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

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

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
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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
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
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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
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
Structures Manual

- Structures Design Guidelines Table 1.11.1-1: Minimum Clearance Requirements at Anchorages for Replaceable Strand and Wire Tendons
Structures Manual- SDG 1.11.5 Tendon Design

• Unbonded with Flexible Filler:
• All substructure strand tendons

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

Profile F12

LEGEND:
- Strand, Wire or Bar Tendon
- Anchorage with Filler Inlet at lower end of Tendon
- Anchorage with Filler Outlet at higher end of Tendon
- Alternate tendon profile immediately adjacent to Anchorage
- Supplementary Filler Inlet
- Filler Port / Outlet
- Drain (See Specifications Section 462 for additional Drain location requirements)
- Direction of Filler Flow
- Inspection Location

* Adjust location to coincide with the true high or low point(s) of the tendon.
**Post-Tensioning Tendon Data Table**

### POST-TENSIONING STRAND TENDON DATA TABLE

<table>
<thead>
<tr>
<th>TENDON DESIGNATION</th>
<th>NO. REQUIRED</th>
<th>TENDON SIZE</th>
<th>TENDON LENGTH (ft-in)</th>
<th>AHEAD-STATION STRESSING FORCE PER TENDON (kips)</th>
<th>BACK-STATION STRESSING FORCE PER TENDON (kips)</th>
<th>FORCE AT HEAD-STATION END AFTER ANCHOR SET (kips)</th>
<th>FORCE AT BACK-STATION END AFTER ANCHOR SET (kips)</th>
<th>STRESSING END</th>
<th>THEORETICAL ELONGATION @ AHEAD-STATION END (in)</th>
<th>THEORETICAL ELONGATION @ BACK-STATION END (in)</th>
<th>TENDON PROFILE</th>
<th>FILLER MATERIAL</th>
<th>ANCHORAGE PROTECTION TYPE</th>
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<tr>
<td>1</td>
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<td>12-0.6</td>
<td>650-0.5</td>
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<td>562.5</td>
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<td>468.9</td>
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<td>650-1.0</td>
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<td>456.2</td>
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<td>650-1.5</td>
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<td>Alt. (back/ahead)</td>
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<td>30.3</td>
<td>F1</td>
<td>FLEXIBLE</td>
<td>在家.</td>
</tr>
</tbody>
</table>

**Profile F1**

(2 Span Profile shown; Profiles for 3 or more Spans similar)
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

<table>
<thead>
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<th>FORCE @ AHEAD-STATION END AFTER ANCHOR SET (kips)</th>
<th>FORCE @ BACK-STATION END AFTER ANCHOR SET (kips)</th>
<th>STRESSING END 1</th>
<th>THEORETICAL ELONGATION @ AHEAD-STATION END (in)</th>
<th>THEORETICAL ELONGATION @ BACK-STATION END (in)</th>
<th>TENDON PROFILE</th>
<th>FILLER MATERIAL</th>
<th>ANCHORAGE PROTECTION TYPE</th>
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<td>32.2</td>
<td>F1</td>
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<td>F1</td>
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<td>10.6</td>
<td>30.3</td>
<td>F1</td>
<td>FLEXIBLE</td>
<td>1</td>
</tr>
</tbody>
</table>
Standard Plans 462-003: Post-Tensioning Anchorage and Tendon Filling Details

1. **FILLER OUTLET CONNECTION TO TENDON**

- Proposed Rigid Filler Pipe or drill grout in flexible pipe.
- Inspect tendon for voids.
- 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 injection.
- Install threaded plug into outlet to form a tight fit.
- Over-ream hole (1/2” over-ream). Clean and roughen sides.
- Fill pocket with epoxy grout.

2. **POCKET PREPARATION**

3. **FILLING POCKET**
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

<table>
<thead>
<tr>
<th>Actual Tendon Profile (See Index 462-001)</th>
<th>Representative Tendon Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1, F2 and F3</td>
<td>A</td>
</tr>
<tr>
<td>F4, F6 and F10</td>
<td>B</td>
</tr>
<tr>
<td>F5, F7 and F11</td>
<td>C</td>
</tr>
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<td>F8 and F9</td>
<td>E</td>
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<tr>
<td>F12, F13 and F14</td>
<td>D</td>
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<tr>
<td>G1</td>
<td>A</td>
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<tr>
<td>G3</td>
<td>B</td>
</tr>
<tr>
<td>G4</td>
<td>C</td>
</tr>
<tr>
<td>G5</td>
<td>D</td>
</tr>
<tr>
<td>G6</td>
<td>E</td>
</tr>
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</table>

![Diagram of Tendon Profiles](image-url)
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 15-50 ft./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

Grouted

Vacuum Assisted

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
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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
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
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
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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