Flexible Filler Material

for Post-Tensioned Systems

2014 Design Training Expo

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FDOT

Presentation Outline

1. **Why** Transition to Flexible Filler?
2. **What** is Flexible Filler?
3. **Where** is Flexible Filler Used?
4. **How** is Design, Construction and Maintenance Affected by Flexible Filler?
5. **What** are the Policies and Procedures of Flexible Filler?

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Why is the FDOT Transitioning to Flexible Filler?

Tendon Corrosion in Florida

1. **Niles Channel Bridge**, Florida Keys
2. **Mid-Bay Bridge**, Destin
3. **Sunshine Skyway Bridge**, Tampa
4. **Seabreeze Bridge**, Daytona Beach

2002

5. **Ringling Bridge**, Sarasota
6. **Wonderwood Bridge**, Jacksonville
7. **I-4 / Crosstown Connector**, Tampa
8. **I-95 / I-295 Interchange**, Jacksonville

Tendon Corrosion

- Excess Bleed Water
- Grout Voids
- Soft Grout
- Contaminates

France

External Cement-Grouted Tendon Failures

- No Observable Warning Prior to Failure
- Excess Bleed Water
- Soft Grout

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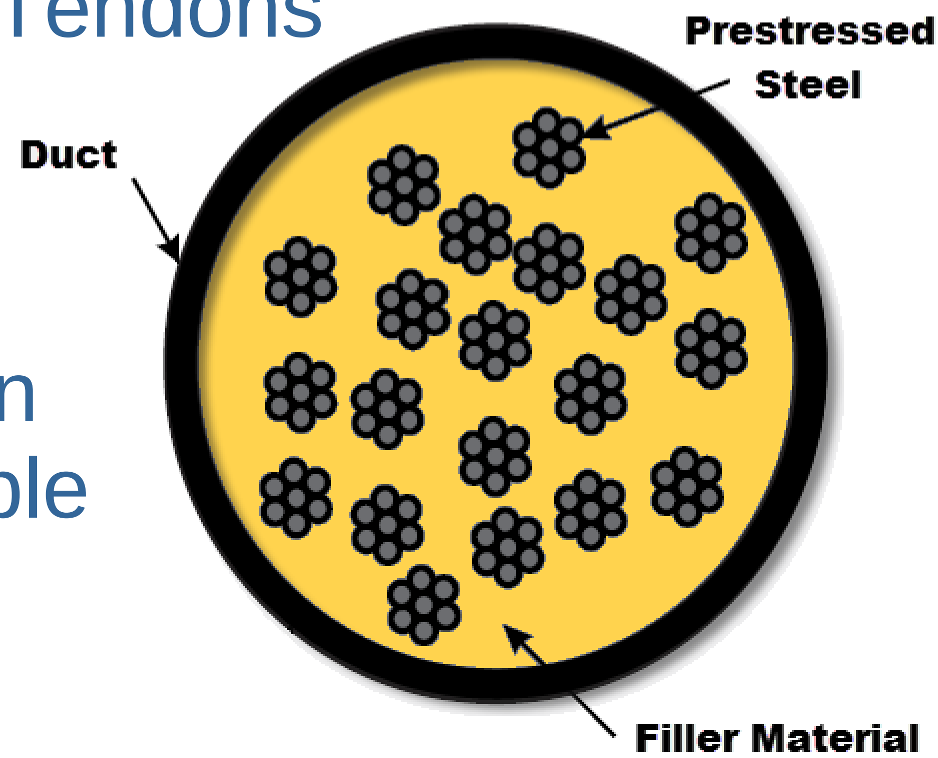
France

External Tendon Regulations in 2001

- Avoid Sudden Breakage of Tendons
- Easily Replaceable Tendons

Result

- Flexible Filler
- No Reported Tendon Failures using Flexible Filler



What is Flexible Filler?

Typical Properties of Flexible Filler

- Microcrystalline Wax Derived from Petroleum
- Homogeneous
- Hydrophobic
- Metal Adhesion Properties

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Where is Flexible Filler Used?

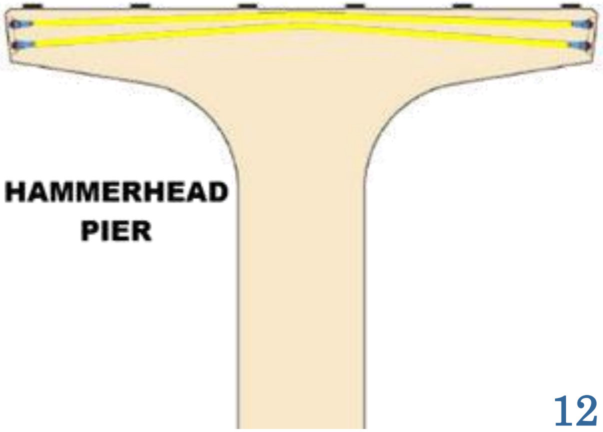
Use as Corrosion Protection

- Naval propulsion machinery after WWI
- During WWII to coat coastal artillery
- Nuclear power facilities for corrosion protection of post-tensioned tendons since 1969
- Used in France for corrosion protection of post-tensioned tendons in bridge applications
- Used in the Ravenel (Cooper River) Bridge cable-stayed anchorages in South Carolina

Use Flexible Filler

External Tendons &
Internal Tendons for Following Applications:

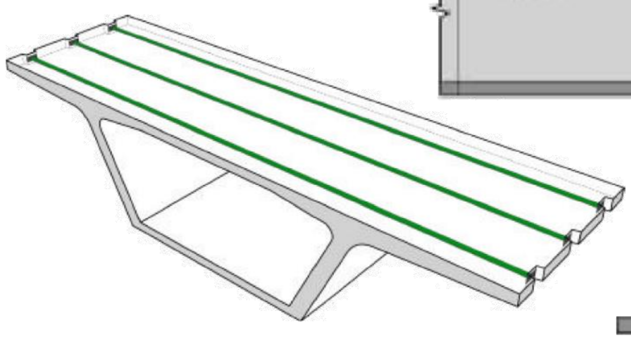
- Tendons with Vertical Deviation > 20 inches
- Continuity Tendons in Segmental Box Girders
- Post-tensioned Tendons in I-Beams and U-Girders
- Vertical Strand Tendons
- Horizontal Tendons in Post-Tensioned Piers



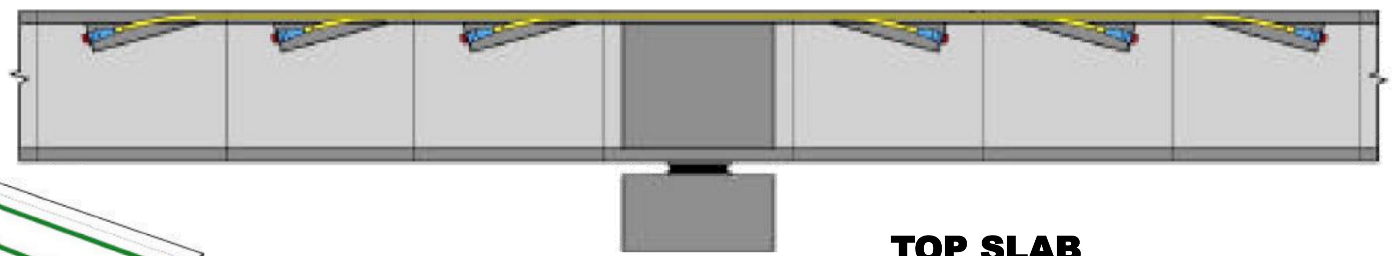
Use Cement Grout

Post-Tensioned Bars &
Internal Tendons for Following Applications:

- Tendons with Vertical Deviation ≤ 20 Inches
- Transverse Tendons in Top Slabs
- Longitudinal Tendons in Top Slabs



TRANSVERSE DECK POST-TENSIONING

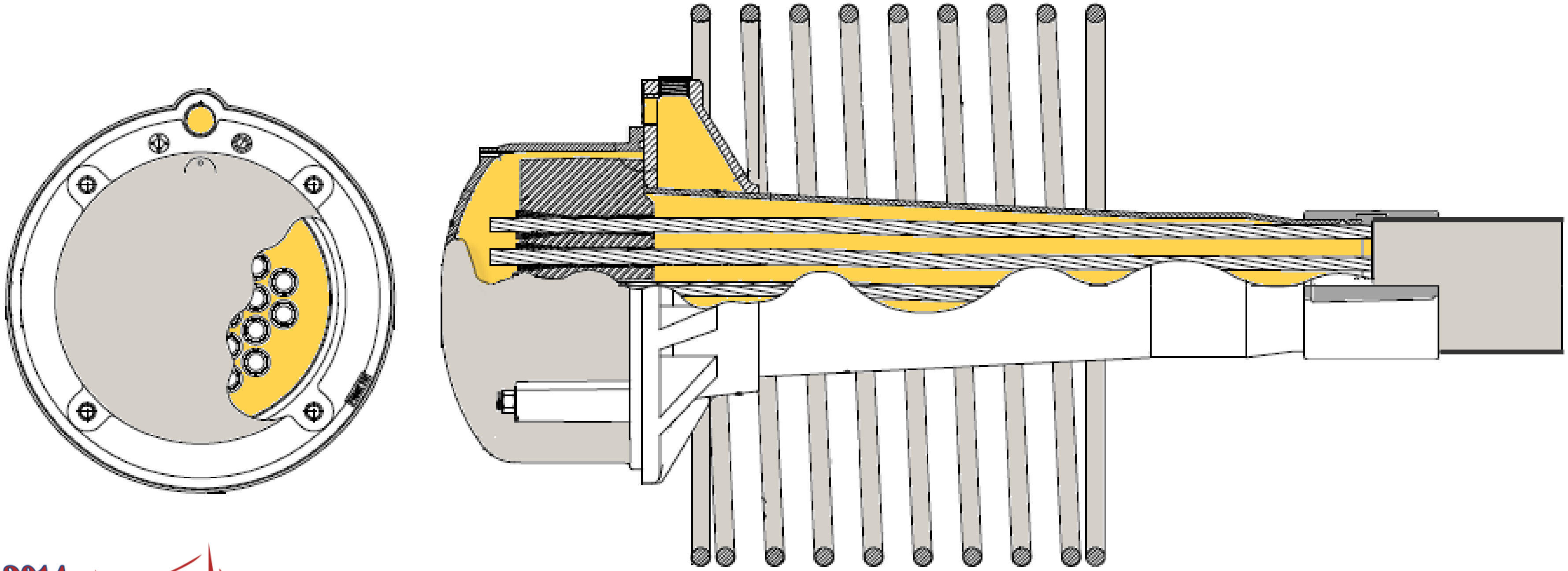


TOP SLAB LONGITUDINAL POST-TENSIONING

What are Design Implications?

Post-Tensioning System with Flexible Filler

- Similar to Cementitious Grouted PT Systems
- Tendons are Replaceable



Design Methodology

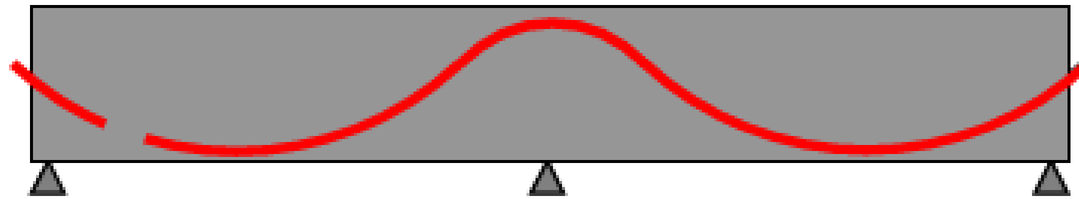
- Unbonded Tendon Design
- Similar to Grouted External Tendon Design

Prestress Behavior of Local Failure

Internal Grouted Tendons

Little to No Warning of **Failed Tendon**

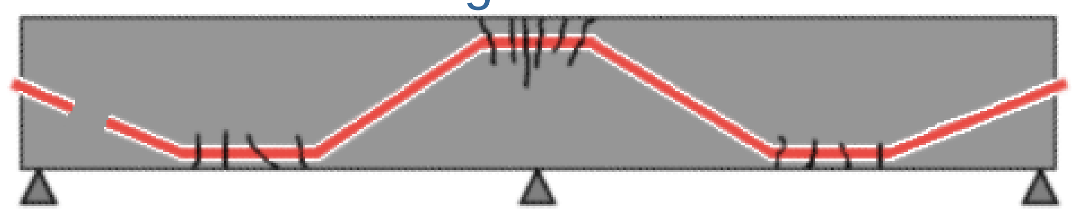
Tendons
Redevelop Prestress



External Grouted Tendons

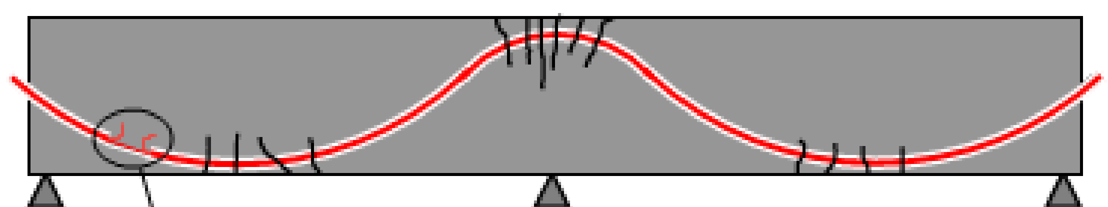
Little to No Warning **Prior** to Tendon Failure

Strands Redevelop within
Grouted Duct



Internal and External Waxed Tendons

Strand Failure Leads
to Incremental Prestress Loss



Progressive Warning **Before**
Tendon Failure

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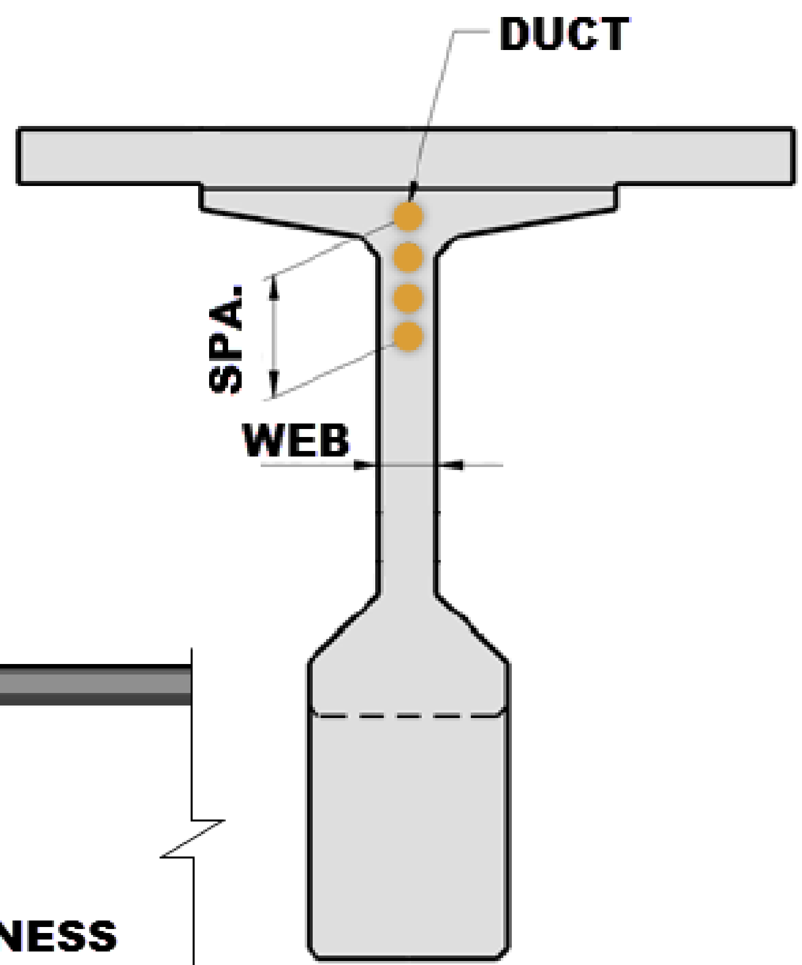
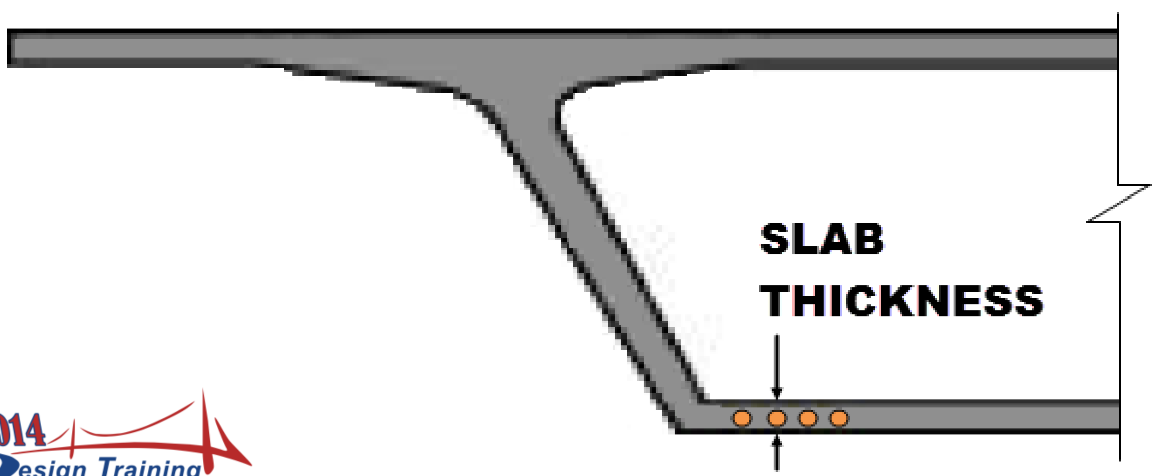
Cross-Section

Potential Implications

- Voids
- Duct Spacing
- Web Width
- Slab Thickness





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Service III Longitudinal Stress

Segmental Box-Girder Bridge Parametric Study				
Property			Tendon Encapsulation	
			Grout Filler	Flexible Filler
At Pier	Cross Section	Area (ft^2)	98.3	**96.0**
		Moment of Inertia (ft^4)	2041.2	1996.9
		Height (ft)	12	12
		Ctop (ft)	4.85	4.95
	Service III Stresses and Rating Factors	Permanent (ksf)	-89.9	-98.0
		Live Load (ksf)	41.5	43.4
		Total Stress (ksf)	-48.4	-54.7
		Rating Factor **(Top Slab)**	2.16	**2.26**
At Midspan	Cross Section	Area (ft^2)	82.3	**81.4**
		Moment of Inertia (ft^4)	986.2	959.1
		Height (ft)	9.5	9.5
		Ctop (ft)	3.10	3.06
	Service III Stresses and Rating Factors	Permanent (ksf)	-109.4	-105.4
		Live Load (ksf)	88.2	91.4
		Total Stress (ksf)	-21.2	-14.1
		Rating Factor **(Bot. Slab)**	1.24	**1.15**

Strength I Moment

AASHTO LRFD Bridge Design Specifications

- Capacity Decreases for Unbonded Design

Table 5.5.4.2.2-1 - Resistance Factor for Joints in Segmental Construction

	ϕ_f Flexure	ϕ_v Shear
Normal Weight Concrete		
Fully Bonded Tendons	0.95	0.90
Unbonded or Partially Bonded Tendons	0.90	0.85

5.7.3.2 - Flexural Resistance $M_r = \phi M_n$

5.7.3.1.2 - Average Stress in Unbonded Prestressing Steel

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

5.7.3.2.2 - Nominal Flexural Resistance

$$M_n = A_{ps} f_{ps}\left(d_p - \frac{a}{2}\right) + A_s f_s\left(d_s - \frac{a}{2}\right) - \ldots$$

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Cracking Moment

AASHTO LRFD Bridge Design Specifications

5.7.3.3.2 Minimum Reinforcement

- Cracking Moment Decreases for Unbonded Design

$$M_r \geq \text{minimum}\ (1.33\, M_u\, ,\, M_{cr})$$

$$M_{cr} = \gamma_3 \left[\left(\gamma_1 f_r + \gamma_2 f_{cpe} \right) S_c - M_{dnc} \left(\frac{S_c}{S_{nc}} - 1 \right) \right]$$

γ_2 = prestress variability factor

= 1.1 for bonded tendons

= 1.0 for unbonded tendons

f_{cpe} = compressive stress in concrete

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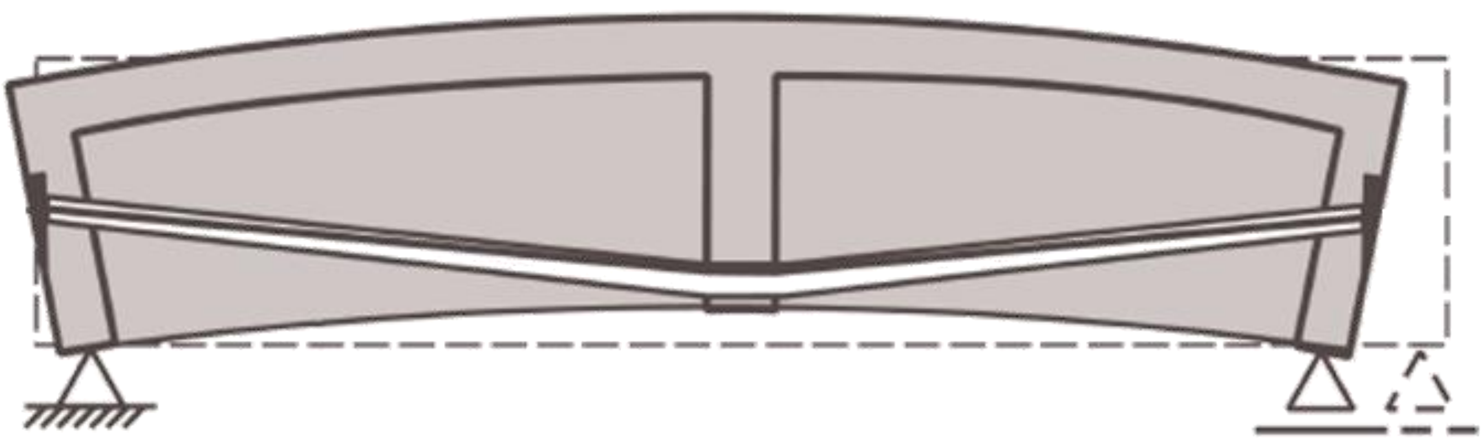
Fatigue & Deflection

Strand Fatigue & Fretting

- Low Stress Range

Creep & Shrinkage

- Not Expected to Change Significantly Between Bonded and Unbonded Design



What are Construction Implications?

Wax Installation Equipment

- Pumping Equipment
- Heater
- Mixer

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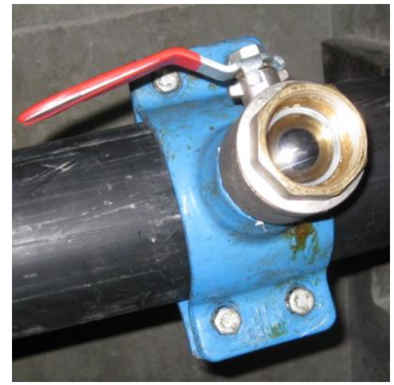
Example Wax Injection Methodology

1. Heat wax to 221°F
2. Pressure and vacuum test duct
3. Apply vacuum at outlet
4. Pump wax at 30 psi
5. Wax fills duct in 3 to 4 minutes



Construction Cost Estimate

- **Post Tensioning Pay Item Cost**
  15% to 26% above similar grouted systems

- **Superstructure Cost**
  0.5% to 2.4% higher than a similar grouted system

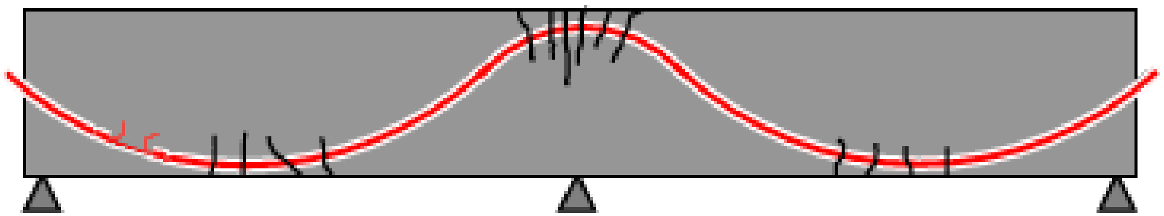
- **Total Project Cost**
  Less than 1% increase compared to a grouted system

What are Maintenance Implications?

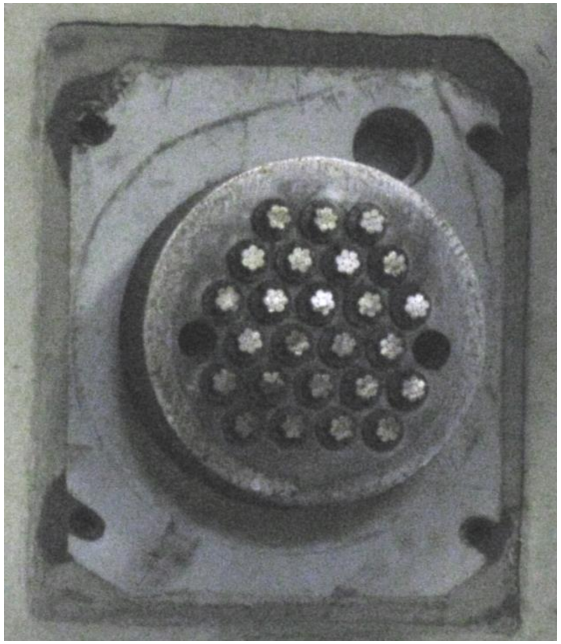
Maintenance

Inspection Areas

- Cracking at Maximum Bending Moment Locations



- Loose Wedges in Anchor Cap
- Loose Strands in Duct



Replaceable Tendons

- Access

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What are FDOT Policies and Procedures for Flexible Filler?

FDOT **S**tructures **D**esign **G**uidelines

SDG 4.5 Post-Tensioning

- Replaceable Tendons
- Access to Anchorage Caps
- Duct Spacing
- Deviators
- Wax and Grout Use Locations

FDOT Structures Manual

FDOT Design Standards

- **Index 21800 Series**

  Post-Tensioning Profiles

  Post-Tensioning Protection

  Post-Tensioning Anchorage and Injection Details

- **Instruction for Design Standards**

  IDS for Index 21800 Series Post-Tensioning

FDOT Specifications

- **Specification 462**
  Construction Post-Tensioning Details
- **Specification 938**
  Materials Post-Tensioning Grout
- **Specification 960**
  Materials Post-Tensioning Components

FDOT Research

- **Un-bonded Tendon System Practices for Bridges in Europe**
  July, 2012

- **Parametric Study of Unbonded Post-Tensioning Systems**
  December, 2012

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FDOT Research

Replaceable Unbonded Tendons for Post-Tensioned Bridges

◆ Literature Review	December 2013
◆ Mock-up Wax Injection	Summer 2014
◆ Internal Tendon Testing	Summer 2015
◆ External Tendon Testing	Summer 2015
◆ Final Report	Early 2016

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