Florida Department of Transportation

New Directions for Florida Post-Tensioned Bridges

Volume 7 of 10: Design and Construction Inspection Of Post-Tensioned Substructures

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Preface

As a result of recent findings of corrosion of prestressing steel in post-tensioned bridges, the Florida Department of Transportation will be changing policies and procedures to ensure the long-term durability of post-tensioning tendons. The recommendations of the Consultant for revising FDOT policies and procedures is presented in this study entitled, *New Directions for Florida Post-Tensioned Bridges*. The study will be presented in several volumes, with each volume focusing on a different aspect of post-tensioning or bridge type.

Volume 1: Post-Tensioning in Florida Bridges presents a history of post-tensioning in Florida along with the different types of post-tensioned bridges typically built in Florida. This volume also reviews the critical nature of different types of post-tensioning tendons and details a new five-part strategy for improving the durability of post-tensioned bridges.

Volumes 2 through 8: Design and Construction Inspection of various types of post-tensioned bridges - applies the five-part strategy of Volume 1 to bridges in Florida. Items such as materials for enhanced post-tensioning systems, plan sheet requirements, grouting, and detailing practices for watertight bridges and multi-layered anchor protection are presented in detail. The various types of inspection necessary to accomplish the purposes of the five-part strategy are presented from the perspective of CEI along with detailed checklists of critical items or activities.

Volume 9: Condition Inspection and Maintenance of Florida Post-Tensioned Bridges addresses the specifics of ensuring the long-term durability of tendons in existing and newly constructed bridges. The types of inspections and testing procedures available for condition assessments are reviewed, and a protocol of remedies are presented for various symptoms found.

Volume 10: Load Rating Segmental Post-Tensioned Bridges in Florida provides guidance for meeting AASHTO LRFD load rating requirements as they pertain to precast and cast-in-place segmental bridges.

Disclaimer

The information presented in this Volume represents research and development with regard to improving the durability of post-tensioned tendons; thereby, post-tensioned bridges in Florida. This information will assist the Florida Department of Transportation in modifying current policies and procedures with respect to post-tensioned bridges. The accuracy, completeness, and correctness of the information contained herein, for purposes other than for this express intent, are not ensured.

Volume 7 – Post-Tensioned Substructures

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Strategy 3 – Multi-Level Anchor Protection

Strategy 4 – Watertight Bridges

Strategy 5 – Multiple Tendon Paths

Introduction

The Florida Department of Transportation is committed to continued development of post-tensioned bridges as a viable solution for many of Florida's infrastructure needs. The challenge, in light of recent instances of corrosion of some post-tensioning tendons, is to consistently produce prestressed bridges with highly durable post-tensioning. The Department defines a durable structure as one that serves its design purpose over the intended life of the bridge, while requiring only routine inspection and maintenance.

Consistent production of durable structures and durable post-tensioning is affected by many factors that become critical at different stages in the life of the structure. The selection of materials and post-tensioning details by the Designer has the first and foremost impact on the resulting durability. During construction, the Contractor's ability to effectively build in accordance with the plans and specifications is critical to creating durable structures. Finally, over the service life of the bridge, inspectors and maintainers must be familiar with symptoms and remedies available to ensure the long-term durability of structures with post-tensioning tendons.

Past performance of post-tensioned bridges in Florida has shown that improper consideration for important design, construction and maintenance features leads to reduced durability. Furthermore, even where post-tensioning tendons have been installed and maintained with existing appropriate standards of care on the part of designers, contractors, and maintainers, there have still been instances where high durability has not been achieved. Consequently, new procedures are needed to create a design, construction and maintenance environment that consistently produces durable post-tensioned bridges.

In response, the Department is taking a new direction to produce more durable post-tensioned bridges, based on a five-part strategy. The components of this strategy, and the requirements that further define them, are devised to raise the level of performance in design, construction, and maintenance to ensure consistency and confidence in post-tensioned structures. The new direction, expressed by the five strategy components, is shown in Figure 1.1.

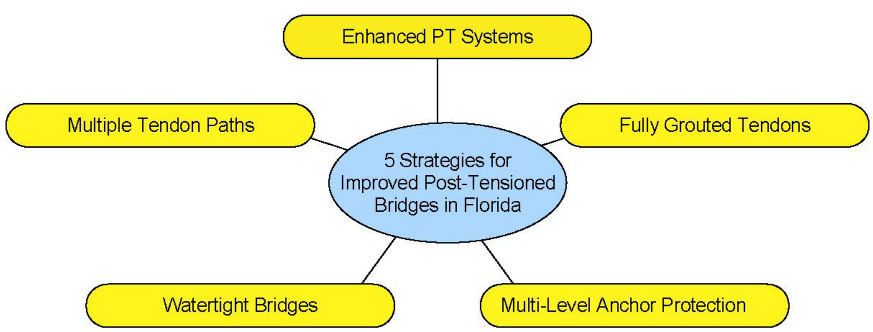


Figure 1.1 – Five-part strategy for more durable post-tensioned bridges in Florida.

Volume 1: Post-Tensioning in Florida Bridges introduced the development of the five-part strategy for more durable post-tensioned bridge in Florida. This volume applies these strategies to a particular type of post-tensioned construction.

Volume 7 – Post-Tensioned Substructures

Post-tensioned substructures are widely used in a variety of applications in Florida. Complex interchanges in urban settings often require the use of post-tensioned hammerhead piers, cantilever piers and straddle bents. Post-tensioning also offers important efficiencies when combined with precast segmental box pier construction for long bridges over water. The precast segments are produced in a factory-like setting and shipped to the site and assembled using vertical post-tensioning, eliminating costly pouring of concrete over water.

This volume provides direction for achieving more durable post-tensioned bridges by applying the Department's five strategies to the specifics of post-tensioned substructures.

Substructure Post-Tensioning Applications

Two classes of tendons are required for post-tensioned substructures, with fundamentally different functions and different grouting requirements. These classes are horizontal or "lateral" tendons and vertical tendons. Some substructures require both lateral and vertical post-tensioning tendons.

Lateral post-tensioning

- Hammerhead columns.
- Straddle Beams (Simply Supported).
- Confinement of Caps (Bearing Reactions).

Lateral and Vertical post-tensioning

- Cantilever Piers (cap, column, footing).
- Portal Frames (Monolithic Straddle Bent).

Vertical post-tensioning

- Hollow Precast Piers.
- Precast I-Section Piers.
- Hollow Reinforced Piers (Service Crack Control).

Strategy 1 – Enhanced Post-Tensioning Systems

Strategy 1 requires that all post-tensioning systems be fabricated using enhanced post-tensioning systems. The Designer implements the strategy by incorporating appropriate details in the plans. The CEI checks that these systems are correctly installed during construction, with allowance for Contractor's chosen post-tensioning system and means and methods of construction.

Summarizing, the responsibilities for meeting Strategy 1 include:

- Designer - incorporate the policies and standards into the Contract Drawings that utilize enhanced post-tensioning system components, materials and appropriate structural details.

- Contractor - install all components and materials in accordance with the Contract Drawings, approved Shop Drawings, Specifications and QPL.

- CEI – inspect the work to verify compliance with the Contract Documents and approved Shop Drawings as required. Advise the Contractor of any areas of non-compliance.

Specific requirements for enhanced post-tensioning systems are provided in the following sections.

1.1 Qualified Products List (Requirement 1.A)

In the future, all post-tensioning systems must be selected from the Department's Qualified Products List (QPL). New components and new post-tensioning systems must be pre-approved by the Department prior to use in any application. This requirement is to be enforced throughout construction.

1.2 Three Level Protection (Requirements 1.B)

Enhanced post-tensioning systems require three levels of protection using the barriers defined in Volume 1 "Post-Tensioning in Florida Bridges". As both internal and external tendons are used in this type of bridge, requirements for both are provided.

Internal Tendons:

Components of the protection system depend upon whether the duct is within the concrete or at a match-cast joint. The three-levels of protection for these two cases are:

- Within the segments:
  (1) Fully grouted tendon.
  (2) Impervious plastic duct.
  (3) Concrete cover.

- At precast joints:
  (1) Fully grouted tendon.
  (2) Effective continuity of the impervious plastic duct.
  (3) Epoxy sealed joints between match-cast segments.

External Tendons:

Components of the protection system depend upon whether the duct is embedded within or is outside the concrete. The three-levels of protection for these two cases are:

- Duct embedded within the concrete:
  (1) Fully grouted tendon.
  (2) Steel pipe.

(3) Concrete cover.

- Duct outside the concrete:
  (1) Fully grouted tendon.
  (2) Impervious plastic pipe.
  (3) Enclosure within the surrounding, watertight and drained, hollow box.

Combined Tendons: Tendons that are both external (unbonded) and internal (bonded) over a significant length are no longer permitted in Florida. Unlike typical external tendons, these combined tendons are virtually impossible to replace.

Levels of Protection:

The first level of protection, Level (1), is provided by filling the annular space between the duct and strands with pre-approved grout. Refer to Strategy 2 “Fully Grouted Tendons” below for these requirements.

The second level of protection, Level (2), is provided by using impervious ducts meeting the following requirements:

- For internal tendons – use corrugated plastic duct (per Specifications and QPL) with positively sealed connections.
- For external tendons - use smooth plastic pipe and steel pipe (per Specifications and QPL) with positively sealed connections.

To achieve the third level of protection, Level (3), provide concrete cover in accordance with FDOT requirements, epoxy seal joints between segments, or enclose the tendon within the hollow box girder. Refer to Strategy 4 “Watertight Bridges” below for these requirements. Also, given the specialized function of post-tensioned substructures and the variation in aggressiveness of Florida environments, satisfy additional requirements:

- Non-Aggressive environment (inland sites):
  - Do not use strand tendons below 5 feet above finished ground level.
  - Bar tendons (minimum 1 ¼ inch diameter) may be used below this elevation and in foundations with approval of the Department.

- Aggressive and Moderately Aggressive Environment (coastal sites):
  - Do not use post-tensioning in or below the splash zone of substructures and foundations (i.e. below 12 feet above mean high water).

1.3 Materials (Requirements 1.A through F)

Responsibilities regarding materials for enhanced post-tensioning systems are:

- Designer - incorporate the policies and standards into the Contract Drawings and Specifications that utilize enhanced post-tensioning system components and materials.

- Contractor – make sure that all materials and components comply with the Standard Specifications and the QPL. These include, but are not limited to, post-tensioning steel, ducts (plastic ducts, plastic pipes, steel pipes), anchors, duct and anchor connections (couplings), grout pipes and connections, and grout. Also assure compliance of:
  - epoxy for sealing match-cast joints (if any) between precast components.
  - non-shrink, high-bond, high-strength, air-cured concrete for filling holes for equipment or temporary access holes.
  - epoxy grout for filling grout recesses and encasing anchors (pour-backs), including coatings for sealing areas of concrete or pour-backs.

  Keep records of submittals, test reports, approved component deliveries, and track materials and components from delivery through installation at precast yard and bridge site. Provide CEI with copy of all records.

- CEI - verify that materials and components comply with Specifications and/or FDOT "Qualified Products List" and keep proper records of submittals, test reports, component deliveries and installation at precast yard and at bridge site.

1.4 Internal Tendons – Ducts and Connections

(a) Plastic Ducts (Requirement 1.C)

Use corrugated plastic duct of high-density polypropylene (HDPP) with continuous spiral or hoop ribs at frequent and regular intervals to provide positive mechanical interlock, enhancing bond between the concrete, duct and grout. HDPP plastic is to contain material to protect against degradation from ultra-violet light. Duct is to be thermally stable for the range of temperatures anticipated for the life of the structure. Duct is to have a minimum wall thickness of 0.08 inches (2 mm). Plastic duct is to be pre-approved as a part of the post-tensioning system.

(b) Duct Connections (Requirements 1.C and 1.D)

Use positively sealed couplings between embedded ducts and anchors and between any separate pieces of plastic duct. Duct tape does not serve as a positive seal in joining pieces of duct or duct to anchorage.

1.5 External Tendons – Ducts and Connections

External tendons may be used to prestress precast segmental piers. Refer to Volume 3, "Design and Construction Inspection of Precast Segmental Span-by-Span Bridges" for requirements concerning:

- Plastic Pipe for External Tendons.
- Steel Pipes for External Tendons.
- Pipe Connections for External Tendons.

1.6 Permanent Grout Cap (Requirement 1.F)

Provide all post-tensioning tendon anchors with a permanent, heavy duty, plastic grout caps mechanically secured and sealed against the anchor plate with a compressible, neoprene o-ring. Show details of a typical permanent grout cap on the Contract Drawings in accordance with FDOT Standard Drawings. Fully fill permanent cap with grout. Provide grout outlet vent of ¾" minimum diameter in the cap. Permanent grout cap is to completely cover the anchor plate and head. For strand tendons, the anchor head is the wedge plate, wedges and strand tails. For bar tendons, the anchor head is the nut and bar tail. Before installing the tendon, temporary caps may be used and then be replaced by permanent caps after stressing but before grouting.

Show details of a typical permanent grout cap on the Contract Drawings in accordance with FDOT Standard Drawings.

1.7 Pipes for Grout Ports, Vents and Drains (Requirement 1.D)

Pipes for grout ports, vents and drains are necessary to allow the escape of air, water, bleed-water and the free flow of grout. Use pipe with an inner diameter of at least 3/4 inch for strand tendons and 3/8 inch for single bar tendons. Pipe is to be flexible, HDPE or HDPP plastic material compatible with that of the main plastic duct for the tendon. Plastic components are not to react with concrete or encourage corrosion of the post-tensioning steel, and must be free of all water-soluble chlorides.

Connect grout pipes to ducts and anchor components in a manner that creates a seal and does not allow leaks or ingress of water, chlorides or other corrosive agents.

To facilitate inspection of complete filling of a tendon with grout, direct grout vents at high points (crests) to exit the top (riding surface) or other appropriate surface. Also, provide caps and seals to all vents to prevent ingress of water or corrosive agents into the tendon. For locations of grout ports, vents and drains see Strategy 2, "Fully Grouted Tendons" below.

1.8 Shop Drawings (Requirements 1.A through D, F and G)

Shop Drawings are required for the integration of approved post-tensioning systems (i.e. post-tensioning supplier's information and details), reinforcement, post-tensioning, and other embedded items (including those for the Contractor's chosen "means and methods" of construction) precast components, precast segments and cast-in-place construction. Shop Drawings responsibilities include:

- Contractor - submit the necessary "Shop Drawings" to the Engineer (Designer) for review and approval.

- Designer - review the Shop Drawings and other relevant information and notify the Contractor and the CEI of its acceptability.

- CEI - coordinate and keep a record of submittals and responses.

1.9 Installation (Requirements 1.A, 1.B, 1.C, 1.D, 1.E and 1.F)

During fabrication at a Precast Yard or Bridge Site, all installation must be done properly. In particular, this includes but is not necessarily limited to:

Ducts For Internal Tendons:

During fabrication make sure that ducts are:

- Installed to correct profile (line and level) within specified tolerances.
- Installed to connect correct duct location in bulkhead with correct duct location in match-cast segment.
- Correctly aligned with respect to the orientation of the segment in the casting cell and the direction of erection.
- Tied and correctly supported at frequent intervals.
- Connected with positively sealed couplings between pieces of duct and between ducts and anchors*.
- Aligned with sealed couplers at temporary bulkheads.

During erection make sure that:

- Ducts have positively sealed connections* at match-cast joints.
- All ducts are thoroughly swabbed at new epoxy joints so that no extruded epoxy causes blockages.
- Match-cast joints are properly prepared and sealed with epoxy (refer to Strategy 4 “Watertight Bridges” below).

  (* Note - duct tape does not qualify as a seal although it may be used for temporary support purposes.)

Ducts For External Tendons:

During fabrication make sure that embedded parts (i.e. steel pipes in deviators and diaphragms) are:

- Installed to correct profile (line and level) within specified tolerances.
- Tied and correctly supported at frequent intervals.
- Connected with positively sealed couplings between pieces of duct and between ducts and anchors*.
- Properly aligned and sealed* at faces of diaphragms.

During erection make sure that:

- Ducts have positively sealed connections between external plastic and steel pipes and between individual lengths of plastic pipe*.
- Match-cast joints are properly prepared and sealed with epoxy (refer to Strategy 4 “Watertight Bridges” below).

  (* Note - duct tape does not qualify as a seal although it may be used for temporary support purposes.)

Cover – make sure that cover is correct to rebar and ducts.

Anchors – for internal and external tendons, make sure that anchors are:

- The correct type and size for the type and size of tendon used.
- Supplied with permanent, heavy duty, plastic caps with o-ring seal.
- Properly aligned and well supported by formwork.
- When required, set in a recess (anchor pocket or block-out) of correct size, shape and orientation.
- Provided with correct bursting reinforcement at correct location and spacing.

Grout injection ports, outlet vents and drains – make sure that all injection ports, grout vents and duct drains are installed correctly, in particular that:

- They are of correct type and size.
- They are correctly located, connected and sealed to ducts.
- Ports or vents at anchors are oriented correctly.
- Grout pipes are taken to proper exit surface.
- Grout pipes, ducts and connections are sealed before concrete is placed.
- (Refer also to Strategy 2 "Fully Grouted Ducts" below).

Epoxy Joints – for match-cast segments, sealed epoxy joints are necessary in order to ensure the integrity of one of the required three levels of protection. For requirements for epoxy joints refer to Strategy 4 "Watertight Bridges" below.

Post-Tensioning Tendons For Substructures (Precast or Cast-in-place) – make sure that:

- Ducts are clear for installation (for internal tendons in particular, ducts may be tested by passing through a suitably sized torpedo prior to installing the tendons).
- Number and size of strands (or bar) per tendon is correct.
- Strands (or bars) are satisfactory (i.e. no rust etc.) per specification.
- Longitudinal PT tendons are installed in their correct duct locations.
- Anchor plates and wedges (or nuts) are properly installed on each strand (or bar).
- For tendons anchoring in precast segments or cast-in-place concrete, check that the strength is satisfactory for stressing.
- At cast-in-place closures, concrete attains the required minimum strength before stressing continuity tendons.
- Tendons are stressed in the correct sequence to the required force and elongation as specified on the plans, the approved shop drawings or erection manual.
- All stressing records are made and kept per specifications.

Temporary Protection of Post-Tensioning Tendons – Make sure that tendons are properly protected by approved temporary protection in accordance with FDOT Standard Specification B460 from the time they are installed in the ducts to the time of grouting (whether stressed or not).

Grout Caps – Permanent plastic grout caps shall be installed prior to tendon installation to keep ducts clean and dry. Caps shall be removed for tendon installation and replaced prior to grouting. Temporary caps may be used if they are replaced by permanent caps before grouting.

1.10 Pressure Test before Grouting (Requirement 1.G)

Pressure test all duct assemblies prior to grouting - preferably before installing tendons. Run tests in accordance with the Standard Specifications, with caps installed and vents plugged and check for possible leaks. Properly seal all leaks as necessary before grouting. If the test is run after installing and stressing the tendon it may be very difficult to repair leaks and make a proper seal.

1.11 Grout Material (Requirement 1.E)

All grout is to be pre-bagged and pre-approved in accordance with FDOT Standard Specification 938. Grout must be fresh, handled, stored and mixed properly for use in accordance with FDOT Specifications for Post-Tensioning and Grouting.

1.12 Sealing of Grout Ports, Vents and Drains – (Requirements 1.B, 1C, 1D)

In order to maintain the integrity of the duct system and its effectiveness as a barrier, all grout ports, vents and drains must be properly terminated and sealed.

- Designer - show details on Contract Drawings and include Specifications for sealing grout pipe recesses

- Contractor - follow and implement details provided on the Contract Plans or approved Shop Drawings.

- CEI - check that this work is performed properly.

One detail for sealing grout ports, vents and drains is shown in Figure 7.1. Requirements for this detail include:

(1) At all grout vents or ports that exit or enter the top slab, provide a recess not less than 2 inches or more than 3-1/2 inches in diameter around the pipe. Make depth of recess not less than 2-1/2 inches or more than 3 inches from the initial roadway surface before grinding and grooving - i.e. final depth of recess after ½ inch of surface has been removed by grinding and grooving to be not less than 2 inches or more than 2-1/2 inches.
(2) Provide a separate recess around each port or vent pipe of each tendon. Do not merge recesses into one large one. Keep each recess separate from an adjacent one by at least 6 inches of concrete (edge to edge of recesses) so that if a recess or pipe is breached only on tendon will be at risk. Multiple grout pipes attached to an individual tendon at one location (such as a grout pipe from an anchor trumpet and grout pipe from cap attached to that anchor) may be housed in one recess.
(3) Provide sides of each recess with an irregular or corrugated finish to ensure a good mechanical bond (in addition to chemical bond with filler.
(4) Form recess with a material that can be easily removed such as corrugated polyethylene or other suitable material.
(5) After grout from both primary and secondary grouting has hardened, trim grout pipes that exit through top slab to 1 inch above bottom of recess.
(6) Seal trimmed grout pipes with permanent plastic cap (or plug) screwed or glued to pipe.
(7) Remove all traces of recess forming material and thoroughly clean sides and bottom of each recess to sound, dry concrete surface.

(8) Fill each recess with an approved low modulus, high-strength, high-bond, sand-filled epoxy grout selected from the Department's Qualified Product List.
(9) In deck and other top, horizontal surfaces use a flow-able epoxy mix with the above characteristics (8) and allow it to set and cure properly before grinding and grooving.
(10) For grout pipes exiting vertical surfaces and soffit, use a stiffer epoxy mix that may be applied with a trowel and secured with a suitable form. Use a form surface that does not adhere to the epoxy (wax paper coating or similar).

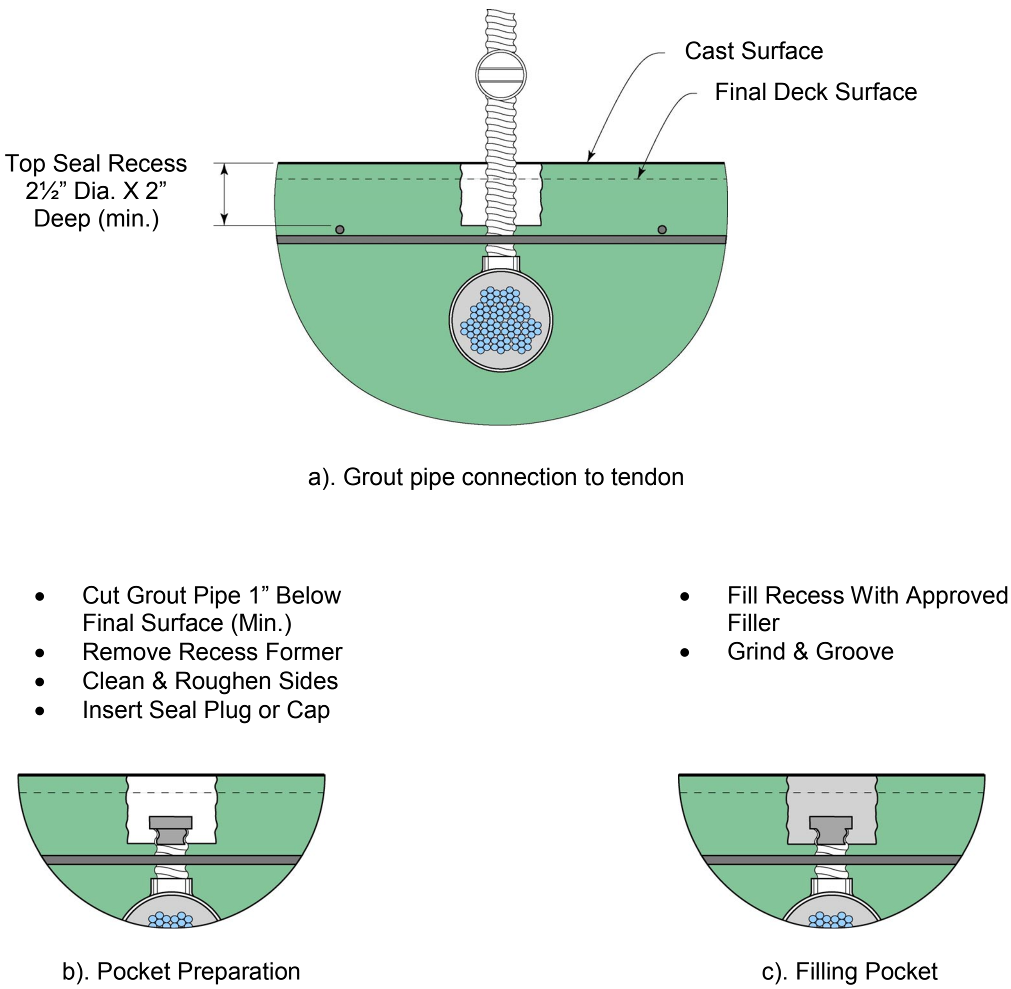


Figure 7.1 – Sealing grout ports and vents in a top surface.

1.13 Internal Tendons - Clearances, Dimensions, Details (Requirements 1.B, 1.C)

To ensure integrity of the structure and protection provided by cover it is necessary to use details that facilitate good quality concrete construction (i.e. that avoid honeycomb concrete).

(a) Member Size or Thickness

Substructure Components in General

The width and thickness of substructure elements typically provide ample space for internal post-tensioning tendons comprised of strands or bars. In some regions, such as anchor zones, intersecting members at columns, and beneath bridge bearings, the reinforcing may be very congested. Typically, it is better to minimize congestion in order to ensure structural integrity and durability than suffer consequences from honeycombed or poorly consolidated concrete. Therefore, provide adequate space and show details for all reinforcement, post-tensioning components, clearances, tolerances and cover. In rebar cages, allow space for tremie pipes and vibrators, to permit proper placement and consolidation of concrete.

Thin Walls of Hollow Section or I-Section Piers

Provide a wall thickness of not less than 12 inches. Otherwise, follow AASHTO Guide Specification for Segmental Bridges. Vertical post-tensioning may be internal and bonded within pier column walls, or may be external and unbonded but protected within the hollow core of column.

Pier Caps

Ensure pier caps are sufficiently thick to accommodate all anchors, lateral bursting steel, local reinforcing for bearing reactions etc. Provide recessed pockets for top anchors of vertical tendons (see “Anchor Protection” below).

(b) Duct Supports (Requirements 1.B and 1.C)

To ensure the integrity of tendon trajectory, for ducts transiting the body of the concrete that cannot be tied directly to top, bottom or sides of rebar cage, provide and show supports at intervals of approximately 2 feet. Use minimum size of #3 or #4 rebar for supports. Bars may be any convenient shape (straight, U, L or Z) and set at any convenient angle or slope providing cover is not violated. Provide duct supports at locations where wet concrete may displace ducts when discharged into the forms.

(c) Reinforcement to Avoid Tendons (Requirement 1.B and 1.C)

In hammerheads, straddle bents and pier caps, the location of lateral post-tensioning takes precedence over rebar. Reinforcing should be detailed to avoid post-tensioning tendons and anchors. The plans should show details of the reinforcing at anchor zones. This is also true for vertical tendons and anchors in columns, caps and foundations. Tolerances for fabrication, bends, placement, cover and other necessary clearances should be taken into account in developing member details.

(d) Space for Placing and Consolidating Concrete (Requirement 1.B)

Hammerheads, Straddle Beams and C-Piers

At anchor zones and member intersections of hammerheads, straddle beams, c-piers diaphragms and similar and heavily reinforced zones with potential for congestion, allow for the following:

- For tremie pipes, allow for a clear opening at least 8 inches by 8 inches in the top of a rebar cage at intervals of no more than 3 feet in any direction.
- Align openings in successive layers of rebar.
- For vibrators (stick type), provide for a minimum clear opening at least 3 inches by 3 inches at intervals of no less than approximately 1 foot in each direction.
- Provide clear space between reinforcing of at least 1.5 times the maximum aggregate size but not less than 2 inches.
- Allow two reinforcing bars side by side in same row at splices.
- Allow three bars side by side in same row for a length of up to 3 feet.
- Provide minimum of 2 inches clearance between reinforcing bars or pairs of reinforcing bars.
- Provide at least 4 inches clear space between post-tensioning ducts.

Pier Columns

Concrete is usually placed down the center using a tremie pipe or chutes. Detail reinforcement to provide clearance for concrete aggregate and access for concrete vibrators (allow for at least 3 inch diameter vibrators).

1.14 External Tendons – Clearances, Dimensions, Details (Requirements 1.B, 1.C)

Refer to Volume 3, "Precast Segmental Span-by-Span Bridges" for recommended minimum dimensions, details and other information.

Strategy 2 – Fully Grouted Tendons

This strategy requires that all post-tensioning tendons in bridge substructures be completely filled with grout. Tendons must be stressed and grouted in within the time period allowed in the Standard Specifications.

To ensure compliance with Strategy 2:

- Designer - incorporate details and requirements in the Contract Drawings to facilitate fully grouted tendons.

- Contractor - install all components and grout in accordance with the Contract Drawings, approved Shop Drawings, Specifications and QPL.

- CEI – inspect the work to verify compliance with the Contract Documents and approved Shop Drawings as required. Advise the Contractor of any areas of non-compliance.

2.1 Accessible Anchors – (Requirement 2.A)

All anchors for both internal and external post-tensioning tendons are to be accessible throughout all construction operations, up to and including the installation and grouting of permanent plastic grout caps. Specific requirements include:

- Provide a 2’ lateral clear dimension from the sides of the anchor plate for a length along the tendon of 1’-3” for dead end (non-stressing) anchorages. For live (stressing) anchors provide clearance for tendon installation and stressing jacks.

- At embedded bottom anchors (i.e., bottom anchors of vertical bar tendons) that are cast into the concrete, provide minimum cover greater than that of the mild reinforcing.

- Anchors in blisters on the interior of a hollow section are accessible for inspection during construction (and subsequent maintenance inspection) from within the interior of the hollow section.

- At anchors embedded under pour-backs (e.g. at outside surfaces and at expansion joints) it will be acceptable, if necessary, for maintenance inspection to remove the seal-coat and concrete pour-back to gain access to the permanent grout cap and anchor head – providing that the pour-back and seal coats are then restored.

Anchors for new construction are to have an inspection port to accommodate probes and/or bore-scope equipment. Although it is desirable to have access for inspection, poorly sealed inspection ports may be potential points of entry for contaminants or chlorides. Consequently, keep the number of deliberately introduced inspection ports (and grout vents) at or near anchors to a minimum.

2.2 Grouting of Tendons – (Requirements 2.B and 2.C)

To help ensure that tendons are fully grouted, certain details and procedures for grouting must be shown on the Contract Drawings, addressed in the Specifications and enforced during construction. Ducts may be moist at the time of grouting, but all freestanding water must be removed before grouting begins. This minimizes the risk of excess water compromising the grout mix, causing bleed or voids. Drains at all low points are required to facilitate removal of freestanding water.

2.3 Lateral Tendons - (Requirements 2.B and 2.C)

In accordance with the FDOT Standard Drawings on the Contract Drawings (Figure 7.2):

- Require all anchors to have temporary seals or caps to keep debris out of ducts during construction prior to grouting.
- Show locations of all low point grout injection ports, outlet vents and drains.
- Show direction of grouting, taking into account the longitudinal profile of the tendon allowing for the profile of the bridge.
- Locate the grout injection port at the lowest point of the tendon profile, accounting for bridge profile.
- If two or more low points are at equal elevations then select one for the injection port and provide drains at the others.
- Provide outlet vents at all high point crests and between 3 to 6 feet beyond the crest in the direction of grouting.
- Locate injection ports, vents and drains on ducts so as to allow free drainage and free

flow of grout unimpeded by the presence of the tendon - whether of strands or bars.

- Locate drains at all low points.
- Locate drains on bottom one third of duct.
- Orient anchors so that the grout vent or injection port is at the top.
- Show sequence of installing and stressing tendons.
- Require all internal ducts for temporary longitudinal post-tensioning be fully grouted during construction whether the PT remains in place or not and whether stressed or not.

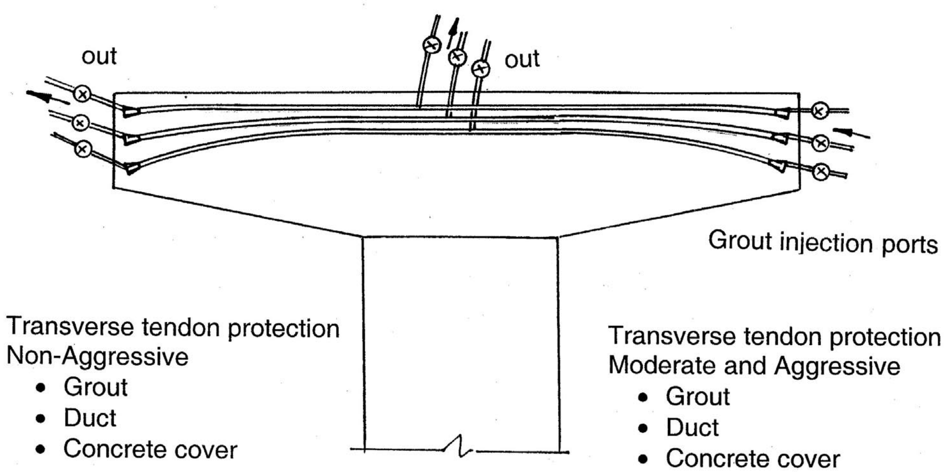


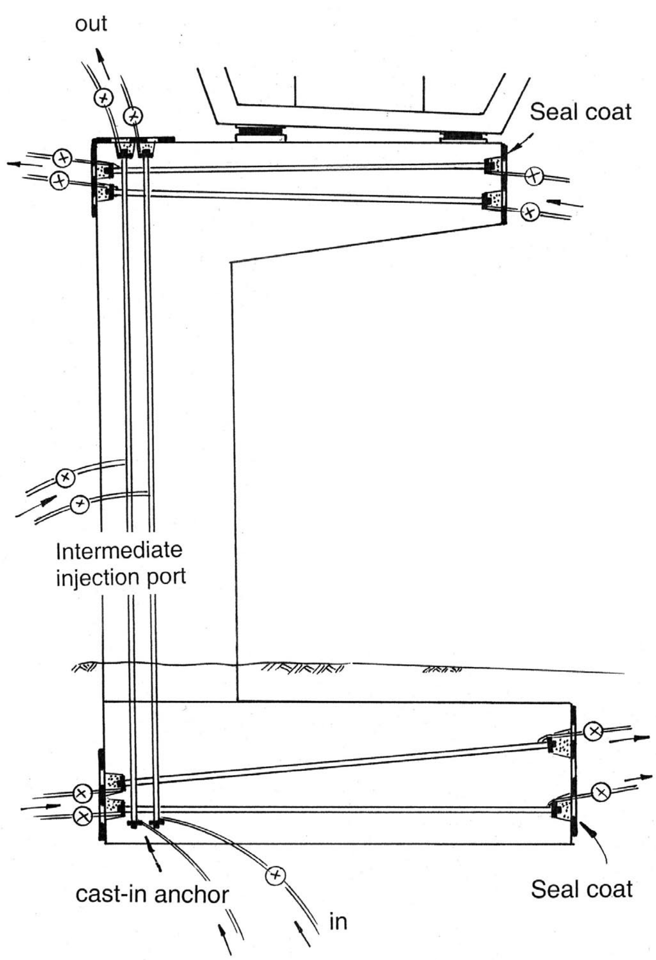
Figure 7.2 – Grouting Lateral Tendons

2.4 Vertical Tendons - (Requirements 2.B and 2.C)

In accordance with the FDOT Standard Drawings, on the Contract Drawings (Figure 7.3 and 7.4):

- Require all anchors to have temporary seals or caps to keep debris out of ducts during construction prior to grouting.
- Show locations of all low point grout injection ports, outlet vents and drains.
- Show direction of grouting, taking into account the longitudinal profile of the tendon allowing for the profile of the bridge.
- Locate the grout injection port at the lowest point of the tendon profile.
- Require intermediate vents/injection ports at intervals not to exceed the least of;
  - 20 feet.
  - The height of an individual precast component.
  - The distance between block-outs for tendon couplers.
- At top of tendon, require an outlet in the center of the wedge plate (for strand tendon) or to one side directly under the anchor plate of a bar anchor. Connect a well-sealed 1' long pipe with a valve at the top to the outlet. Connect a clear plastic standpipe at least 4 feet tall to the top of the valve. Also, provide a grout injection port at top anchors to access the anchorage just below the bottom of the plate.
- Show sequence of installing and stressing tendons.

- Require all internal ducts for temporary longitudinal post-tensioning be fully grouted during construction whether the PT remains in place or not and whether stressed or not.



Anchor Protection:
- Grout
- Plastic Cap
- Pour-Back Material
- Elastomeric Coating*

*minimum 12” all around pour-back

Note: Use of post-tensioning bars below an elevation of 5’ in non-aggressive environments may be permitted with the approval of the Department.

Figure 7.3 – Grouting and Anchor Protection in Vertical Tendons in Cantilever Piers

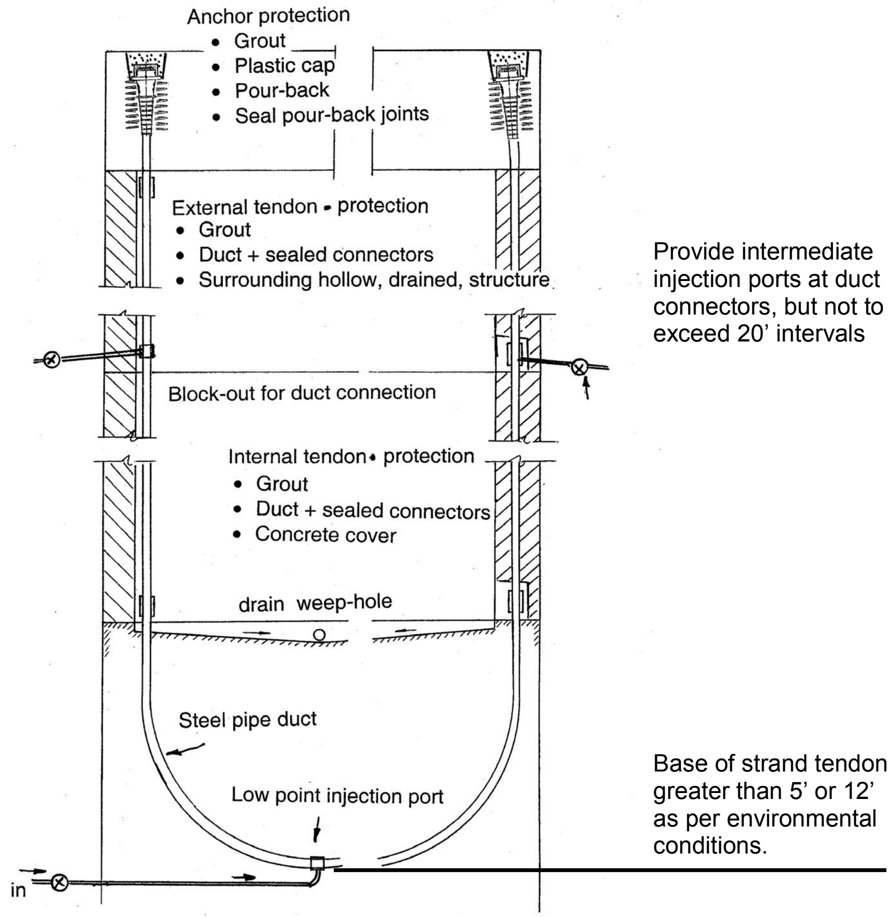


Figure 7.4 – Grouting and anchor protection of vertical tendons in hollow precast piers.

2.5 Shop Drawings (Requirements 2.A, 2.B, 2.C)

Shop Drawing responsibilities include:

- Contractor – submit necessary "Shop Drawings" to the Engineer (Designer) for review and approval.
- Designer - review the Shop Drawings and other relevant information and notify the Contractor and CEI of its acceptability.
- CEI – coordinate and keep a record of submittals and responses and check that the correct details are followed – e.g. that grout ports, vents and drains are correctly installed. This requires checking at the precast plant before casting and on the job site where such items are installed in cast-in-place closures.

On Shop Drawings, show injection ports, grout vents and drains at locations in accordance with details shown on the Contract Drawings and required by the Specifications. In particular show:

- Port or vent type and size (e.g. plastic / diameter).
- Location, connection and seal to ducts.
- Grout pipes taken to proper exit surface.
- Grout pipes, ducts and connections to be sealed before concrete is placed.
- Anchors oriented so that ports and vents are to the top and remain accessible not only for grout installation but also for inspection and checking for complete filling by grout.

2.6 Materials – Grout (Requirements 2E, 2.F, 2.G and 1.E)

In existing structures, corrosion damage to tendons has been found at locations of incomplete grouting. Major contributors to voids in tendons include significant bleed water and entrapped air. Much research and effort has been invested in improving the performance of grout to reduce bleed-water and air voids. Consequently, Strategy 1 requires that all grout must be pre-bagged and pre-approved in accordance with FDOT Standard Specification 938.

Careful attention to proper mixing, injection and venting procedures is required in order not to negate the benefits of improved pre-bagged grout materials.

2.7 Installation (Requirements 2.A through 2.G)

Responsibilities regarding installation include:

- Designer – make sure that the Contract Documents address installation of post-tensioning duct system components and grout.

- Contractor - install anchors, grout injection ports, outlet vents and drains in accordance with the Contract Drawings or approved Shop Drawings or approved Grouting Plan.

- CEI - inspect the installation of grout injection ports, outlet vents and drains for compliance. Make sure grouting is carried out in accordance with the approved Grouting Plan, Shop Drawings, Specifications and QPL. Witness the acceptability of the grouting on Contractor’s records and keep a separate copy.

Specific installation requirements include:

- Grouting to be done only by qualified personnel.
- Prior to grouting, ducts to be pressure tested for leaks (can be done prior to installing the tendon).
- Cross-flow or leaks are sealed.
- Consistency of grout mix (flow cone) to be satisfactory before injection (use moist cone).
- Grout to be injected at lowest point of tendon profile.
- Rate of injection in accordance with the Specifications.
- Grout to be evacuated at each vent in turn until consistency is same as that being injected (test evacuated grout using flow-cone, as necessary).
- Pressure to be held at 75 psi for two minutes – checked for leaks and fixed.

- If no leaks are present, reduce pressure to 5 psi and wait 10 minutes to allow entrapped air to flow to high points.
- Open vents to release any air or bleed water.
- Pressure to be pumped to 30 psi and locked off to allow initial set.
- After set, grout caps to be checked and any voids completely filled. (Do not remove cap except for unusual circumstances.)
- After set, vents and anchors to be probed, inspected and any voids filled by secondary vacuum grouting.

2.8 Grouting Plan (Requirements 2.A through 2.G)

Grouting Plans shall be developed for all bridges and implemented during construction. Responsibilities regarding the Grouting Plan include:

- Contractor – prepare and submit a "Grouting Plan" according to the requirements of the Specification for Post-Tensioning (B460).

- CEI - record submittals, review and notify the Contractor of acceptability of Grouting Plan. The CEI may seek an opinion from the Designer regarding the Grouting Plan. However, the CEI has responsibility for review and approval of the Contractor's plan.

The Grouting Plan must address (but is not necessarily limited to):

- Grouting procedures to be followed on site.
- Qualifications and Certification of Grouting Personnel.
- Proposed grout material and reports of qualification tests (must be to QPL) and may require different grout for horizontal and vertical applications.
- Equipment for mixing and testing daily grout production.
- Stand-by equipment.
- Accessibility of anchors for injection and evacuation of grout and inspection of anchor for completeness of filling (follow details per FDOT Standard Drawings, the Contract Plans or approved Shop drawings).
- Sequence of injecting and evacuating grout for each tendon type (i.e. lateral, horizontal, draped, vertical internal tendons, vertical external tendons).
- Injection of grout at the low point of each tendon
- Injection of vertical tendons in stages at intervals not exceeding 20 feet.
- Direction of grout injection and sequence of closing vents.
- Provisions for grouting of a group of tendons*.
- Means of checking or ensuring all tendons are completely filled.
- Means and details for sealing grout inlets, vents and drains – particularly at top anchors of vertical tendons or at vents in top deck (riding) surface.
- Procedure for secondary (vacuum) grouting.
- Forms or other means of keeping records of grouting operations (supply copy to CEI for corroboration and witness).
- Temporary PT - procedures to ensure that all internal ducts used for temporary post-tensioning bars for erection are fully grouted at the end of erection, whether bars remain in place or not and whether stressed or not.

* Note: It is anticipated that tendons in substructures would be grouted only one at a time. If grouting of a group of tendons is needed, then simultaneous grouting must combine operations for all proposed tendons in the group. These combined operations should account for injection at several injection ports, in sequence or in parallel, and the presence of multiple outlet vents requiring closing in sequence. External tendons are grouted one at a time.

2.9 Secondary Vacuum Assisted Grouting (Requirement 2.G)

After primary grouting has been done, all anchors, ports and vents must be inspected and probed. If a void is found, then it must be completely filled with grout using vacuum-assisted grouting. Figure 7.5 illustrates principal details of vacuum injection connections. The procedure is as follows:

(1) After the grout has set, open each vent in turn and probe to see if duct and vent is full.
(2) Where any void is found, introduce additional grout by vacuum assisted means.
(3) Attach a T-connector to the exit vent and attach to it two lines, each with a shut-off valve. Attach grout injection pipe to one of them. Attach vacuum pump to other.
(4) With the grout valve closed and vacuum valve open, draw a vacuum to evacuate any air or bleed water.
(5) When no more air or water can be withdrawn, switch valves and inject grout under pressure up to 75 psi – but no more.
(6) When secondary grout fills voids, reduce pressure to between 30 psi and 40 psi, and close vents.
(7) Repeat, in turn, at each voided vent as necessary.
(8) After completion of both primary and (when implemented) secondary vacuum-assisted grouting, seal all grout injection ports, grout outlet vents and drain vents. (See "Sealing of Grout Ports, Vents and Drains").

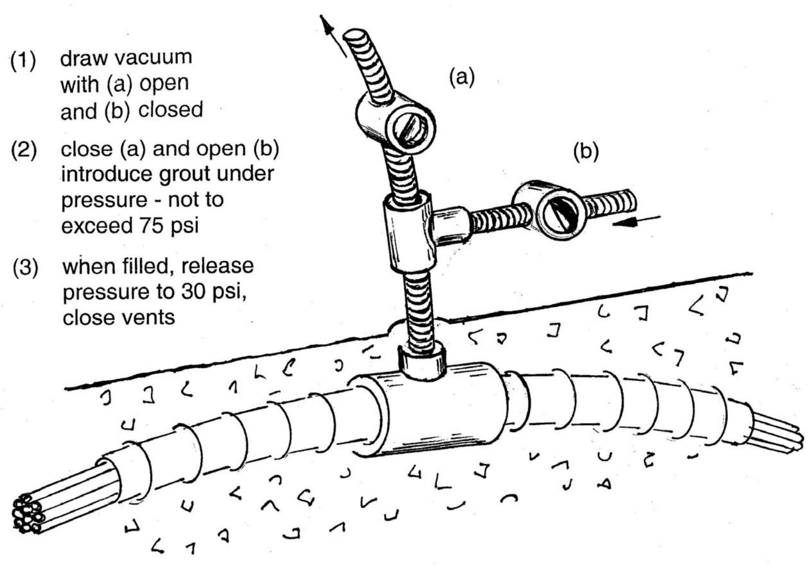


Figure 7.5 – Details of Vacuum Grouting Connections

Strategy 3 – Anchor Protection

Significant corrosion of post-tensioning tendons has resulted from lack of adequate protection at anchorages. To help mitigate this and other corrosion issues, Strategy 3 requires that all anchors shall have a minimum of four levels of corrosion protection. In this context a “level” is not necessarily a layer of material, but rather it is a step taken to ensure protection. A level may be a layer created by a material (such as a pour-back) or it may be a layer made up of one or more coats of a sealing compound or it may be action taken to seal a cold joint.

For hollow box girder structures, a distinction is made between anchors inside a hollow box away from direct exposure to corrosive elements and anchors directly exposed to water and windborne salts.

Responsibilities in meeting the requirements of Strategy 3 are:

- Designer - incorporate details and requirements in the Contract Drawings to provide the necessary levels of anchor protection.

- Contractor - install all components and materials in accordance with the Contract Drawings, approved Shop Drawings, Specifications and QPL. Correct execution and completeness of the work involved is the sole responsibility of the Contractor.

- CEI – inspect the work to verify compliance with the Contract Documents and approved Shop Drawings as required. Advise the Contractor of any areas of non-compliance.

3.1 FDOT Standard Drawings (Requirement 3.A)

Show anchor protection on the Contract Drawings in accordance with the FDOT Standard Drawings.

3.2 Shop Drawings (Requirements 3.A, 3.B, 3.C)

Shop Drawings and other relevant information (e.g. manufacturer’s catalogue data) are required for the post-tensioning system. Anchor protection details on Shop Drawings must comply with that shown on the Contract Plans, in accordance with the FDOT Standard Drawings. For substructure construction, relevant information (such as dimensions, angles, sizes, cover etc. for anchor pockets, blisters or block-outs) must also be integrated into Shop Drawings for concrete components as appropriate. Shop Drawing responsibilities include:

- Contractor - submit the necessary “Shop Drawings” to the Engineer (Designer) for review and approval.

- Designer - review the Shop Drawings and other relevant information and notify the Contractor and CEI of its acceptability.

- CEI - coordinate and keep a record of submittals and responses.

3.3 Materials (Requirements 3.A, 3.B, 3.C)

Responsibilities regarding materials for anchor protection include:

- Designer – make sure that the Contract Documents address and require the proper materials for anchor components and protection.

- Contractor - ensure that all materials and components comply with the Contract Plans, Specifications, FDOT Qualified Products List and the approved Shop Drawings. This includes but is not necessarily limited to: grout, permanent plastic grout caps, epoxy grout for pour-backs to anchors and seal coatings as necessary. Also, keep records of submittals, test reports, approved component deliveries, and track materials and components from delivery through installation at both precast yard and bridge site.

- CEI - verify that materials and components comply with contract requirements. Check and record submittals, test reports, component deliveries and installation at both precast yard and bridge site.

3.4 Installation (Requirements 3.A, 3.B, 3.C)

Responsibilities regarding installation of anchor protection include:

- Designer – make sure that the Contract Documents address proper installation for anchor components and protection.

- Contractor - install components and materials in accordance with the Contract Drawings, approved Shop Drawings and Specifications.

- CEI – inspect the work to verify compliance with the Contract Documents and approved Shop Drawings as required. Advise the Contractor of any areas of non-compliance.

3.5 Anchors inside a Hollow Box - (Requirement 3.A, 3.B, 3.C)

Provided that the structure is sealed from leaks to the interior hollow core and is drained at all low spots, so that water cannot accumulate against anchorages, the four-levels of anchor protection are provided by:

- Grout.
- Permanent grout cap.
- Elastomeric seal coat.
- Surrounding box structure.

Specific requirements for anchors inside a hollow box girder include:

- Correct grout (per FDOT QPL) properly installed to completely fill tendon and anchor.
- Permanent grout cap of high density plastic, of the correct size and mechanically secured and sealed against the anchor plate with a compressible neoprene O-ring.
- Permanent grout cap fully filled with grout.
- Elastomeric seal coat selected from FDOT QPL.
- Seal coat applied over the cap, over the edge of anchor plate and overlapping onto adjacent structural concrete by a minimum of 12 inches all around the anchor plate.

- The surrounding box-structure designed, detailed and built properly to be ventilated, watertight and drained.

3.6 Anchors under Exposed Surfaces - (Requirements 3.A, 3.B, 3.C)

At exposed surfaces where anchors or concrete containing anchors are exposed to windborne spray and water, anchors require protection using a fourth layer of seal coat material (Figure 7.6). Typical anchor locations that fall into this category include:

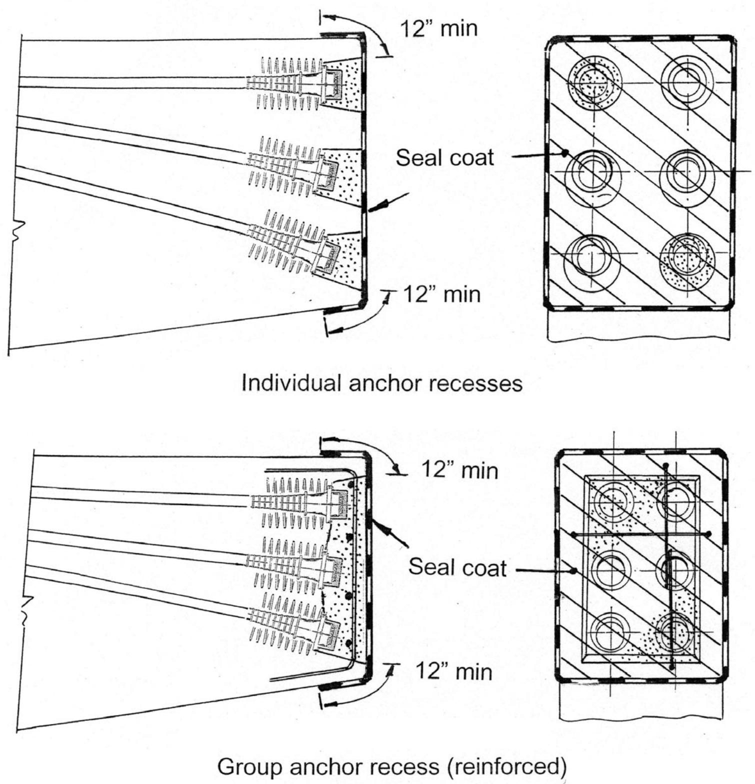
- Cantilever tendons that anchor in ends of a hammerhead pier cap.
- Draped tendons that anchor at the ends of a straddle beam.
- Lateral tendons that anchor in the end cap of a C-Pier.
- Tendons that exit laterally and anchor in the vertical faces of footings.
- Vertical tendons that anchor under the top surface of a pier-cap or straddle-beam.

The four levels of protection for these tendons are:

- Grout.
- Permanent grout cap.
- Pour-back.
- Elastomeric seal coat.

Specific requirements for anchors under exposed surfaces include:

- Correct grout (per FDOT QPL) properly installed to completely fill tendon and anchor.
- Permanent grout cap of high density plastic, of the correct size and mechanically secured and sealed against the anchor plate with a compressible neoprene O-ring.
- Permanent grout cap fully filled with grout.
- The pour-back encapsulating the anchor and grout-cap of an approved, high-strength, high-bond, low-shrink, sand-filled epoxy grout selected from FDOT QPL.
- Pour-back to provide minimum cover over cap of 1-1/2 inch.
- For an individual anchor in a recess, surface of pour-back shall be even with adjacent face of substructure element.
- For a group of anchors, similar individual recesses or, a single enclosing pour-back to encase all anchors in the group.
- Use a single enclosing pour-back secured to concrete substrate with embedded reinforcement (screw coupled rebar may be used) in order to ensure bond.



Four Level Anchor Protection:
- Grout
- Permanent Plastic Cap
- Pour-Back Material
- Elastomeric Surface Seal Coat*

*Elastomeric coat to extend a minimum of 12 inches around edges of pour-backs, and be of a color to match surrounding concrete or Class V finish as required.

Figure 7.6 – Anchor Protection for Exposed Surfaces (End of Pier Caps or Hammerhead Caps)

- Shape and dimensions of single enclosing pour-back be even with adjacent features of structural concrete with chamfers at all outside corners.
- All concrete surfaces of recesses and pour-back substrates be cleaned and roughened prior to casting pour-backs.
- All finished surfaces of pour-backs and adjacent structural concrete shall be properly prepared to receive seal-coats.
- Elastomeric seal coat selected from FDOT QPL be applied over the pour-back overlapping onto adjacent structural concrete by a minimum of 12 inches all around.
- Color of seal coat to match surrounding surface color of finished concrete or Class V coating as appropriate.

3.7 Temporary Protection during Construction (Requirement 3.C)

During construction, all post-tensioning ducts and tendons must be temporarily sealed or capped to prevent ingress of water, corrosive agents or site debris and any low point drains should remain open.

In particular, ensure that:

- Post-tensioning anchors are sealed at all times to prevent the entrance of water or waterborne contaminants and are not blocked with construction debris.
- Temporary caps are used as necessary.
- Permanent grout caps are installed immediately after stressing.
- Vents and ports in anchors, grout caps and intermediate grout pipes are closed with threaded plugs or threaded caps until grouting.
- Plugs and caps are replaced after grouting but prior to completing permanent anchor protection.

Strategy 4 – Watertight Bridges

4.1 Sealed Joints (Requirement 4.A)

Cast-in-Place Substructures

All joints in cast-in-place construction are continuously reinforced. In some cases, internal post-tensioning tendons may be installed. Ducts must pass through construction joints and be properly spliced with sealed couplings. Construction joints must be properly prepared and roughened in accordance with the Specifications prior to further casting.

Precast Hollow Box and I-Piers

All match-cast joints in precast segmental piers shall be fully sealed with epoxy applied to both faces of the mating segments. Responsibilities regarding epoxy sealed joints include:

- Designer – make sure Contract Documents require appropriate epoxy joining for bridge construction, application, site location and weather conditions.

- Contractor – prepare segments and apply epoxy in accordance with Contract Specifications and requirements.

- CEI - check that epoxy is properly applied to seal joints.

Requirements for epoxy sealed joints include:

- Epoxy is the correct formulation (i.e. usually normal-set for cantilever erection or slow-set for span-by-span erection).
- Formulation is correct for application temperature and relative humidity.
- Materials do not exceed shelf life.
- Components are mixed according to manufacturers recommendations.
- Mating surfaces are properly prepared, clean and dry.
- Correct amount of epoxy is applied (i.e. number of cans for face area of application).
- Epoxy is properly applied to both faces - but carefully around internal ducts to avoid unnecessary spillage of epoxy into any internal duct connectors.
- Pier column segments are drawn together within the open time before epoxy can take initial set.
- Required temporary PT force is applied to compress tight the epoxy, create the seal and secure the new segment to the previous one.

- After mating, all internal ducts are swabbed to remove any exuded epoxy and prevent blockages.
- All exuded epoxy is cleaned from visible joints (may be done after epoxy has set).

4.2 Small Diameter Holes in Substructures (Requirement 4.C)

For construction, it is often necessary to provide holes for attaching formwork, temporary support devices, falsework, formwork, stability frames, access platforms for tools and personnel, or for securing other erection equipment. Vertical holes may be needed through hammerheads, caps or straddle beams. Horizontal holes may be needed through pier walls or columns.

Forming and Filling Vertical Holes (Requirements 4.C, 4.D)

Avoid placing holes where leaks would drip directly onto anchor heads or onto post-tensioning inside a hollow structure.

- Designer - show permissible sizes and locations of temporary holes on the Contract Drawings and make sure Contract Documents address required filling and sealing.

- Contractor - use only tapered (top wider than bottom) temporary holes in accordance with the details on the Contract Drawings or approved Shop Drawings.

- CEI - check that all such holes are correctly installed, filled and sealed after use.

Requirements for Temporary vertical holes:

(1) Taper sides - top larger diameter than bottom by at least ¾ inch.
(2) Form with removable mandrel to provide a clean, interior concrete surface.
(3) Locate at least 12 inch from the nearest anchor.
(4) Use no pipe of any kind (plastic, steel, ribbed or plain) as permanent liner through slab unless over 18 inch deep – in which case a ribbed plastic liner may be used.
(5) Sides to be clean of all dirt, debris, grease and oil immediately prior to filling.
(6) Fill with an approved high strength, high bond, non-shrink, quick set, air cured concrete material or epoxy grout.
(7) Seal of top surface (deck) with an approved sealer (methyl methacrylate) applied over and around the filled holes. A seal is not required when epoxy grout is used.
(8) Where temporary holes pass through the full depth of structure (e.g. straddle beam or diaphragm) – make appropriate allowance and adjust details for local geometry, super-elevation, grade and possible interference with other components or tendons.

Filling Horizontal Holes

Clean, fill and finish horizontal temporary holes in columns and caps in accordance with the Standard Specifications.

4.3 Block-Outs for Vertical PT Anchors, Couplers or Mechanical Splices (Requirements 4.B, 4.C)

For precast segmental piers and connection of other precast components, vertical post-tensioning bars or mechanical splices are needed to secure segments to a previous one or a prepared base. Post-tensioning bars may be permanent or temporary until the permanent tendons are installed and stressed.

Initially, the post-tensioning bars must compress the precast segments under a minimum pressure of 40psi (0.3MPa) and as uniform as possible over the section to seal the epoxy. (Slow set epoxy may be used for tall, precast piers with multiple segments.)

Avoid placing block-outs near permanent tendons or anchors, where any leaks might seep into ducts or connections. All block-outs must be fully filled and sealed after temporary use.

Requirements for PT block-outs:

- For structures in an aggressive (coastal) environment, do not use block-outs at the base of pier columns below 12 feet above mean high water.
- For structures in non-aggressive (inland) environments, do not use block-outs below 5 feet above finished ground level.
- Locate block-outs carefully so as to avoid tendons and anchors, in particular, avoid block-out grazing duct to cause a local void or defect – keep clear by at least 3 inches.
- For access to couple and stress post-tensioning bars use block-out opening to interior of hollow pier.
- Make block-out sufficiently long, or enlarged duct, to accommodate bar anchor nuts and couplers especially as bars elongate and fits within rebar and details.
- Avoid excessive application of sealant or layers of duct tape to ends of internal tendon ducts at temporary bulkheads or joints that might cause a local defect.
- Provide detail to establish effective continuity of duct system through block-out.
- Form block-outs to leave a neat internal concrete surface.
- Clean sides of all dirt, debris, grease and oil prior to filling.
- Fill block-outs with an approved no-shrink, high-bond, high-strength, air-cured concrete or epoxy grout.
- Finish surface even and uniform with adjacent concrete.
- Seal over and around pour-back for at least 12” with an approved elastomeric seal coat (Class V finish is not a sealer).

4.4 Temporary Block-Outs in Pier Walls or Columns (Requirement 4.B)

Temporary block-outs (rather than holes) are necessary for supporting certain types of construction equipment (e.g. pier-brackets, stability frames, needle beams, pier-tables and falsework) – especially for large structures involving significant construction loads, temporary reactions or forces. Such temporary block-outs usually require local reinforcement around their perimeters or corners along with screw coupled reinforcement for reinstatement.

Requirements for temporary block-outs:

- Locate and size block-outs so as not to intersect any post-tensioning tendons or anchors - keep edge of block-out clear by at least 3 inches.
- Design and detail pier reinforcement for to accommodate necessary block-outs.
- Provide local reinforcement to pour-back to block-out if over 12 inches wide by 18 inches high using screw coupled rebar or other acceptable means.

- Provide local reinforcement to contain any concentrated (bursting) forces.
- Provide ribs or diaphragms or temporary frames to distribute or carry concentrated horizontal forces - as necessary.
- Ensure that length of block-out or widened duct fits with other details and rebar.
- Clean all block-out surfaces of grease, debris, dirt, oil and lightly roughen surface.
- Require concrete backfill to be an approved high-strength, high-bond, non-shrink, air-cured concrete, thoroughly consolidated and cured.
- After construction and pour-back, finish surface to match exterior surface of columns, even and uniform in color and texture.
- Seal surface and edges of pour-back with an approved sealer compatible with Class 5 finish. (Class 5 finish does not qualify as a sealer.)

4.5 Corbels for Temporary Supports

Unlike anchor blisters in superstructures, corbels on the exterior of pier columns spoil the appearance and are generally not a practical alternative to temporary block-outs.

4.6 Temporary Access Holes (Requirement 4.B)

Access manholes or openings are often needed for removing heavy or large pierces of essential equipment or formwork. Also, manholes, doorways or trap doors may be needed for future maintenance inspection. Responsibilities regarding temporary access holes include:

- Designer - show acceptable range of locations, dimensions and details for temporary access holes on the Contract Drawings.

- Contractor - use only tapered (top wider than bottom) access holes in accordance with details on the Contract Drawings or approved Shop Drawings.

- CEI – check that access holes are correctly installed, filled and sealed.

For a permanent pour-back to a temporary manhole:

- Provide reinforcement to temporary access (may be screw coupled or field bent).
- Provide tapered sides all around (top of manhole larger than bottom).
- Thoroughly clean and roughen sides.
- Fill with an approved material from the FDOT QPL.
- Seal top with approved sealer (e.g. methyl-methacrylate). A seal is not required when epoxy grout is used.

Alternatively, provide permanent access doors or trap doors as necessary, with drip details and seals that prevent flow of water to interior of structure.

4.7 Substructure Drains and Weepholes – (Requirement 4.D)

Provide drains to the interior of hollow cores in substructures to prevent water that enters from any source, including condensation, from ponding in the vicinity of post-tensioning components (Figure 7.4). Responsibilities regarding drains include:

- Designer – Contract Drawings, show locations and details for bottom slab drains.

- Contractor - install segment drains in accordance with the details on the Contract Drawings or the approved Shop Drawings – including drains at all low points made by barriers introduced to accommodate means and methods of construction, such as additional blocks or blisters.

- CEI - check that all segment drains are correctly installed.

Requirements for drains:

- Provide drains to interior voids or cells of hollow straddle beams.
- Use 2 inch diameter permanent plastic pipes set flush with the concrete.
- Provide a small drip recess, ½ inch by ½ inch around bottom of vertical pipe insert.
- Provide at all low-points against internal barriers.
- Provide weep holes to interior of hollow columns.
- Provide solid section to base of pier columns (or fill with concrete).
  - For aggressive environments (ocean sites) below 12 feet above high water.
  - For non-aggressive environments (inland sites) below 1 foot above finished ground level.
- Slope interior top of solid base to drains or weep-holes.
- Provide weep-holes with vermin guards.

Strategy 5 – Multiple Tendon Paths

5.1 Lateral Post-Tensioning (Requirements 5.A, 5.B and 5.C)

Hammerhead Piers

A typical hammerhead pier is built using cast-in-place construction. The pier cap behaves as a statically determinate cantilever in each direction. Internal cantilever post-tension tendons are supplemented with mild-steel distribution reinforcement in routine post-tensioned design and construction practice. For the pier cap of straddle bents where post-tensioning is the primary means of load resistance:

- Do not use a tendon size greater than 19-0.6 inch diameter strands or 27-0.5 inch diameter strands.
- Select a tendon size to maximize the number of individual tendons.
- Provide a minimum of 6 individual tendons.

Straddle Beam (Simply Supported)

A typical simply supported straddle beam is built using cast-in-place construction. It behaves as a statically determinate beam. Internal post-tensioning tendons are supplemented with mild-steel distribution reinforcement in routine post-tensioned design and construction practice - (even if the straddle beam was to be precast and lifted into place.) For the beams of this type of straddle bent where post-tensioning is the primary means of load resistance:

- Do not use a tendon size greater than 19-0.6 inch diameter strands or 27-0.5 inch diameter strands.
- Select a tendon size to maximize the number of individual tendons.
- Provide a minimum of 6 individual tendons.

Confinement of Caps

Confinement post-tensioning provided for localized forces (e.g. very large bearings) is selected according to design techniques for bursting and/or secondary post-tensioning distribution effects. Post-tensioning tendons are internal to the concrete and may be either bars or hoop strand tendons, which are typically supplemented by a significant amount of mild reinforcement. Though the details of these tendons are very project specific, in general:

- Provide multiple tendons – a minimum of 6 straight bars or 4 fully looped strand tendons.

5.2 Lateral and Vertical Post-tensioning - (Requirements 5.A, 5.B and 5.C)

Cantilever Piers

A typical cantilever pier (C-Pier) is statically determinate and is built using cast-in-place construction. Internal post-tensioning tendons are supplemented with mild-steel distribution reinforcement in routine post-tensioned design and construction practice. Vertical bar tendons from the column cross with lateral bar tendons in the footing. At the knee (top of column / cantilever junction), vertical bar tendons in the column must cross with lateral bar tendons from the cantilever. Both must be well anchored as they cross at the knee. For cantilever piers of this type where post-tensioning is the primary means of load resistance:

- Use post-tensioning bars of 1 ¼ inch minimum diameter.
- Select a bar size to maximize the number of individual bars.
- Provide a minimum of 6 individual bar tendons per main member (i.e., 6 in the cap, 6 in the column, and 6 in the footing).

Portal Frames (Monolithic Straddle Bent)

Typically, a portal frame or monolithic straddle bent is cast-in-place and is a statically indeterminate structure. Internal post-tensioning tendons are supplemented with mild-steel distribution reinforcement. For this type of straddle bent where post-tensioning is the primary means of load resistance:

- Do not use a tendon size greater than 19-0.6 inch diameter strands or 27-0.5 inch diameter strands (in the beam) and/or use post-tensioning bars with a minimum of 1¼-inch diameter (all members).
- Select a tendon size to maximize the number of individual tendons or bars.
- Provide a minimum of 6 individual tendons or bars per main member (i.e., 6 in the cap, 6 in the column, and 6 in the footing).
- Only post-tensioning bars may be used below an elevation of 5 feet above ground level on land sites.

5.3 Vertical Post-Tensioning - (Requirements 5.A, 5.B and 5.C)

Hollow Precast Piers

Single, hollow, precast segmental pier columns are statically determinate. However, they have discrete (match-cast, epoxy) joints where vertical reinforcement is discontinuous. The post-tensioning tendons for these piers can be either internal or external. For this type of pier:

- Do not use a tendon size greater than 12-0.6 inch diameter strands or 17-0.5 inch diameter strands and/or post-tensioning bars with a minimum diameter of less than 1¼".
- Select a tendon size to maximize the number of individual tendons.
- Provide a minimum of 8 individual tendons at any section.
- Only post-tensioning bars may be used below an elevation of 5 feet above ground level on land sites.

Precast I-Section Piers

Single, I-section piers – whether comprised of several precast, match-cast, segments with epoxy joints or a single precast column piece with epoxy or other (i.e. mortar or grouted) joints – are statically determinate and the vertical reinforcement is discontinuous. The post-tensioning tendons are internal to the concrete. For this type of pier:

- Do not use a tendon size greater than 12-0.6 inch diameter strands or 17-0.5 inch diameter strands and/or post-tensioning bars with a minimum diameter of less than 1¼".
- Select a tendon size to maximize the number of individual tendons.
- Provide a minimum of 8 individual tendons at any section.
- Only post-tensioning bars may be used below an elevation of 5 feet above ground level on land sites.

5.4 Extra (Corrosion Loss) Post-Tensioning - (Requirement 5.C)

For cast-in-place substructures with continuity of mild reinforcing, no extra post-tensioning to compensate for possible loss due to corrosion of tendons needs be installed at the time of construction. However, because internal bonded tendons are not replaceable, satisfy the following requirements:

- Consider the long-term condition only – i.e. after all normal PT losses, shrinkage and creep redistribution have taken place (e.g. "day 4000").
- Consider only the critical section.
- For this section only - assuming a loss to corrosion of 20% of the internal tendons - provide sufficient longitudinal mild steel reinforcing in conjunction with the remaining 80% undamaged internal tendons, to satisfy the following conditions:
  - AASHTO LRFD limit state Strength IV.
  - AASHTO LRFD limit state Strength II for all FDOT permit vehicles.

For precast substructures with match-cast, epoxy joints, provide extra post tensioning at the time of construction to compensate for possible loss due to corrosion of tendons as follows:

- Consider the long-term condition only – i.e. after all normal PT losses, shrinkage and creep redistribution have taken place (e.g. “day 4000”).
- Consider only the critical section.
- For this section only - assuming a loss to corrosion of 20% of the internal tendons - provide sufficient external tendons in conjunction with the remaining 80% undamaged internal tendons, to satisfy the following conditions:
  - AASHTO LRFD limit state Strength IV.
  - AASHTO LRFD limit state Strength II for all FDOT permit vehicles.

5.5 Construction - Multiple Tendon Paths (Substructures)

Once established by the design, the number of longitudinal tendons must be implemented in Construction. The Contractor must follow the Contract Drawings or otherwise comply with all the requirements of this Volume related to Multiple Tendon Paths. This means that it may not be acceptable to substitute via Shop Drawings or a VECP fewer large sized post-tensioning tendons for smaller sized ones of the original design. Responsibilities regarding multiple tendon paths during construction include:

- Contractor - comply with the above requirements when preparing Shop Drawings or changes by VECP, when allowed by the Contract and submit the necessary “Shop Drawings” to the Engineer (Designer) for review and approval.

- Designer - review Shop Drawings and other relevant information and notify the Contractor and CEI of its acceptability.

- CEI - coordinate and keep a record of submittals and responses.