

Florida Department of Transportation

New Directions for Florida Post-Tensioned Bridges



Volume 8 of 10: Design and Construction Inspection Of Transverse Post-Tensioning Of Superstructures

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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.

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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.

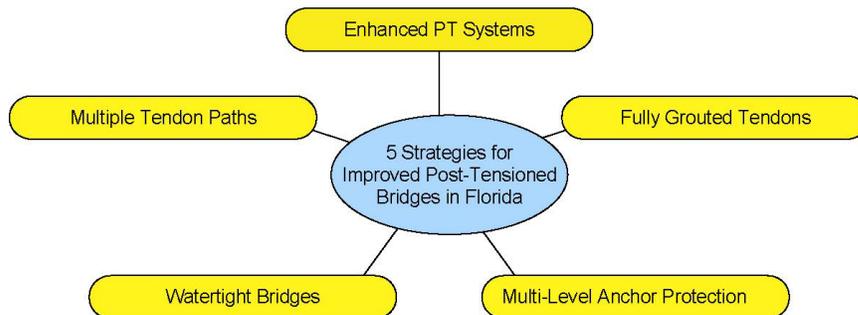


Figure 1.1 – Five-part strategy for more durable post-tensioned bridges in Florida.

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 8 – Transverse Post-Tensioning of Superstructures

Applications for transverse post-tensioning with bar or strand tendons include:

- Transverse connection of precast, pre-stressed planks.
- Transverse prestress for cast-in-place slabs (either solid or voided).
- Transverse connection of Double-T's.
- Transverse post-tensioning of deck slabs of box girders – precast and cast-in-place.
- Transverse post-tensioning in diaphragms.
- Vertical post-tensioning in diaphragms or anchor blocks.
- Vertical post-tensioning bars in webs of large box girders.

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

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 (Requirement 1.B)

Enhanced post-tensioning systems require three levels of protection using the barriers defined in Volume 1 “Post-Tensioning in Florida Bridges”. Transverse post-tensioning tendons are usually internal, and the three levels of protection are provided by:

- (1) Fully grouted tendon.
- (2) Impervious plastic duct.
- (3) Concrete cover.

Each of these levels of protection depends upon appropriate design details, proper construction and varies with the type of application. Typical cases are as follows:

(a) Transverse Post-tensioning for Precast, Pre-stressed Planks

Longitudinal joints between precast planks are typically made with unreinforced cast-in-place concrete. Transverse tendons pass through ducts cast into the planks and through short pieces of duct inserted in each cast-in-place joint to connect the ends of ducts in adjacent planks. The quality of the seal of the discontinuous ducts and susceptibility of joints to leaks depends heavily upon design details, fabrication and site installation.

Use oversized ducts in precast planks in order to accommodate differences in fabrication tolerances between planks not necessarily cast in same bed and differences in elastic shortening, shrinkage and creep between adjacent planks. In this context, an oversized duct is one that provides at least 5 times the net area of post-tensioning steel.

Use one of the following two methods for making a continuous sealed duct:

- Extend ends of ducts into cast-in-place joints by at least 3 inches and surround duct with an overlapping, sealed mechanical or sealed flexible connection between ends of ducts. (Note: duct tape does NOT meet the requirements for a positive seal in joining any pieces of duct or duct to anchorage.)
- Use an oversized duct cast with the planks with an inner duct continuous from anchor to anchor and fully grout both inner and outer ducts.

(b) Transverse Post-tensioning of Slabs of Boxes – Precast and Cast-in-place

Transverse tendons are internal to the top deck slab, being protected and bonded by fully grouting the duct. Ducts are usually of a “flat” oval section - to accommodate three or four strands laid side-by-side, usually located below the top-most mild steel reinforcement. Transverse tendons typically have a slight vertical profile.

(c) Transverse Post-tensioning in Diaphragms

Transverse tendons run laterally across diaphragms of precast or cast-in-place concrete segments at interior piers or expansion joints. Tendons may be comprised of strands or bars. Strand tendons may be straight or draped. In most cases, these tendons are deeply embedded within the diaphragm that cover is not an issue.

(d) Vertical post-tensioning in diaphragms or anchor blocks

Vertical post-tensioning may be needed in diaphragms or anchor blocks to confine or control local concentrated forces induced by longitudinal post-tensioning tendons. Vertical tendons are typically short and comprised of post-tensioning bars in order to minimize the effects of seating loss. Ducts extend from the dead end bottom anchor to the top, stressing anchor. Post-tensioning bars are relatively massive so that for a similar application and breach of protection, corrosion tends to be less severe than compared to strands. Also, post-tensioning bars and anchors are usually deeply embedded within a diaphragm or anchor block that cover is rarely a major concern.

(e) Vertical post-tensioning bars in webs of large box girders

Occasionally it may be necessary to provide vertical post-tensioning in a web in order to satisfy crack control or enhance shear performance. Vertical web tendons are typically short and comprised of post-tensioning bars in order to minimize the effects of seating loss. Typically, post-tensioning bars are centered on each web at intervals along the structure, beginning at a pier, until no longer required. Ducts extend from the dead end bottom anchor to the top, stressing anchor. Post-tensioning bars are relatively massive so that for a similar application and breach of protection, corrosion tends to be less severe than compared to strands. Also, post-tensioning bars and anchors are usually deeply embedded within a web that cover is rarely a major concern.

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 girder components,
 - non-shrink, high-bond, high-strength, air-cured concrete for filling holes for cast-in-place joints, 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 project 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. Refer to Volume 2 “Design and Construction Inspection of Precast Segmental Balanced Cantilever Bridges” for treatment of connections and precast joints.

1.5 External Tendons – Ducts and Connections (Requirements 1.C and 1.D)

Transverse post-tensioning tendons are seldom placed external to the concrete. Refer to Volume 3 “Design and Construction Inspection Precast Segmental Span-by-Span Bridges” for requirements if transverse external post-tensioning tendons are used.

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 $\frac{3}{4}$ ” 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 $\frac{3}{4}$ inch for strand tendons and $\frac{3}{8}$ 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) for precast components, precast segments and cast-in-place construction as necessary. 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 the precast yard and during erection on site when making closures or other cast-in-place construction, installation shall include but not be limited to:

Ducts For Internal Tendons:

During fabrication make sure that ducts are:

- Installed to correct profile (line and level) within specified tolerances.
- 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.)

Cover – make sure that cover is correct to rebar and ducts (longitudinal and transverse).

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 – are not normally used in transverse post-tensioned applications. Refer to Volume 2 – “Design and Construction Inspection of Precast Segmental Balanced Cantilever Bridges” if epoxy joints are used.

Post-Tensioning Tendons – 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)

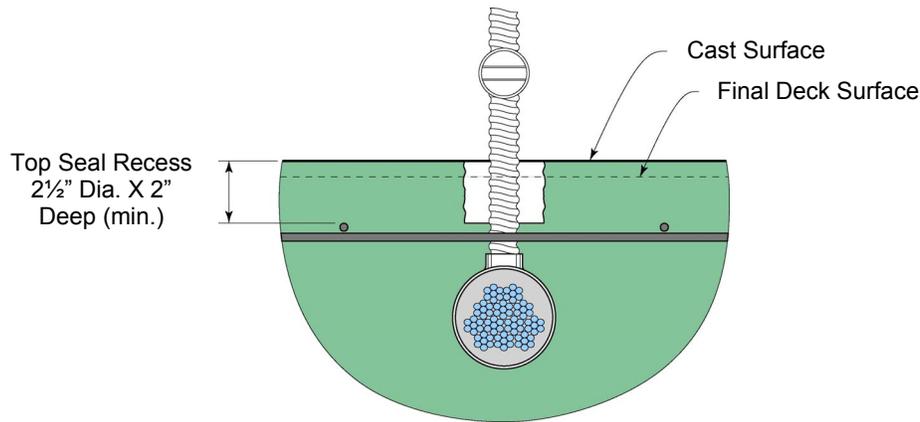
In order to maintain the integrity of the duct system and its effectiveness as a barrier, all grout ports, vents and drains must be properly terminated and sealed.

- Designer - show details and/or include post-tensioning Standard Drawings into the Contract Drawings.
- 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 8.1. Requirements for this detail include:

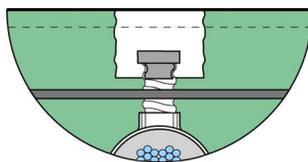
- (1) At all grout vents or ports that exit or enter the top slab, provide a recess not less than 2 inches or more than 3-1/2 inches in diameter around the pipe. Make depth of recess not less than 2-1/2 inches or more than 3 inches from the initial roadway surface before grinding and grooving - i.e. final depth of recess after 1/2 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.

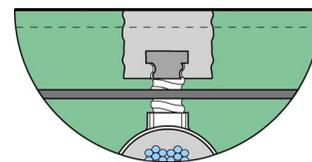


a). Grout pipe connection to tendon

- Cut Grout Pipe 1" Below Final Surface (Min.)
- Remove Recess Former
- Clean & Roughen Sides
- Insert Seal Plug or Cap
- Fill Recess With Approved Filler
- Grind & Groove



b). Pocket Preparation



c). Filling Pocket

Figure 8.1 – Sealing grout ports and vents in top slabs.

- (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).

1.13 Internal Tendons – Clearances, Dimensions and Details

(a) Thickness of Components (Requirements 1.B and 1.C)

Refer to Volume 2, “Design and Construction Inspection of Precast Segmental Balanced Cantilever Bridges” for recommended clearances, dimensions, details and thickness of components.

(b) Duct Supports (Requirements 1.C)

Provide duct supports at intervals of 2 feet (or per recommendations of the duct supplier) when the ducts cannot be directly tied to either the top or bottom mat of reinforcing. Supports may be #3 rebar or D4 wire. Bars may be any convenient shape (straight, U, L or Z) and set at any convenient angle or slope providing cover is not violated.

1.14 External Tendons – Clearances, Dimensions and Details

Refer to Volume 3, “Design and Construction Inspection of Precast Segmental Span-by-Span Bridges” if external transverse post-tensioning tendons are used.

Strategy 2 – Fully Grouted Tendons

This strategy requires that all transverse post-tensioning tendons 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. Anchors for new construction are to have an inspection port to accommodate probes and/or bore-scope equipment.

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

To help ensure that tendons are fully grouted, specific details and procedures for grouting must be shown on the Contract Drawings, addressed in the Specifications and enforced during construction. In accordance with the FDOT Standard Drawings on the Contract Drawings:

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. Consequently, provide drains at all low points.

(a) Transverse Tendons

In accordance with the FDOT Standard Drawings, on the Contract Drawings:

- 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 transverse profile of the tendon (allow for super-elevation).
- Locate the grout injection port at the lowest point of the tendon 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.
- 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.

(b) Vertical Tendons

In accordance with the FDOT Standard Drawings, on the Contract Drawings:

- 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.
- Provide drain / injection port at lowest point of tendon.
- Provide intermediate vent / injection port if height exceeds 20 feet.
- 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. Secure standpipe with at temporary frame.
- Also, provide a grout injection port at top anchors to access the anchorage just below the bottom of the plate.
- Show direction of grouting beginning at the lowest injection port.

2.3 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.

2.4 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.

2.5 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.

2.6 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 at precast yard and on site (may be separate grouting plans).
- Qualifications and Certification of Grouting Personnel (at precast yard and site).
- Proposed grout material and reports of qualification tests (must be to QPL).
- 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).
- Means of pressure testing duct system for leaks and sealing as necessary.
- Sequence of injecting and evacuating grout for each tendon type - i.e. longitudinal cantilever, top continuity, bottom continuity, per examples below - or others. (For external tendons, see Volume 3, “Precast Segmental Span-by-Span Bridges”.)
- Injection of grout at the low point of each profile.
- 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 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.

2.7 Secondary Vacuum-Assisted Grouting (Requirement 2.G)

After primary grouting is accomplished, require anchors to be inspected and filled using vacuum-assisted grouting if a void is found. See Figure 8.2 for 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, as follows.

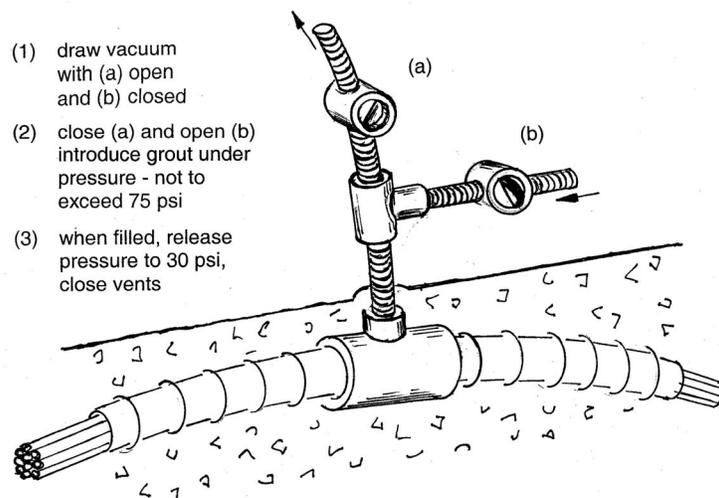


Figure 8.2 – Details of Vacuum Grouting Connections

- (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 secondary grouting (when implemented) of tendons, seal all grout injection ports, grout outlet vents and drain vents. (See “Sealing of Grout Ports, Vents and Drains”)

Strategy 3 – Multi-Level 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.

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 transverse post-tensioning tendons, relevant information (such as dimensions, angles, sizes, cover etc. for anchor pockets, blisters or block-outs) must also be integrated into Shop Drawings for structural 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 for Transverse Tendons – (Requirements 3.A, 3.B, 3.C)

Transverse post-tensioning for precast, prestressed concrete planks and deck slabs of box girders - both precast and cast-in-place:

Case (1) - Where an anchor is under a traffic barrier, the four-levels of protection comprise:

- Grout.
- Permanent grout cap.
- Encapsulating pourback*.
- Concrete traffic barrier.

Case (2) - Where anchor is under a traffic surface, (e.g. anchors in segment wings on each side of a longitudinal cast-in-place closure between boxes), the four levels of protection comprise:

- Grout.
- Permanent grout cap.
- Encapsulating pour-back*.
- Seal coat of methyl methacrylate.

*The pour-back material encapsulating the anchor and grout-cap may be – either an approved, high-strength, high-bond, low-shrink, fast-set, air-cured concrete – or a high-strength, high-bond, low-shrink, sand-filled epoxy grout - selected from FDOT QPL

Transverse post-tensioning in diaphragms:

For transverse tendons that run laterally across diaphragms of precast or cast-in-place concrete segments at interior piers or expansion joints and anchor in exterior faces - or similar applications – the four levels of protection comprise:

- Grout.
- Permanent grout cap.
- Encapsulating pour-back**.
- Elastomeric seal-coat***.

**The pour-back material encapsulating the anchor and grout-cap is a high-strength, high-bond, low-shrink, sand-filled epoxy grout selected from FDOT QPL

*** Elastomeric seal-coat to be color coordinated with exterior surface finish as necessary and to extend for 12" minimum beyond edge of pour-back. (Note: Class V finish does not qualify as an elastomeric seal coat)

Specific requirements for anchors at ends of transverse tendons:

- 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.
- At least 1-1/2 inches end cover over permanent plastic cap to finished surface.
- Cover from anchor recess to other surfaces is at least equal to rebar cover.
- For single anchors, provide an individual recess for each end anchor.
- For a group of anchors, provide either multiple individual anchor recesses or a large single recess and encapsulating pour-back.
- For a large single recess provide minimum D4 wire or #3 rebar reinforcement. (Wire or rebar may be temporarily bent to clear jacks – or screw-couplers may be used.)
- Make finished surface even with adjacent structural concrete.
- Concrete surfaces of recess to be cleaned, properly roughened and prepared prior to casting pour-back material (do not leave in place any recess former).
- Pour-back encapsulating anchor and cap to be an approved material to FDOT QPL.
- Surface of pour-backs and adjacent structural concrete be properly prepared to receive seal-coats.
- For top (traffic riding) surface of components apply approved sealer (methyl-methacrylate) to pour-back and adjacent concrete, for exterior (web) surfaces apply elastomeric seal coat (Note: Class V finish does not qualify as an elastomeric seal coat).

3.6 Top Anchors for Vertical PT-Bars in Diaphragms, Anchor Blocks or Webs - Requirements 3.A, 3.B, 3.C)

In general, vertical PT bars in these applications terminate under a traffic surface where each anchor is in individual recess. The four-level protection for vertical PT bar anchors comprises:

- Grout.
- Permanent grout cap.
- Encapsulating pour-back of epoxy-grout.
- Seal coat of methyl methacrylate.

Specific requirements for top anchors for vertical PT bars:

- 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.
- At least 1-1/2 inches end cover over permanent plastic cap to finished surface.
- Concrete surfaces of recess to be cleaned, properly roughened and prepared prior to casting pour-back material (do not leave in place any recess former).
- Surface of pour-back and adjacent structural concrete be properly prepared to receive seal-coats.
- For top (riding) surface apply approved sealer (methyl-methacrylate) to pour-back and adjacent concrete for minimum of 12" all around.

3.7 Anchors Inside a Hollow Box – (Requirements 3.A, 3.B, 3.C)

Transverse tendons might anchor on the interior of a hollow box – e.g. top slab tendons that connect two parallel boxes and anchoring at the intersection of the top slab and web – or similar applications.

Providing that the structure is otherwise sealed from all sources of leaks through the bridge deck into the hollow core, and is drained at all low spots, against blisters, ribs or diaphragms, so water, from any source including condensation, cannot accumulate against an anchorage; 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:

- 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.

3.8 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

This strategy requires that all post-tensioned bridges be watertight. A watertight structure is the first line of defense against attack by corrosive agents. Sources of ingress are improperly sealed cast-in-place joints or pour-backs to block-outs or pockets where concrete can shrink or fill material may not bond properly.

The deliberate use of construction joints, such as the transverse connection of precast, pre-stressed planks or double-T's at cast-in-place strips or joints offer potential for shrinkage cracks or avenues for seepage of water into a structure or tendons if the ducts or connections are not sealed. Give attention to details and provide sealer to all such joints. In some cases, transverse tendons in decks of box girders and diaphragms and vertical tendons in diaphragms or webs are deeply embedded within the concrete and well protected (unless the concrete itself is poor quality or honeycombed) that basic cover is rarely a concern.

4.1 Seal Joints (Requirement 4.A)

Transverse connections of precast, pre-stressed planks and Double-T's involve cast-in-place concrete joints, sometimes with block-outs and pour backs at anchors and couplers. All concrete must be sound, of good quality, and well consolidated.

Seal finished tops of cast-in-place concrete and joints between cast-in-place and precast components with an approved surface sealer (methyl methacrylate).

4.2 Forming and Filling Temporary Holes (Requirement 4.C, 4.D)

For precast construction, vertical holes (approximately up to 3 inch dia) through precast planks or top slabs of boxes or diaphragms are required for a variety of reasons – mostly for attaching lifting frames or other equipment such as access platforms.

Avoid placing holes where leaks would lead directly to anchors or post-tensioning ducts. Responsibilities regarding forming and filling temporary holes include:

- 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 holes:

- (1) Taper sides - top larger diameter than bottom by at least $\frac{3}{4}$ 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. diaphragms) – make appropriate allowance and adjust details for local geometry, super-elevation, grade and possible interference with other components or tendons.

Strategy 5 – Multiple Tendon Paths

5.1 Multiple Tendon Paths (Requirement 5.A)

Transverse post-tensioning in – Precast Prestressed Concrete Planks, Slabs, Double-T's, Deck Slabs of Boxes (Requirement 5.A)

Two-way slab action is the primary feature of transversely post-tensioned decks. In these cases, transverse post-tensioning consists of individual tendons (strands or bars) at regular intervals along the bridge deck. Multiple tendon paths are thus a fundamental feature of the system. If a tendon is lost for some reason (i.e. corrosion or damage) load may be redistributed by plate action (longitudinal continuity of slab) – with a change of internal stresses. Effects may also be distributed by the presence of edge stiffening barriers.

Transverse post-tensioning in Diaphragms - (Requirement 5.A)

For diaphragms in box-girder bridges, transverse post-tensioning may supplement the capacity provided by plain rebar or it may provide all the capacity. Consequently, a simple requirement for multiple tendon paths is not straightforward. However, where capacity is based solely on post-tensioning, as far as practically possible, provide at least 6 tendons. If the capacity is based upon a combination of post-tensioning and rebar, provide at least 4 tendons.

Vertical post-tensioning in Diaphragms - (Requirement 5.A)

In diaphragms or anchor blocks of segmental bridges, vertical post-tensioning generally supplements mild reinforcement provided to contain or distribute local concentrated forces.

It is recognized that there is a need to save weight by the appropriate use of vertical post-tensioning. Make structural proportions (and weights) sufficient to contain forces primarily by means of mild reinforcement, secondarily supplemented by post-tensioning. Provide, check and detail proportions to minimize tension crack widths.

When vertical post-tensioning is used, provide at least two tendons (i.e. two post-tensioning bars) in the tension face of the one anchor block/diaphragm face for a total of four tendons for a two-web box girder.

Vertical post-tensioning bars in webs of large box girders - (Requirement 5.A)

Multiple post-tensioning bars distributed along the web are a fundamental feature of this system. Loss of a bar from corrosion or damage would lead to internal redistribution of stress.

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

For transversely post-tensioned members with continuous mild reinforcing, no extra post-tensioning to compensate for unknown loss due to corrosion of tendons need 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 a critical section
- Assuming a loss to corrosion of 20% of the internal tendons - provide sufficient transverse 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.

5.3 Construction – Multiple Tendon Paths (Requirements 5.A, B and C)

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.