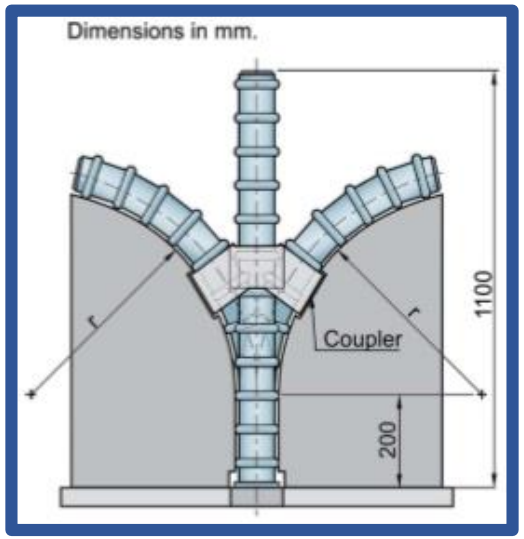
# 960 Post-Tensioning Components

- Duct Testing
  - fib Bulletin 75: Polymer-duct systems for internal bonded post-tensioning
    - The Fédération internationale du béton
      → International Federation for Structural Concrete
    - Annex A: Component assessment procedures, test to Protection Level 2



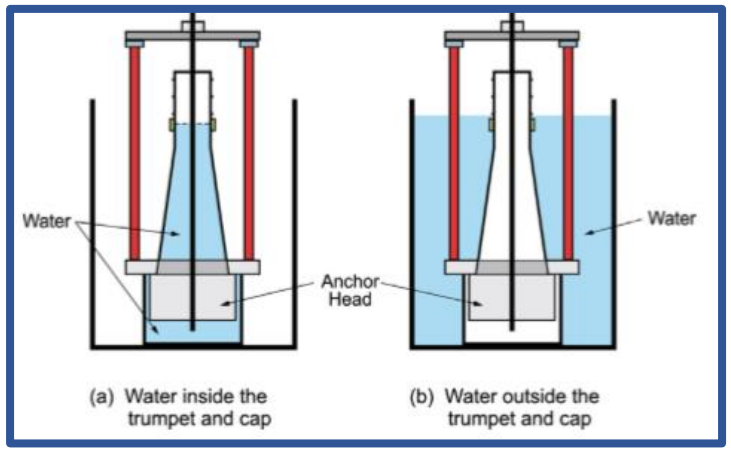



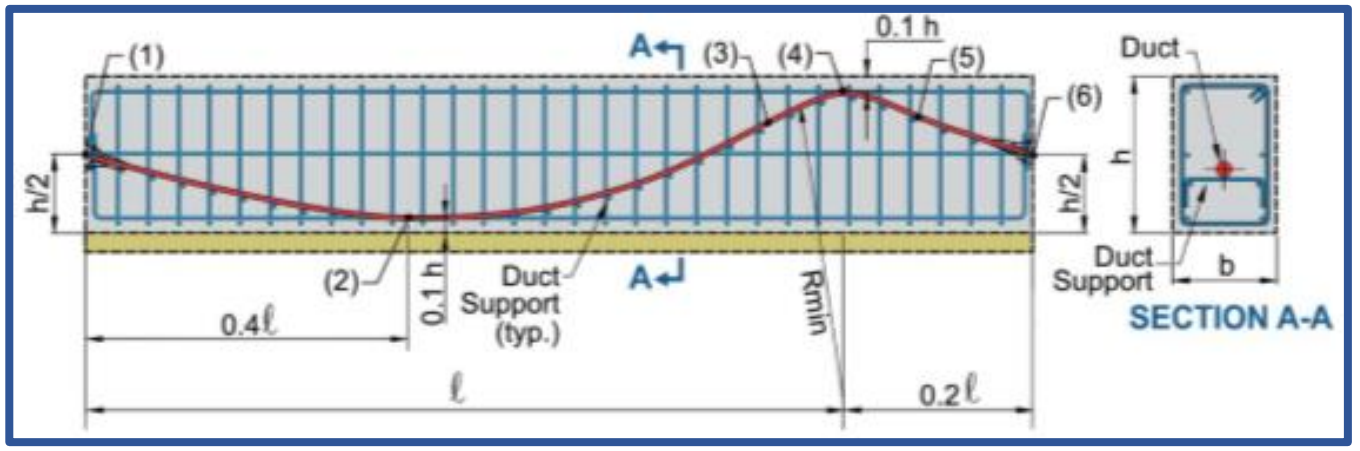




Images from: *fib Bulletin 75*

# 960 Post-Tensioning Components

- System Testing
  - fib Bulletin 75: Polymer-duct systems for internal bonded post-tensioning
    - Annex B: System assessment procedures
  - Filler Containment Assembly Pressure Test
  - External PT System Pressure Test
  - Vacuum Test for Internal and External PT Systems with Flexible Filler



# Summary

- Corrosion on tendons using grout filler have lead to major changes in the FDOT's policy on post-tensioning. These changes were implemented in 2016.
- Outcomes of the policy change include the use of flexible filler, increased requirements for installers and inspectors in the field and additional testing on post-tensioning system materials, components and assemblies.
- The Department's policy on post-tensioning is provided in the Structures Manual, Standard Plans and Standard Specifications for Road and Bridge Construction.
- Many of the components between systems using grout and flexible filler are identical with the exception of ducts, injection pipes, valves, couplers and heat shrink.

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