Florida Department of Transportation

New Directions for Florida Post-Tensioned Bridges

Volume 6 of 10: Design and Construction Inspection Of Bridges Cast-In-Place On Falsework

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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 6 – Design and Construction Inspection of Bridges Cast-in-Place on Falsework

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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.

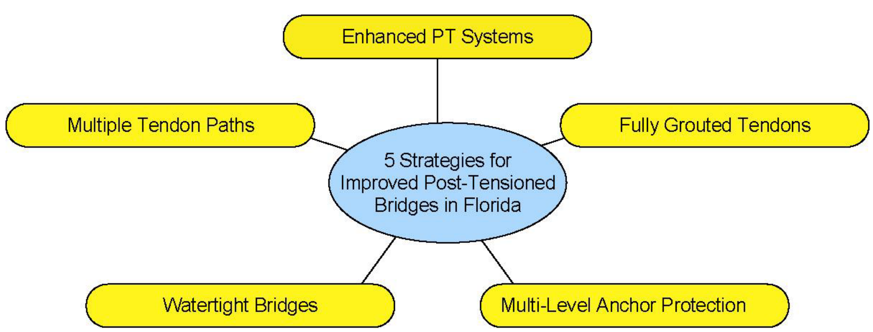


Figure 1.1 – Five-part strategy for more durable post-tensioned bridges in Florida.

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 6 – Bridges Cast-in-Place on Falsework

Typical cast-in-place structures on falsework usually include solid slabs, voided slabs and multi-cell box sections that have the following characteristics:

Solid Slab Bridges

- Thickness up to 18 inches for the full width of the bridge deck.
- Span lengths up to approximately 40 feet.
- Spans may be simply supported or continuous over the interior piers.

Voided Slab Bridges

- Trapezoidal cross sections with several circular voids.
- Depths that range from 16 inches to 48 inches.
- Spans lengths from 30 feet to 90 feet.
- Spans may be simply supported or continuous over interior piers.

Cellular Box Bridges

- Cross sections comprised of a top slab, bottom slab, and two or more webs.
- Depths that vary from 3 feet to 10 feet.
- Span lengths ranging from 50 feet to 250 feet.
- Spans that are simply supported or continuous over interior supports.

Longitudinal post-tensioning typically consists of multi-strand tendons draped in a smooth, vertically curved profile. In continuous spans, the tendon profile drapes to the bottom of the section in the mid-span region and rises to the top of the section over interior supports. A draped profile of this type provides the most effective distribution of internal prestressing. Though tendons in these bridges are typically internal to the concrete, external tendons may also be used. Post-tensioning bars rather than strands are also used in some applications.

This volume provides direction for achieving more durable post-tensioned bridges by applying the Department's five strategies to the specifics of bridges that are cast-in-place on falsework.

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". 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 of the segment or at a match-cast joint. The three-levels of protection for these two cases are:

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

- At cast-in-place joint faces*:
  (1) Fully grouted tendon.
  (2) Effective continuity of the impervious plastic duct.
  (3) Concrete cover.

*Internal tendon ducts at joint faces protrude into next segment and are connected with sealed duct connectors.

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 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 or enclose the tendon within the hollow box girder. Refer to Strategy 4 "Watertight Bridges" below for these requirements. Also, in order to accommodate internal tendons, adopt recommended clearances, dimensions and details herein (Sections 1.13 and 1.14 below).

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:
  - 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 in the bridge. 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 in the bridge.

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 (Requirements 1.A, 1.B, 1.C, 1.D, 1.G)

External tendons may be used in cast-in-place hollow cellular box bridges. 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.
- Diabolo Deviators 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) for bridges cast-in-place on falsework. 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 Bridge Site, 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.
- 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.

  (* 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 and deviators.

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 (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).

Post-Tensioning Tendons For Bridges Cast-in-Place On Falsework – 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 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 6.1. 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).

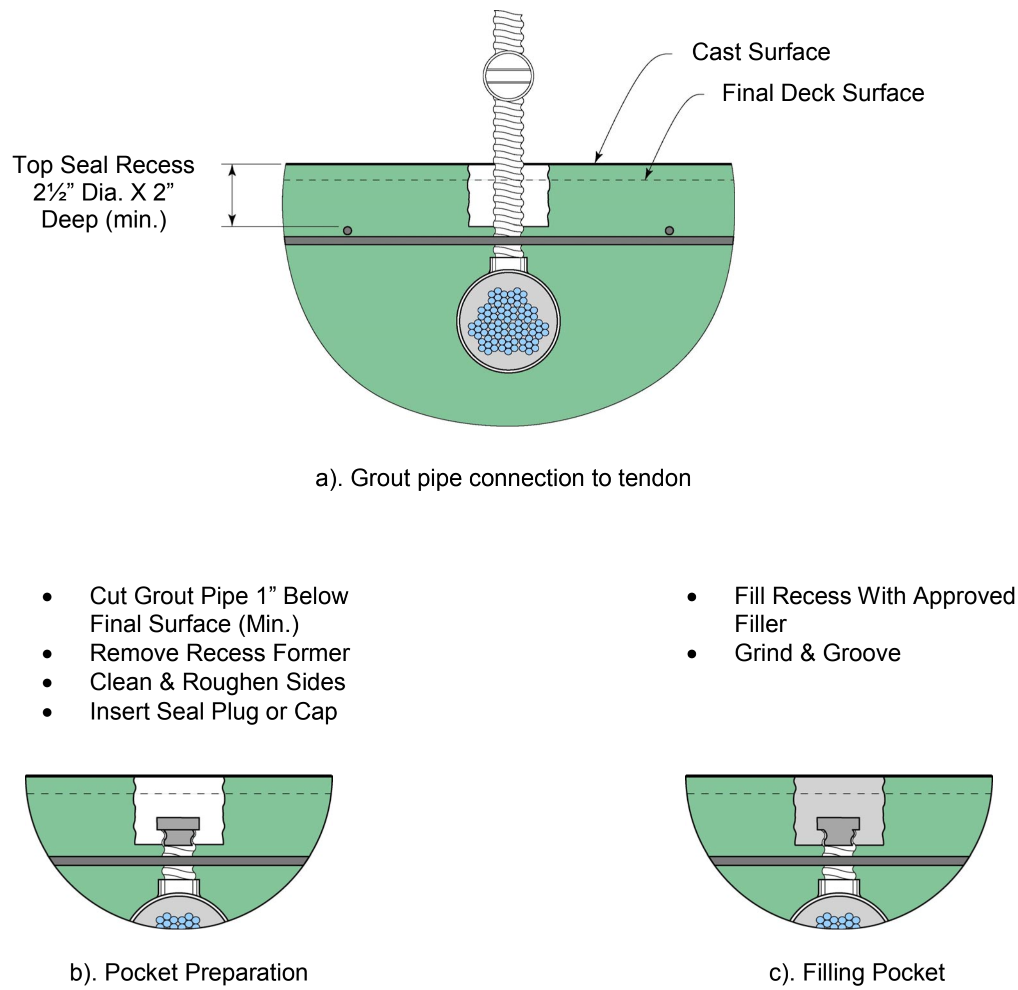


Figure 6.1 – Sealing grout ports and vents in top slabs.

1.13 Internal Tendons – Clearances, Dimensions, Details

(a) Spacing of Ducts and Web Widths (Requirement 1.B)

Solid Slab Bridges

Tendons are typically spaced 2' to 4' apart as a function of the bridge deck width and the loads being resisted. End anchors at expansion joints should be approximately at mid-depth of the slab.

Voided Slab Bridges

Tendons are usually inside the concrete in the webs between the voids (Figure 6.2). There may be one or more tendons per web. The center of gravity of the post-tensioning force at the end anchors should be positioned near the cross section centroid to minimize local end tensions. Other requirements for this type of structure include:

- Provide sufficient minimum clear distance between voids to accommodate vertical rebar (stirrups), largest O.D. of duct and a side cover to void former of at least 1.5 times the maximum size of aggregate. The minimum clear distance between voids and the duct shall be 2-½ inches when using circular voids.
- Web width shall also be dimensioned to include cover, rebar, duct sizes, spacing and ½ inch overall tolerance.
- For multiple draped tendons in web, ensure that minimum vertical clearance between ducts at any point along the tendon is at least 1.5 times the maximum size of the aggregate, but not less than 2 inches.

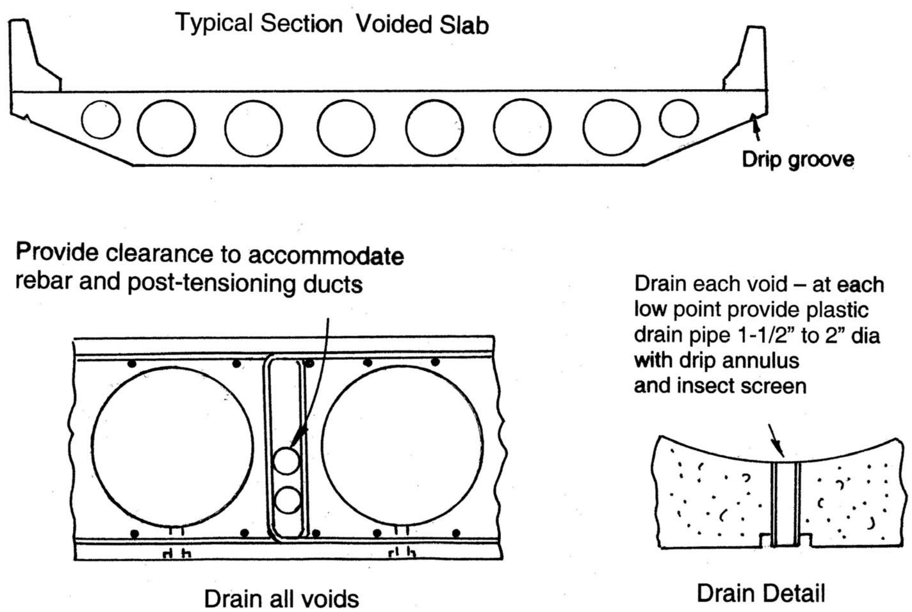


Figure 6.2 – Duct spacing and web widths in voided slab bridges

Cellular Box Bridges

Tendons are usually internal to the concrete and draped within the webs. There may be one or more draped tendons per web. In longer spans, tendons may also be placed in the top and bottom slabs. At the ends of spans, vertically space anchors so that the resultant force is approximately on the centroid of the section to minimize any local tension in top or bottom. Other requirements for this type of structure include:

- For a single, vertical row of ducts in web provide a web width of 3 times diameter of largest duct, or 12 inches whichever is the greater.

- For two or more ducts side by side in web provide a clearance of at least 3 inches between parallel (draped) ducts and a side cover to the nearest duct of one duct diameter or 3 inches whichever is the larger.
- Web width shall also be dimensioned to include cover, rebar, duct sizes, spacing and ½ inches overall tolerance.
- For multiple draped tendons in web, ensure that minimum vertical clearance between ducts at any point along the tendon is at least 1.5 times the maximum size of the aggregate, but not less than 2 inches.
- The gap between the outside of the duct and the side of the web needs to be adequate to allow concrete to pass during placement and to allow for use of stick type (poker) vibrators, if necessary. Allow at least 3 inches of clearance for inserting vibrators.

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

In order to support and maintain the integrity of the post-tensioning ducts, show the following information on the Contract Drawings:

Solid Slab Bridges

- Duct profile and minimum clearances.
- Duct supports – use at least #3 rebar or D4 wire tied to top and bottom mat at intervals of no more than 2 feet.
- Duct support bars may be straight, L, U, or Z-shape as necessary.
- Duct supports may be placed at any angle or slope as necessary.
- Appropriate cover requirements.

Voided Slab Bridges

- Duct profile and minimum clearances.
- Duct supports – use at least #3 rebar or D4 wire tied to top and bottom mat at intervals of no more than 2 feet.
- Duct support bars may be straight, L, U, or Z-shape as necessary.
- Duct supports may be placed at any angle or slope as necessary.
- Appropriate cover requirements.

Cellular Box Bridges

- Duct profile and minimum clearances.
- Duct supports – use at least #3 rebar or D4 wire tied to top and bottom mat.
- Provide duct supports at intervals of no more than 2 feet.
- Duct support bars may be straight, L, U, or Z-shape as necessary.
- Duct supports may be placed at any angle or slope as necessary.
- On curved layouts, provide lateral ties across ducts draped in webs (and check vertical web rebar) to control radial force effect from plan curvature as necessary. These bars may also serve as duct supports.
- Appropriate cover requirements.

(c) Space for Concrete Vibrators (Requirement 1.B)

Detail reinforcement to provide clearance for concrete aggregate and access for stick-type concrete vibrators in congested and heavily reinforced zones such as anchor blocks and diaphragms. Allow at least 3 inches clearance for inserting vibrators.

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

Refer to Volume 3, "Precast Segmental Span-by-Span Bridges" for recommended minimum dimensions and details for expansion joint segments and for segments containing deviators.

Strategy 2 – Fully Grouted Tendons

This strategy requires that all post-tensioning tendons in cast-in-place bridges on falsework 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 shall be accessible throughout all construction operations, up to and including the installation and grouting of permanent plastic grout caps.

In cast-in-place construction, anchors are usually enclosed by surrounding concrete or covered by a pour-back. Consequently, they are only accessible for inspection during construction. In cellular boxes, some tendons may anchor inside the hollow box and may be accessible for maintenance inspection.

Solid Slab Bridges

Anchors shall be accessible throughout construction, including tendon grouting and post-grouting inspections. Anchors are not typically accessible for maintenance inspection without removing pour-back concrete.

Voided Slab Bridges

Anchors shall be accessible throughout construction, including tendon grouting and post-grouting inspections. Anchors are not typically accessible for maintenance inspection without removing pour-back concrete.

Cellular Box Bridges

Anchors shall be accessible throughout construction, including tendon grouting and post-grouting inspections. Depending upon the size of the structure and cells, only limited access may be possible to interior anchors for maintenance. It will be necessary to remove seal and pour-back to exterior anchors to inspect.

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.

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, 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:

- 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.
- 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.

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.

Examples of application to internal tendons for bridges cast-in-place on falsework are given in Sections 2.7, 2.8 and 2.9 below.

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.

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.

Application of these requirements to different types of tendons in bridges cast-in-place on falsework is provided in Sections 2.7, 2.8 and 2.9 below.

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 on site (may be separate grouting plans).
- Qualifications and Certification of Grouting Personnel.
- 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).
- Embedded Face Anchors - extra precautions for grouting and sealing embedded face anchors (see 3.8 below).
- Means of pressure testing duct system for leaks and sealing as necessary.
- Sequence of injecting and evacuating grout for each tendon type.
- 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.

* Note: Provision for group grouting is necessary in the event of potential cross-flow between internal tendons. It is not likely to be needed for bridges cast-in-place on falsework. However, should it ever be necessary, refer to Volumes 2 or 5 for further details.

2.7 Grouting Procedure – Solid Slab (Requirements 2.B, 2.C, 2.E, 2.F, 2.G)

Figure 6.3 illustrates application for grouting a typical tendon in a solid slab ridge of three spans. Applying the above requirements to this example:

- Take into account longitudinal gradient and establish intended direction of grouting.
- Because the change in depth of the tendon profile is small (less than 18 inches) grout may be injected from end anchor (A).
- Provide outlet at end anchor (G).
- Orient both end anchors (A and G) so that grout injection and evacuation vent is at top.
- Even though the variation in duct profile may is shallow, provide drains at low points of duct path – (e.g. at B, D and F).
- Provide outlet vents at a point approximately 2 to 3 feet beyond high point crests in direction of grout flow – (e.g. at C and E).
- Grout may be injected from anchor A (at bottom) or at vent B.
- Provide drain vents at low points (B, D and F).
- Show direction of grouting.
- Show sequence of closing vents.

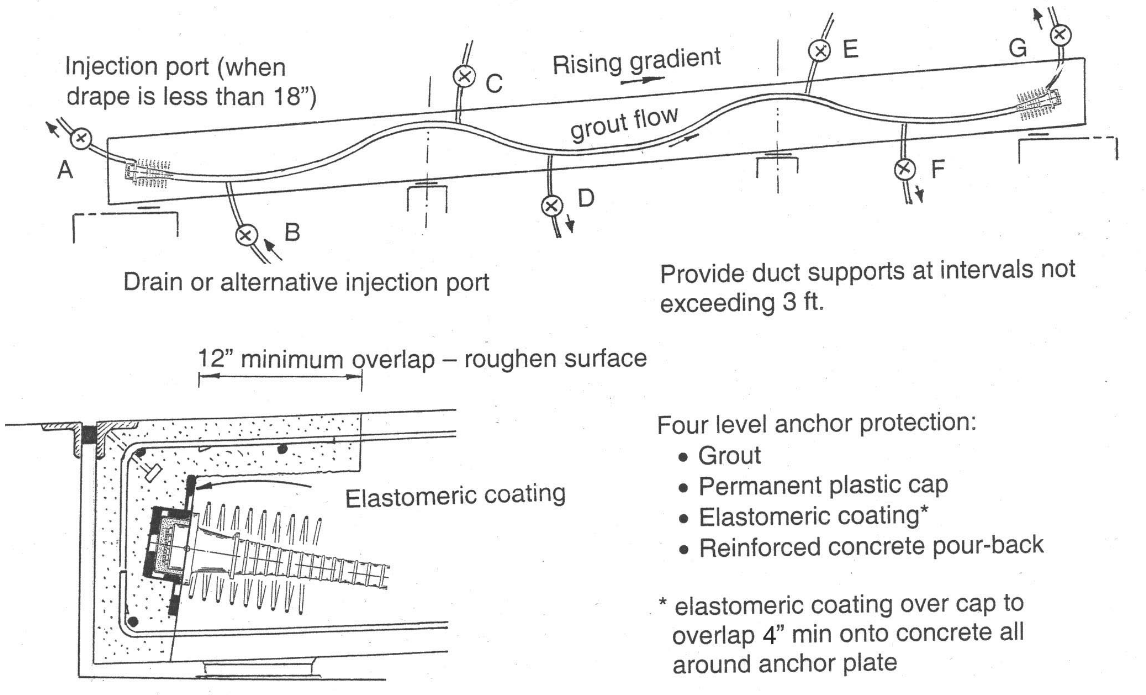


Figure 6.3 – Grouting tendons in solid slabs

After construction of the cast-in-place concrete superstructure, but prior to installation of post-tensioning tendons, the system should be blown out using clean, oil-free air and the ducts tested with a torpedo in accordance with the Standard Specifications. If satisfactory, post-tensioning tendons may then be installed and tensioned to force in the required sequence.

Grouting Operation

(1) Open all vents (C, E and G) and drains (B, D, and F) and check that there is no free water in the ducts – if there is, then blow out with oil free air.
(2) Close drains (B, D and F).
(3) Mix grout and perform QA/QC material field tests per specifications.
(4) Only because of the shallow profile, inject grout at end anchor (A).
(5) Inject grout at a steady rate in accordance with the Specifications.
(6) Allow air, excess water and grout to flow freely from crest vent (C) until consistency is satisfactory per specifications. Then close vent (C) and continue pumping at steady rate.
(7) Allow air, excess water and grout to flow freely from crest vent (E), until consistency is satisfactory consistency per specifications. Then close vent (E) and continue pumping at steady rate.

(8) Continue injecting and evacuating air, water and grout until consistent grout flows from last vent (G) at end anchor. Close vent (G).
(9) Pump to a pressure of 75 psi – hold for two minutes and check for grout leaks. If leaks are indicated by a reduced pressure then fix the leaks.
(10) If no leaks are present, reduce pressure to 5 psi for 10 minutes to allow entrapped air to flow to the high points.
(11) Open vent (C) to release any accumulated air or bleed water. If necessary, pump grout in again until grout flows consistently from vent (C). Then close vent (A). (Normally grouting pressures should be approximately 80 to 100 psi. Do not exceed a grouting pressure of 150 psi.)
(12) Open vent (E) to release any accumulated air or bleed water. If necessary, pump grout in again until grout flows consistently from vent (E). Then close vent (E).
(13) Repeat for last vent at end anchor (G). (Note – grout may be injected at any intermediate low-point – such as drains at (B, D, and F) – these must be fitted with vents for drainage and possible injection).
(14) Pump up pressure and lock off at 30 psi.
(15) Allow grout to take an initial set.
(16) Probe each vent - for any vents not completely filled, or where nearby voids are suspected, implement vacuum-assisted, secondary grouting of unfilled zones. (Refer to "Secondary, Vacuum Assisted Grouting" - below.)
(17) After completion of both primary and secondary grouting (if implemented) of tendons, seal all grout injection ports, grout outlet vents and drain vents. (See "Sealing of Grout Ports, Vents and Drains".)

2.8 Grouting Procedure – Voided Slab (Requirements 2.B, 2.C, 2.E, 2.F, 2.G)

Figure 6.4 illustrates application for grouting a typical tendon in a voided slab of three spans. Applying the above requirements to this example:

- Take into account longitudinal gradient and establish intended direction of grouting.
- Because the change in depth of the tendon profile in a voided slab bridge may be significant (greater than 20 inches), grout must be injected from low point. If two or more low points are at same elevation, then select one as injection point.
- Provide outlet vents at end anchors (A and I).
- Orient end anchors (A and I) so that grout outlet vent is at top – show a detail.
- Provide outlet vents at high point crest of profile, allowing for grade – (i.e. at C and F).
- Provide outlet vents at point approximately 3 to 6 feet beyond crests in direction of grout flow – (e.g. at D and G).
- Determine which location is at lowest point of profile and show injection vent (in this example, point B).
- Provide drain vents at other low points (E and H).
- Show direction of grouting.
- Show sequence of closing vents.

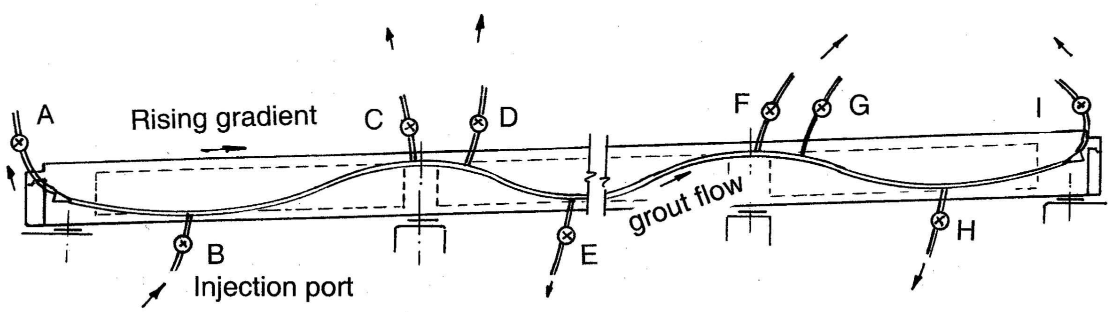


Figure 6.4 – Grouting voided slab tendons

After cast-in-place construction, but prior to installation of post-tensioning tendons, the system should be blown out using clean, oil-free air and the ducts checked tested with a torpedo per Specifications. If satisfactory, post-tensioning tendons can be installed and tensioned to force in the specified sequence.

Grouting Operation

(1) Open all vents and drains (B, E, and H) and check that there is no free water in the ducts – if there is, then blow out with oil free air.
(2) Choose lowest point of tendon (if two low points are at equal elevations, then select one (B) and but leave others (E and H) open.
(3) Mix grout and perform QA/QC material field tests per specifications.
(4) Inject grout at selected port (i.e. point B).
(5) Inject grout at a steady rate in accordance with the Specifications.
(6) Allow air, excess water and grout to flow freely from end anchor vent (A) until consistency is satisfactory per specifications. Then close vent (A) and continue pumping at steady rate.
(7) Allow air, excess water and grout to flow freely from vent (C), at crest at a satisfactory consistency per specifications. Then close vent (C) and continue pumping at steady rate.
(8) Allow air, water and grout to flow from vent (D), on downstream side of crest, until consistency is satisfactory per specifications. Then close vent (D) and continue pumping at steady rate. (Note – at this time, it may be necessary to evacuate grout at vent (E), (step 9) and close vent (E) in order to fill duct between (D) and (F) before consistent grout flows from vent (D)).
(9) Allow air, water and grout to flow from vent (E) until consistency is satisfactory per specifications. Then close vent (E) and continue pumping at steady rate.
(10) Continue pumping and allow air, excess water and grout to flow from drain vent (F) until consistency is satisfactory per specifications. Then close vent (F) and continue pumping at steady rate.
(11) Repeat for vent (G). (Note – at this time, it may be necessary to evacuate grout at vent (H), (step 12) and close vent (H) in order to fill duct between (G) and (I) before consistent grout flows from vent (G).)

(12) Continue pumping and allow air, water and grout to flow from vent (H) until consistency is satisfactory per the specifications. Then close vent (H) and continue pumping at a steady rate.
(13) Continue injecting and evacuating air, water and grout until consistent grout flows from last vent (I) at end anchor. Close vent (I).
(14) Pump to a pressure of 75 psi – hold for two minutes and check for grout leaks. If leaks are indicated by a reduced pressure then fix the leaks.
(15) If no leaks are present, reduce pressure to 5 psi for 10 minutes to allow entrapped air to flow to the high points.
(16) Open vent (A) to release any accumulated air or bleed water. If necessary, pump grout in again until grout flows consistently from vent (A). Then close vent (A). (Normally grouting pressures should be approximately 80 to 100 psi. Do not exceed a grouting pressure of 150 psi.)
(17) Open vent (C) to release any accumulated air or bleed water. If necessary, pump grout in again until grout flows consistently from vent (C). Then close vent (C).
(18) Repeat - checking each vent in turn (D, F, G, and I).
(Note – grout may be injected at any intermediate low-point – such as drains at (E, and H) – these must be fitted with vents for drainage and possible injection).
(19) Pump up pressure and lock off at 30 psi.
(20) Allow grout to take an initial set.
(21) Probe each vent - for any vents not completely filled, or where nearby voids are suspected, implement vacuum-assisted, secondary grouting of unfilled zones.
(Refer to "Secondary, Vacuum Assisted Grouting" – below).
(22) After completion of both primary and secondary grouting (if implemented) of tendons, seal all grout injection ports, grout outlet vents and drain vents. (See "Sealing of Grout Ports, Vents and Drains").

2.9 Grouting Procedure – Cellular Box (Requirements 2.B, 2.C, 2.E, 2.F, 2.G)

Figure 6.5 illustrates application for grouting a typical tendon of a cellular box of three spans. Applying the above requirements to this example:

- Take into account longitudinal gradient and establish intended direction of grouting.
- Orient end anchors (A and I) so that grout injection and evacuation vent is at top.
- Determine which location is at lowest point of profile and show injection vent (in this example, point B. If two or more low points are at same elevation, then select one as injection point.
- Provide vents at each crest (C and F) and at 3 to 6 feet (1 to 2m) beyond crest (D and G) in direction of grouting.
- Provide drain vents at other low points (E and H).
- Provide grout outlet vent at end anchor (I).
- Show direction of grouting.
- Show sequence of closing vents.

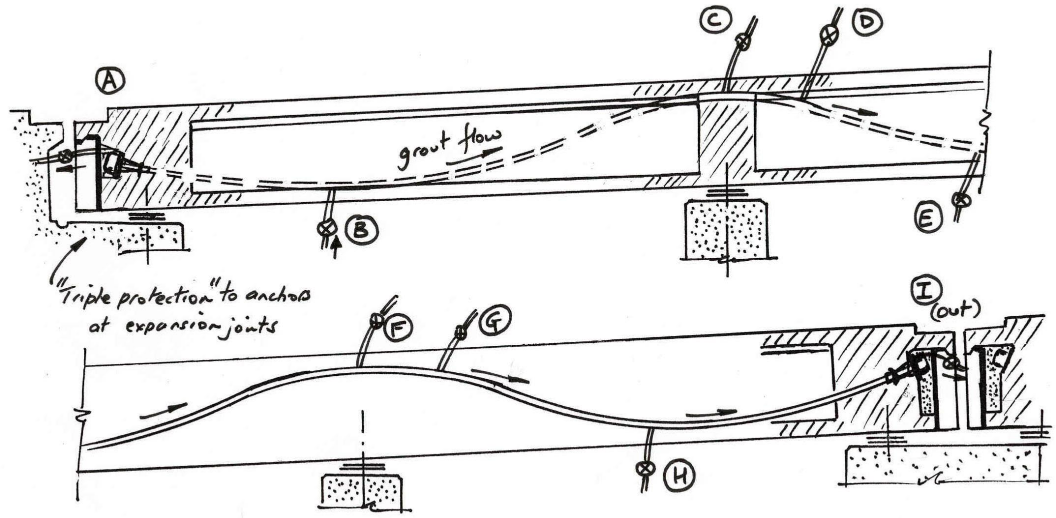


Figure 6.5 – Grouting cellular box girder tendons

After cast-in-place construction, but prior to installation of post-tensioning tendons, the system should be blown out using clean, oil-free air and the ducts checked tested with a torpedo per Specifications. If satisfactory, post-tensioning tendons can be installed and tensioned to force in the specified sequence.

Grouting Operation

(1) Open all vents and drains (B, E, and H) and check that there is no free water in the ducts – if there is, then blow out with oil free air.
(2) Choose lowest point of tendon (if two low points are at equal elevations, then select one (B) and but leave others (E and H) open.
(3) Mix grout and perform QA/QC material field tests per specifications.
(4) Inject grout at selected port (i.e. point B).
(5) Inject grout at a steady rate in accordance with the Specifications.
(6) Allow air, excess water and grout to flow freely from end anchor vent (A) until consistency is satisfactory per specifications. Then close vent (A) and continue pumping at steady rate.
(7) Allow air, excess water and grout to flow freely from vent (C), at crest at a satisfactory consistency per specifications. Then close vent (C) and continue pumping at steady rate.
(8) Allow air, water and grout to flow from vent (D), on downstream side of crest, until consistency is satisfactory per specifications. Then close vent (D) and continue pumping at steady rate. (Note – at this time, it may be necessary to evacuate grout at vent (E), (step 9) and close vent (E) in order to fill duct between (D) and (F) before consistent grout flows from vent (D).)

(9) Allow air, water and grout to flow from vent (E) until consistency is satisfactory per specifications. Then close vent (E) and continue pumping at steady rate.
(10) Continue pumping and allow air, excess water and grout to flow from drain vent (F) until consistency is satisfactory per specifications. Then close vent (F) and continue pumping at steady rate.
(11) Repeat for vent (G). (Note – at this time, it may be necessary to evacuate grout at vent (H), (step 12) and close vent (H) in order to fill duct between (G) and (I) before consistent grout flows from vent (G).)
(12) Continue pumping and allow air, water and grout to flow from vent (H) until consistency is satisfactory per the specifications. Then close vent (H) and continue pumping at a steady rate.
(13) Continue injecting and evacuating air, water and grout until consistent grout flows from last vent (I) at end anchor. Close vent (I).
(14) Pump to a pressure of 75 psi – hold for two minutes and check for grout leaks. If leaks are indicated by a reduced pressure then fix the leaks.
(15) If no leaks are present, reduce pressure to 5 psi for 10 minutes to allow entrapped air to flow to the high points.
(16) Open vent (A) to release any accumulated air or bleed water. If necessary, pump grout in again until grout flows consistently from vent (A). Then close vent (A). (Normally grouting pressures should be approximately 80 to 100 psi. Do not exceed a grouting pressure of 150 psi.)
(17) Open vent (C) to release any accumulated air or bleed water. If necessary, pump grout in again until grout flows consistently from vent (C). Then close vent (C).
(18) Repeat - checking each vent in turn (D, F, G, and I). (Note – grout may be injected at any intermediate low-point – such as drains at (E, and H) – these must be fitted with vents for drainage and possible injection.)
(19) Release pump pressure, then pump up to 75 psi and hold for two minutes, then gradually release pressure by venting the ducts (repeating steps 15, 16 and 17) and lock off at 30 psi.
(20) Allow grout to take an initial set.
(21) Probe each vent - for any vents not completely filled, or where nearby voids are suspected, implement vacuum-assisted, secondary grouting of unfilled zones. (Refer to "Secondary, Vacuum Assisted Grouting" – below).
(22) After completion of both primary and secondary grouting (if implemented) of tendons, seal all grout injection ports, grout outlet vents and drain vents. (See "Sealing of Grout Ports, Vents and Drains").

2.10 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 6.6 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".)

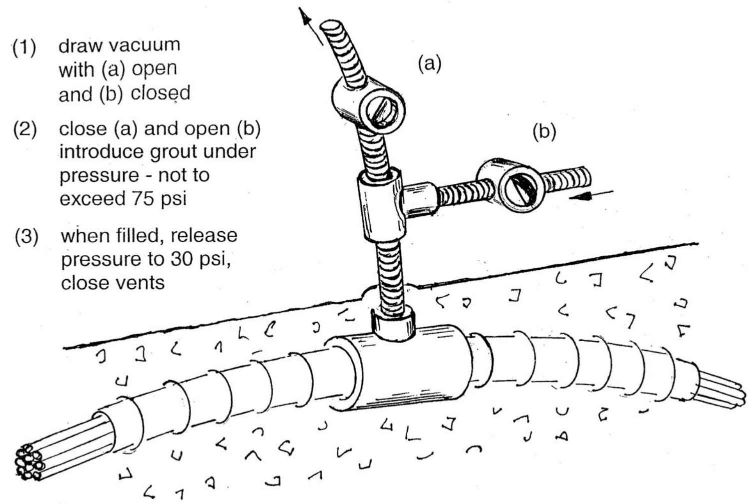


Figure 6.6 – Details of Vacuum Grouting Connections

Strategy 3 – Multi-Level Anchor Protection

Significant corrosion of post-tensioning tendons has resulted from lack of adequate protection at anchorages. Many early balanced cantilever bridges have top slab cantilever tendons anchored on the end faces of the segments (i.e. "face anchors"). These anchors required block-outs, typically extending to the roadway surface, to provide access for grouting. The block-outs were then filled with concrete, burying the anchor. Shrinkage of the pour-back concrete often led to separation of this concrete from the superstructure concrete, leaving the anchors susceptible to leaks and potential corrosion.

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 cast-in-place construction on falsework 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 the cast-in-place superstructue 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 the bridge site.

- CEI - verify that materials and components comply with contract requirements. Check and record submittals, test reports, component deliveries and installation at the 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.

Specific requirements for installation are addressed in Sections 3.5 through 3.8, below.

3.5 Anchors in Ends of Solid and Voided Slabs (Requirements 3.A, 3.B, 3.C)

Where the deck slab concrete or pour-back containing embedded anchors is directly exposed to windborne spray and water, the four levels of anchor protection comprise:

Detail 1 – For an accessible, individual anchor:

- Grout.
- Permanent plastic grout cap.
- Encapsulating pour-back of epoxy grout.
- An approved sealer coat.

Detail 2 – For an accessible individual anchor or a group of anchors:

- Grout.
- Permanent plastic grout cap.
- Pour-back of high strength, high bond, low shrink, air-cured concrete.
- Seal with Methyl Methacrylate.

Detail 3 – For a group of anchors in a continuous recess (Figure 6.3)

- Grout.
- Permanent plastic grout cap.
- Elastomeric seal coat.
- Encapsulation in reinforced concrete pour back.

Solid Slab Bridges and Voided Slab Bridges are typically too thin to detail expansion joint block-outs separate from block-outs required for the longitudinal post-tensioning tendon anchors. For these bridges, it is appropriate to detail one block-out for both the expansion joint and end anchors (Figure 6.3). However, once the pour-back is made the anchors are no longer accessible for inspection and tendons cannot be replaced. As a result, the tendon must be grouted, inspected and sealed before the pour-back is cast.

Specific requirements for anchors at ends of solid and voided slabs:

- 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.
- Anchors placed in a recess in-board from end face to provide at least 4 inches end cover over the end of the permanent plastic cap.
- Cover from anchor recess to other surfaces is at least equal to rebar cover.
- For individual anchor recesses, provide at least 3 inches of structural concrete cover to the top surface of the slab.
- For a group of anchors, provide a large single encapsulating pour-back, with a step-back detail to avoid a direct water path to anchor per Figure 6.3.
- Make finished surface even with adjacent structural concrete.
- For a group of anchors, provide reinforcing to enclose anchor and secure any expansion joint angles or hold-down devices as necessary.
- All concrete surfaces of single or group recesses to be cleaned, properly roughened and prepared prior to casting pour-back material.
- For an accessible individual anchor: (Detail 1) - First, recess is completely filled with an approved material (epoxy grout) to encapsulate the anchor and plastic cap. Then, end face of finished surface is coated with an approved sealer.
- For an accessible, individual anchor or a group of anchors: (Detail 2) - First the enclosing pour-back of high bond, no-shrink, air-cured concrete is placed full width across deck to encapsulate anchors, reinforcement and any fixing devices for expansion joints. Then an approved sealer (methyl-methacrylate) is applied to the top surface of pour-back and construction joint.
- For a group of anchors in a continuous recess (Figure 6.3): (Detail 3) – First an elastomeric seal coat is applied to the cap and anchor for a distance of 4" around edge of cap. Then enclosing pour-back of normal structural, reinforced concrete is placed full width across deck to encapsulate anchors, reinforcement and any fixing devices for expansion joints.

3.6 Anchors Inside Hollow Cellular Boxes - (Requirements 3.A, 3.B, 3.C)

Typical anchor locations that fall into this category include (Figure 6.7):

- Anchors in blisters typically at the intersection of the web with the top or bottom slab.
- Anchors in interior diaphragms or deviator ribs.
- Face-anchors in recesses permanently open to the interior hollow core.

Provided that the structure is sealed from leaks through the bridge deck 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.

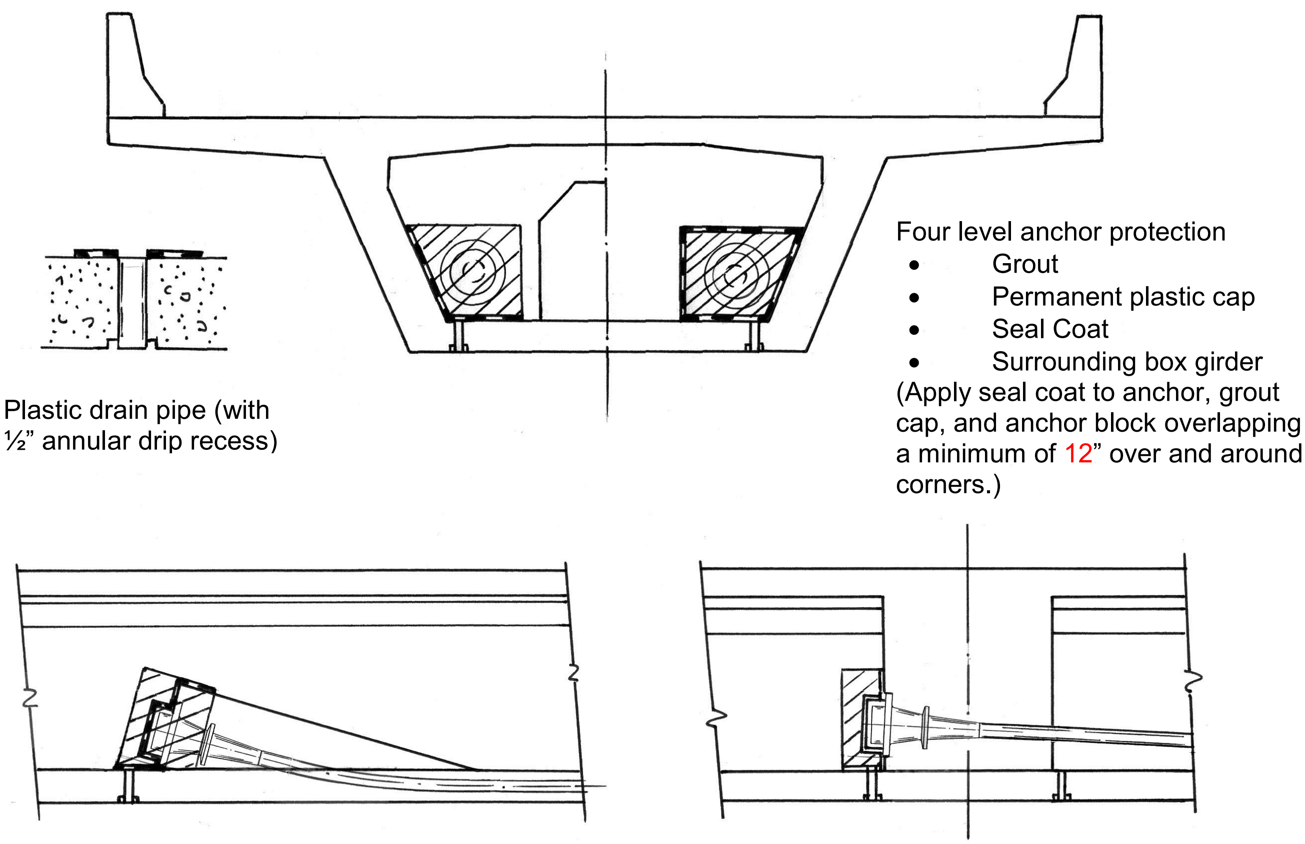


Figure 6.7 – Anchor protection for anchors inside a hollow cellular box girder

3.7 Anchors At Expansion Joints of Hollow Cellular Boxes - (Requirements 3.A, 3.B, 3.C)

At expansion joints where an anchor or concrete containing anchors is directly exposed to windborne spray and water the four levels of anchor protection are (Figure 6.8):

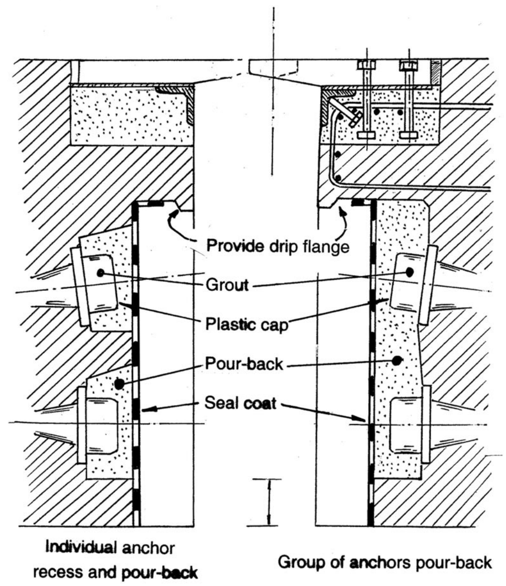
- Grout.
- Permanent grout cap.
- Encapsulating pour-back.
- Elastomeric seal coat.

Particular requirements for anchors at expansion joints:

- 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 be even with adjacent face of diaphragm or anchor block.
- For a group of anchors, similar individual recesses or, a single enclosing pour-back to encase all anchors in the group.
- A single enclosing pour-back shall be secured to concrete substrate with embedded reinforcement (screw coupled rebar may be used) in order to ensure bond.
- 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.
- An approved elastomeric seal coating (per FDOT QPL) be applied over the pour-back overlapping onto adjacent structural concrete by a minimum of 12 inches all around.

Also, protect anchors from dripping water at expansion joints. (Note - a drip flange provides a positive, protective edge for the top of the seal coat.)

In coastal areas, consider providing additional protection by means of skirts or baffles at expansion joints to minimize the direct effect of wind borne spray. Typical details for anchor protection at expansion joints is shown in Figure 6.8.



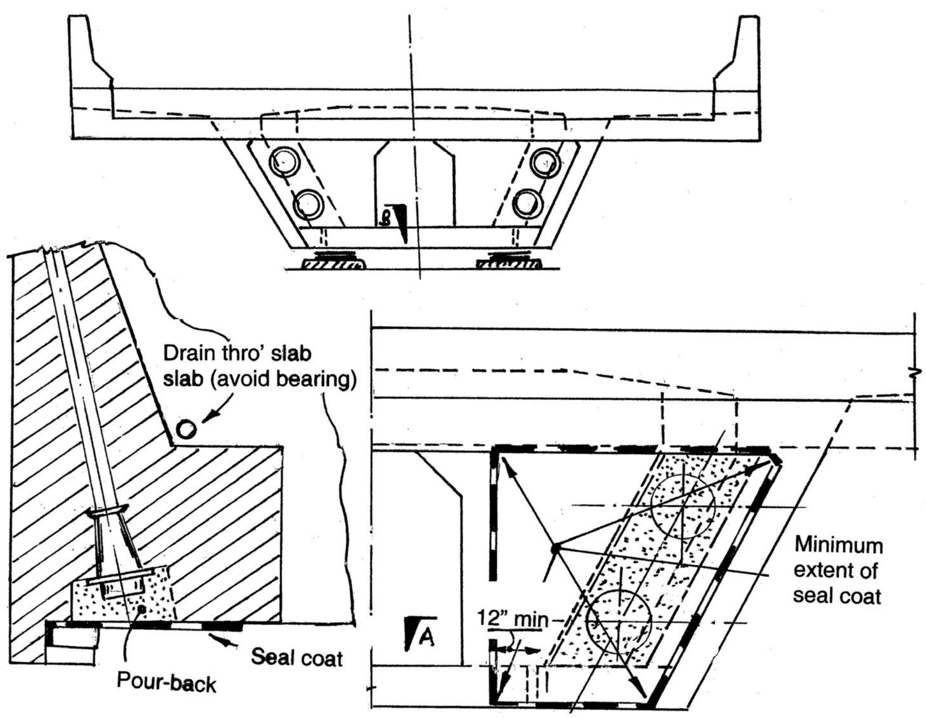


Figure 6.8 – Anchor protection at expansion joints.

3.8 Embedded Face Anchors (Requirements 3.A, 3.B, 3.C)

Embedded face anchors are rarely used in cast-in-place construction on falsework. However, should the need arise, refer Volume 3, "Design and Construction Inspection of Precast Segmental Span-by-Span Bridges.

3.9 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 bridge decks of post-tensioned bridges be watertight. A watertight structure is the first line of defense against attack by corrosive agents.

4.1 Cast-in-Place (cold) Joints (Requirements 4.A, 4.D and 1.B)

Construction joints in bridges cast-in-place on falsework are continuously reinforced with post-tensioning tendons passing through the joints in continuous plastic ducts. Prepare and roughen all joint faces in accordance with the specifications prior to further casting.

4.2 Forming and Filling Temporary Holes in Slabs (Requirements 4.C and 4.D)

Avoid placing holes where leaks would drip directly onto anchor heads and, as far as possible, onto post-tensioning inside hollow cellular boxes. Where possible, locate temporary holes for frames, devices or equipment attachments outboard of webs in the cantilever wings. 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 through Top Slabs:

(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. diaphragms) –make appropriate allowance and adjust details for local geometry, super-elevation, grade and possible interference with other components or tendons.

4.3 Temporary Access Holes – Cellular Boxes (Requirements 4.C and 4.D)

In cast-in-place construction, temporary access holes (manholes) are often needed through slabs for removing heavy or large pierces of essential equipment. Usually these access holes are placed at mid-span closures or similar suitable locations and are typically sized to accommodate pieces of equipment, such as stressing jacks, and should be at least 2'-6" diameter, square or rectangular up to approximately 2'-6" by 3'-6". 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.

Requirements for temporary access holes (manholes):

- Allow one access hole per span per cell in top or bottom slab.
- Locate to avoid tendons and anchors.
- Locate to avoid possibility for water to drip onto anchors or components.
- Locally design transverse post-tensioning and mild reinforcement to accommodate access hole.
- Reinforce pour-back to hole with spliced and / or screw-coupled rebar.
- Provide tapered sides all around with top of manhole larger than bottom.
- Sides to be thoroughly cleaned and roughened.
- Sides to be free of dirt, debris, grease and oil prior to filling.
- Fill with an approved no-shrink, high-bond, high-strength, air-cured concrete or grout.
- On the top slab, seal with an approved sealer (e.g. methyl methacrylate). A seal is not required when epoxy grout is used.
- On the bottom slab, seal with approved elastomeric coatings (to FDOT QPL).

4.4 Expansion Joint Recess and Seat – Cellular Boxes (Requirements 4.C and 4.D)

At expansion joints it is necessary to provide a recess and seat across the segment to receive the assembly, anchor bolts and frames of the expansion joint device. In the past, block-outs have been made in these seats to provide access for stressing jacks of anchors located high in the diaphragm. These block-outs are a source of leaks during and after construction.

Expansion joint recesses and seats for new construction shall contain no block-outs (See Figure 6.8). Lower the upper tendon anchors and re-arrange the anchor layout as necessary to provide access for the stressing jacks. It is unlikely that this will result in any significant loss of tendon eccentricity or structural efficiency. Responsibilities regarding expansion joint recesses and seats include:

- Designer – select and show required expansion joint details on Contract Drawings.
- Contractor - construct expansion joint device recesses and seats in accordance with the details on the Contract Drawings or the approved Shop Drawings.
- CEI - check there are no block-outs or penetrations of the expansion joint recess and seat, that it is constructed correctly and cast monolithically.

4.5 Drip Notches and Flanges – Cellular Boxes - (Requirement 4.F)

Even though protected by expansion joint glands or drainage troughs, water can leak into the recesses and seats. It can then seep behind pour-backs into anchorages. To prevent this, provide flanges on the underside of the transverse seat for the expansion joint so that any leaking water cannot flow back under the slab and behind seal coats or pour-backs. Responsibilities regarding drip notches and flanges include:

- Designer - on the Contract Drawings show details and locations for drip notches or flanges where water may directly flow to any component of the post-tensioning system.
- Contractor - construct drip notches or flanges in accordance with the details on the Contract Drawings or the approved Shop Drawings.
- CEI - check that drip notches and flanges are correctly installed.

4.6 Void and Cell Drains – (Requirement 4.G)

Voided Slabs and Cellular Boxes

Provide drains through bottom slab in voids and cells to prevent water that enters from any source, including condensation, from ponding in the vicinity of post-tensioning components (Figure 6.7). Responsibilities regarding void and cell 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:

- Use 2-inch diameter permanent plastic pipes set flush with the top of the bottom slab.
- Provide a small drip recess, ½ inch by ½ inch around bottom of pipe insert.
- Provide at all low-points against internal barriers.
- To avoid confusion, provide drains on both sides of box, regardless of cross-slope.
- Show locations and details for drains taking into account bridge grade and cross-slope.
- Provide same drain details at internal barriers created by barriers introduced as a consequence of the Contractor's chosen means and methods of construction.

Strategy 5 – Multiple Tendon Paths

5.1 Multiple Tendon Paths

Solid Slab Bridges (Requirement 5.A)

Requirements for multiple tendon paths include:

- Provide post-tensioning load path redundancy by distributing tendons across the width of the bridge.
- Do not use a tendon size greater than 9-0.6 inch diameter strands or 12-0.5 inch diameter strands.
- Select maximum size of tendon so that the loss of an individual longitudinal tendon does not result in the loss of more than 15% of the total longitudinal force at any section.

Voided Slab Bridges (Requirement 5.A)

Requirements for multiple tendon paths include:

- Provide post-tensioning load path redundancy by distributing tendons across the width of the bridge.
- Do not use a tendon size greater than 12-0.6 inch diameter strands or 17-0.5 inch diameter strands.
- Ensure that webs are sufficiently wide to accommodate ducts, rebar, cover etc.
- Provide a minimum of 2 (internal) individual tendons per web between voids.

Cellular Box Bridges (Requirements 5.A)

Requirements for multiple tendon paths include:

- For single cell boxes (2 webs) provide a minimum of 4 tendons per web.
- For two or more cell boxes (3 or more webs) provide a minimum of 3 individual tendons

per web of box.

- Do not use a tendon size greater than 19-0.6 inch diameter strands or 27-0.5 inch diameter strands.

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

In the top slab of cast-in-place solid slabs, voided slabs and cellular box girder bridges, the grout, duct and concrete cover afford corrosion protection. Also, continuous, longitudinal mild steel reinforcing over the piers and in the bottom mid-span regions contributes to internal redundancy. As a result, no extra post-tensioning to compensate for the possible loss of tendons to corrosion need be installed at the time of construction.

However, because internal, bonded tendons are not replaceable, these types of bridges shall satisfy the following requirements:

- Consider the long-term condition only – i.e. after all normal PT losses, shrinkage and creep redistribution have occurred (i.e. “day 4000”).
- Consider only the section over each interior pier.
- For each of these sections 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.
- Place required mild reinforcing symmetrically over each interior pier so that it is fully developed in each direction for a distance of at least 15 percent of the span length.
- Verify that sections of maximum positive moment (e.g. midspan) satisfy the above conditions for redistribution of load due to the assumed loss of prestress at the pier.

5.3 Provisional Post-Tensioning (Requirement 5.C)

Unless directed by the Department, do not make detail solid and voided slab bridges with provisions for future post-tensioning. For cellular box girder bridges, provide superstructure with details to accommodate straight or draped, external tendons for future strengthening or rehabilitation in accordance with the AASHTO – LRFD Specification, Paragraph 5.14.2.3.8c. However, make the details such that the 10 percent provisional prestressing force (of all permanent tendons) closely follows the center of gravity of the final post-tensioning force in the completed structure after all long-term effects.

5.4 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.