Florida Department of Transportation

New Directions for Florida Post-Tensioned Bridges

Volume 4 of 10: Design and Construction Inspection of Precast Concrete Spliced I-Girder Bridges

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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 (FDOT) will be changing policies and procedures to ensure the long-term durability of post-tensioning tendons. The recommendations of the Consultant for revising 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 4 – Design and Construction Inspection of Precast Concrete Spliced-I Girder Bridges

Contents

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.

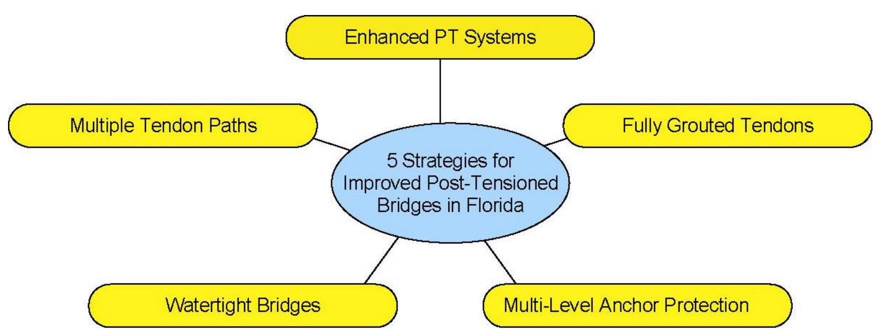

Figure 1.1 – Five-part strategy for more durable post-tensioned bridges in Florida.

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 4 – Precast Concrete Spliced I-Girder Bridges

Precast post-tensioned concrete girders typically have a Bulb-T or modified AASHTO I-girder cross section. Girders are prefabricated and pre-tensioned with a sufficient number of strands to be self-supporting for delivery and erection in the bridge. Post-tensioning ducts for the internal draped continuity tendons are installed at the precast yard. Precast I-girders and Bulb-T's are erected and spliced together in a three basic configurations:

Configuration (1)

Partial span length AASHTO I-girders are placed end to end with a cast-in-place splice between each girder segment. Splices are typically made in each span of the bridge and over each interior pier. This configuration is typically used for two-span highway crossings to eliminate piers near the outside shoulders. A temporary tower is required in each span to facilitate erection.

Configuration (2)

Full span length Bulb-T or Modified AASHTO I-girders span from pier to pier and are connected by cast-in-place splices over each interior pier. This configuration is mostly used for long, multiple-span bridges over water.

Configuration (3)

Partial span length Bulb-T or Modified AASHTO I-girders combined with variable depth precast, cantilever girders of similar shape are used in cantilever and suspended (drop-in) span construction. Splices are made in each span between the constant depth and variable depth girder segments. This configuration is mostly used for three-span main span units of major water crossings. Temporary towers are required in the side spans to facilitate erection.

Staged post-tensioning

In each of these configurations, the precast I-girder is pre-tensioned to carry, at a minimum, its own self weight. Post-tensioning, that is typically stressed in two stages, is used to carry the deck slab, barrier rails and other superimposed dead loads along with the live loads. First stage post-tensioning is typically stressed after the cast-in-place splices have been made, but before the deck slab is cast. The deck slab is then cast and cured (usually in a specific sequence of pours to minimize deck cracking) and the second (final) stage of post-tensioning is installed and stressed.

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

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.

Tendons for spliced I-girders and bulb-T's are internal to the concrete. End anchors, usually at expansion joints, are exposed to direct affects of the weather or wind-blown salt spray and must be protected accordingly.

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, 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". Post-tensioning tendons in spliced I-girder construction are internal. The required three levels of protection are:

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

- At splice joints:
  (1) Fully grouted tendon.
  (2) Sealed splice connection of the impervious plastic duct.
  (3) Concrete cover.

The first level of protection, Level (1), is provided by filling the tendons full of 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 duct for internal tendons. The ducts shall be corrugated plastic (per Specifications) with positively sealed connections (See Section 1.4).

Concrete cover provides the third level of corrosion protection (Level (3)). In addition use recommended clearances, dimensions and details provided in this document for detailing spliced I-girders with internal tendons.

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 Specifications and/or FDOT "Qualified Products List" (QPL). These include, but are not limited to, PT 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 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.

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

External tendons are not normally used in spliced I-girder construction. Refer to Volume 3 “Design and Construction Inspection of Precast Segmental Span-by-Span Bridges” for specific requirements when using external tendons for repair or future strengthening.

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 precast components. 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 when making cast-in-place splices at the Bridge Site, installation shall include but not be limited to:

Ducts For Internal Tendons:

During fabrication ensure that ducts are:

- Installed to correct profile (line and level) within specified tolerances.
- Tied and correctly supported at frequent intervals (Figures 4.1 and 4.2).
- Connected with positively sealed couplings between pieces of duct and between ducts and anchors – within girders and within cast-in-place joints or splices*.
- Aligned with sealed couplers at temporary bulkheads.

During erection make sure that:

- Internal ducts have positively sealed connections* at cast-in-place spliced joints.

  (* 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 (Figures 4.3, 4.4, 4.5).
- 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 – sealed epoxy joints are not normally used in spliced I-girder construction – if necessary, refer to Volume 2, "Design and Construction Inspection of Precast Segmental Balanced Cantilever Bridges".

Post-Tensioning Tendons For Spliced I-Girder Bridges – 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 or cast-in-place concrete, check that the strength is satisfactory for stressing.
- At cast-in-place splices, concrete attains the required minimum strength before stressing 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.

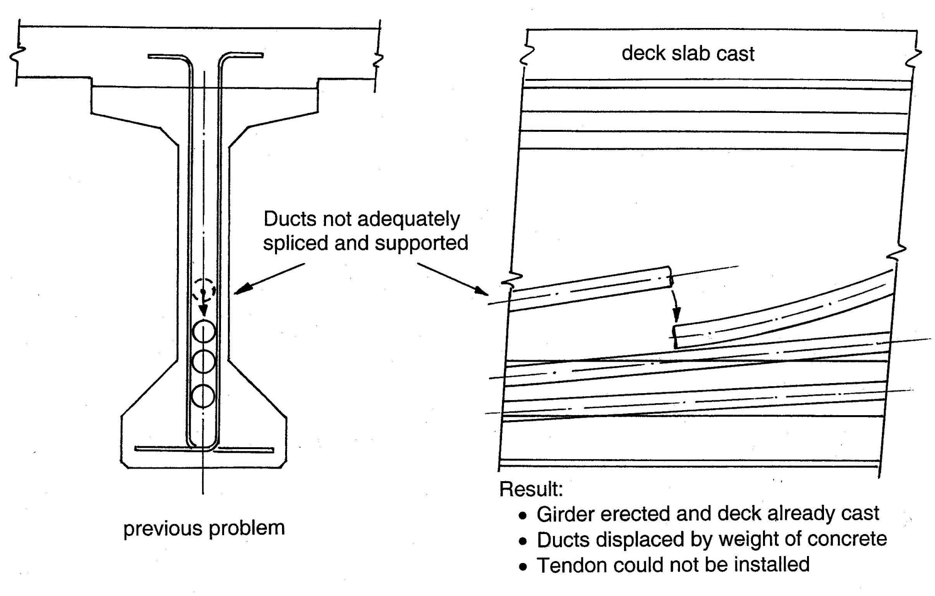

Figure 4.1 - Duct connections in post-tensioned girders

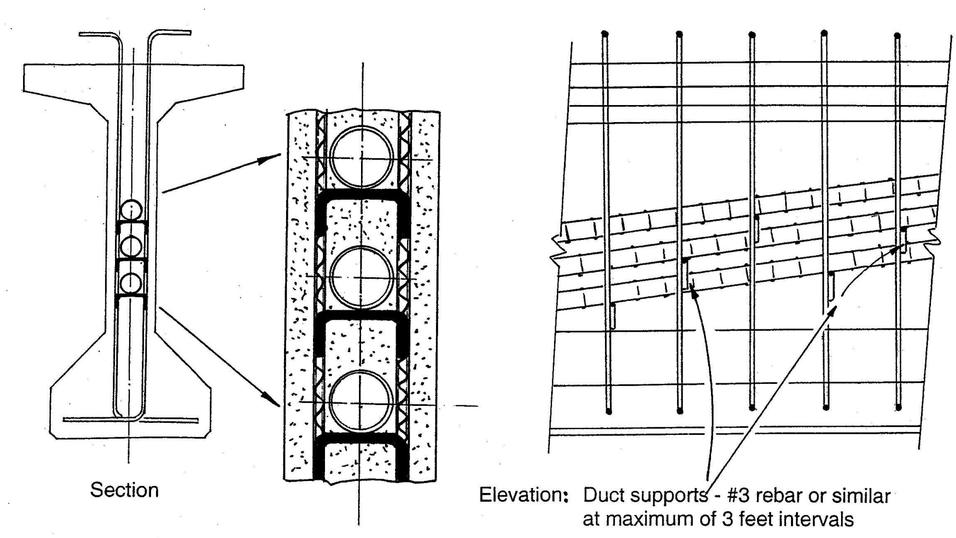

Figure 4.2 - Duct supports in post-tensioned girders

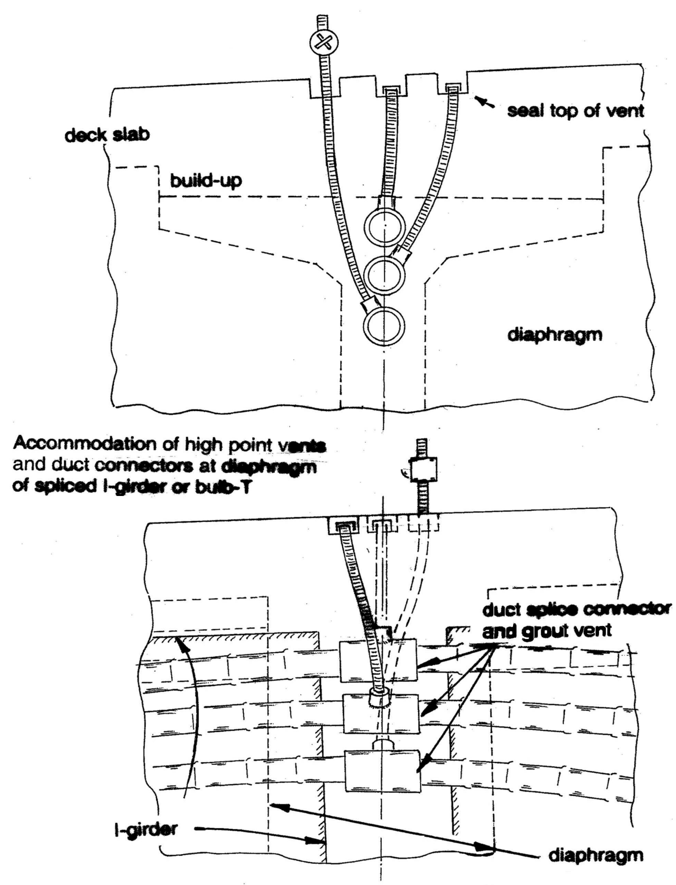

Figure 4.3 - High point vents in continuous post-tensioned girders

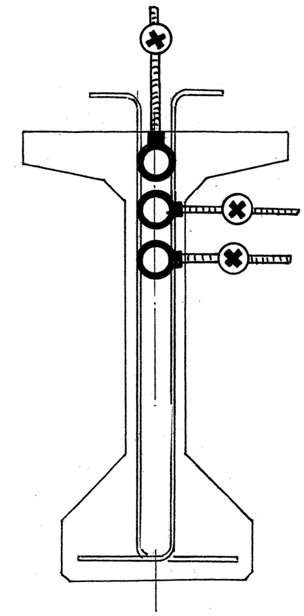

Figure 4.4 - High point vents in spliced post-tensioned girders

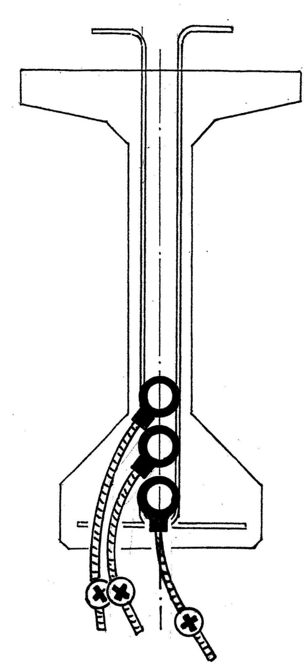

Figure 4.5 - Low point injection ports and drains in post-tensioned girders

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. Responsibilities regarding sealing of grout ports, vents and drains include:

- 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 4.6. 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).

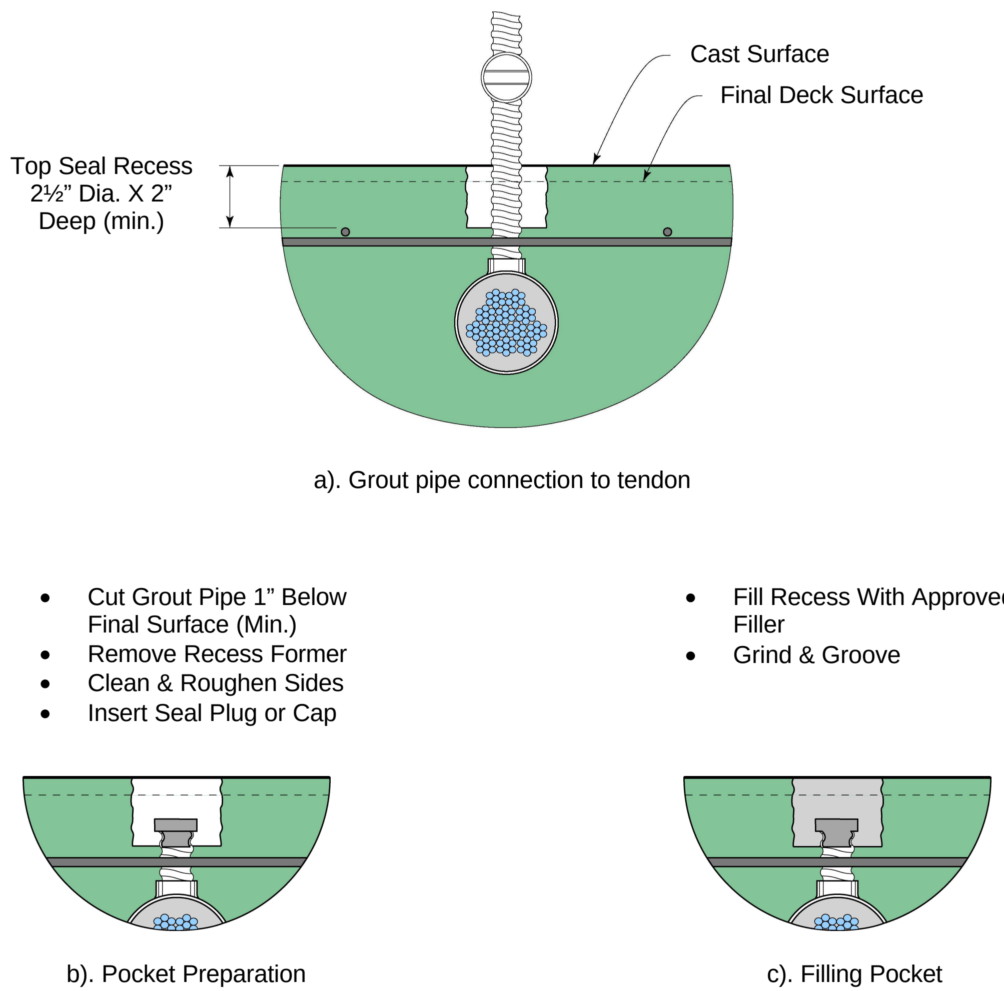

Figure 4.6 - Sealing grout ports, vents and drains

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

(a) Web Width and Duct Size (Requirement 1.B)

In order to ensure and maintain the integrity of the ducts, avoid honeycombing or similar difficulties, check web width for cover, fit of stirrup rebar and tolerances. Consider the difference between nominal and actual sizes of components (rebar and ducts) and allow for tolerances. A past "rule of thumb" was that the web width should be at least 3 times the duct size.

Duct size for Tendon

Ideally, the area provided by the inside diameter of a duct should be 2.5 times the net area (As) of the (multiple-strand) tendon. Duct that provides and area less than 2.5 times the net area of the tendon should only be used when there is good control over duct alignment to reduce wobble and avoid potential tendon threading difficulties. In no circumstance should the duct area be less than 2.0 times the net tendon area.

Available Plastic Duct

The most commonly available plastic ducts are:

Inside Diameter		Out. (Rib*) Diameter		Area of Duct	Maximum number of strands			
					0.5" strands		0.6" strands	
mm	inch	mm	inch	in^2	Ideal	Max	Ideal	Max
59	2.32	73	2.87	4.24	11	13	7	9
76	2.99	91	3.58	7.03	18	23	13	16
100	3.94	116	4.56	12.19	31	39	22	28
130	5.12	147	5.79	20.59	53	67	38	47

(*note that the ribs control the O.D. not the duct wall thickness)

The above leads to the following for I-girders with 8 inch webs:

Duct I.D. mm	Duct I.D. Inch	Duct O.D. Inch	Minimum web width if based on 3* I.D. Inch
59	2.32	2.87	6.96
76	2.99	3.58	8.97

To satisfy the requirements of Strategy 1.B and ensure duct integrity, for AASHTO Girders and Bulb-T's with 8 inch web then: (Figure 4.7)

- Limit duct to nominal (59mm) size.
- Practical tendon is limited to max of 12-0.5 inch diameter or 9-0.6 inch diameter strands.
- It is essential to detail and show all duct supports for good control of wobble and profile.
- Use only circular ducts in webs (to avoid cracks or spalls).
- Lock-off grout under 30 psi pressure (likewise for girder integrity and no bleed).

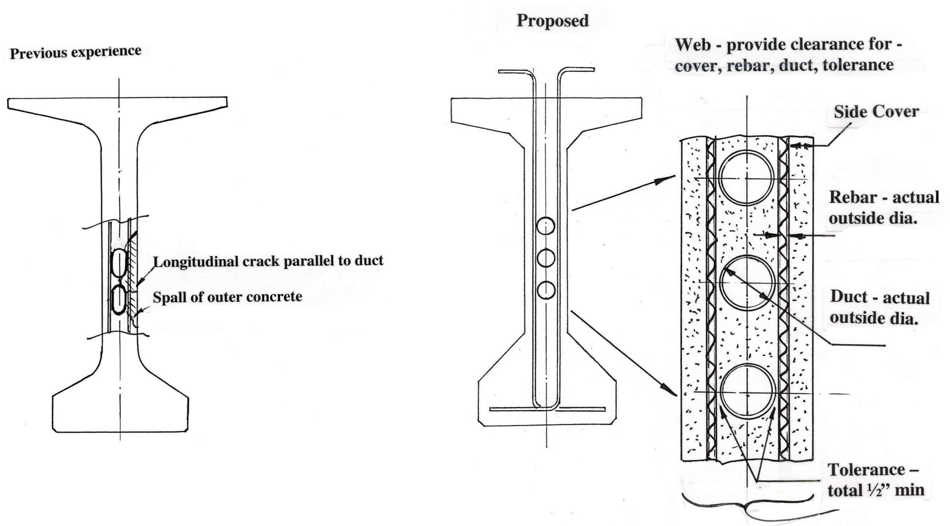

Figure 4.7 - Duct size in post-tensioned girders

(b) Spacing of Ducts and Clearances for Concreting (Requirement 1.B)

In order to ensure good placement and consolidation of concrete and to ensure and maintain duct integrity: (Figure 4.8)

- Ensure that the minimum vertical clearance between ducts at any point along the tendons is at least 1.5 times the maximum size of the aggregate and not less than 2 inches
- For available size of plastic duct, the duct spacing center to center should be not less than 4.0 inches.
- Place a note on Plans stating the maximum allowable size of aggregate.
- Ensure that the distance between the outside of the duct and the side of the web is not less than 2-1/2 inches. (e.g. for an 8 inch web and nominal (59mm) commercially available duct with OD = 2.87 inches, the gap is about 2.5 inches on each side).

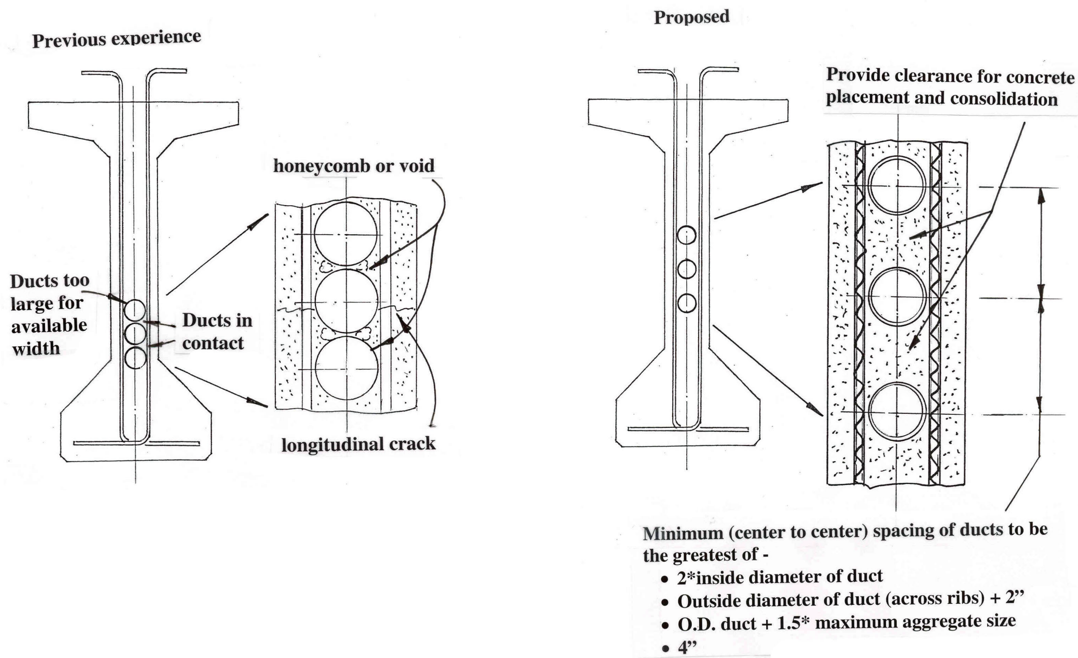

Figure 4.8 - Duct spacing and clearances in post-tensioned girders

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

In order to maintain support of the post-tensioning ducts, show the following information on Contract Drawings (Figure 4.2):

- Duct profile and minimum clearances.
- Duct supports – use at least #3 rebar or D4 wire tied to web reinforcing.
- Duct support bars may be straight, L, U, or Z-shape as necessary.
- Provide supports at intervals of no more than 2 feet (or per recommendations of duct supplier).

(d) Space for Concrete Vibrators (Requirements 1.B and 1.C)

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, diaphragms, girder-splices and webs (provide a clear space of at least 2.5 inches).

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

External tendons are not normally used in Spliced I-Girder Bridges. Refer to Volume 3, "Design and Construction Inspection of Precast Segmental Span-by-Span Bridges" for requirements if external tendons are used.

Strategy 2 – Fully Grouted Tendons

This strategy requires that all post-tensioning tendons in spliced I-girder bridges 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 post-tensioning tendons are to be accessible throughout all construction operations, up to and including the installation and grouting of permanent plastic grout caps.

In spliced I-girder construction, tendons are only easily accessible for inspection during construction. The tendon anchors are eventually covered by the concrete of a transverse diaphragm or in the top of a girder under a top slab. The tendons are not directly accessible for maintenance inspection.

Anchors for new construction shall 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 details for duct splices (couplers) and grout connectors - These usually take up a larger outside diameter than the duct. Locate along the tendon so as to fit between vertical web bars and avoid crimping of ducts.
- Show sequence of grouting of longitudinal tendons.
- 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.
- 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 any temporary longitudinal post-tensioning for erection be fully grouted at the end of erection whether the temporary PT remains in place or not and whether stressed or not.

Ducts may be moist at the time of grouting, but 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 these principles applied to different configurations of spliced girder bridges for two-span I-girder, four-span I-girder/bulb-T and three-span cantilever with drop-in span unit are given in Sections 2.7, 2.8 and 2.9. Effects of longitudinal bridge grade on pressure head in very long tendons are considered in 2.10 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. This requires checking at the precast plant before casting and on the job site where such items are installed in cast-in-place concrete.

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 PT 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 (may be before installing tendon), ducts to be pressure tested for leaks.
- 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.
- Injection of grout at the low point of each tendon profile.
- Direction of grout injection and sequence of closing vents.
- Provisions for grouting 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 ducts - procedures to ensure that all internal ducts used for temporary post-tensioning for erection are fully grouted at the end of erection, whether temporary PT remains in place or not and whether stressed or not.

* Note: Provisions for group grouting is only necessary in the event of potential cross-flow between internal tendons at a defect or splice. Group grouting might be preferred for efficiency and quality control of operations in some circumstances, but internal draped tendons in an I-girder are usually grouted one at a time. Prior to grouting as a group, ensure that there is sufficient supply of materials and back-up equipment in case of breakdown. Simultaneous grouting of a group of internal tendons must combine operations for all proposed tendons in the group, recognizing that injection will be done at several injection ports, in sequence or in parallel, with multiple outlet vents requiring closing in sequence after evacuation of grout of required consistency.

2.7 Grouting Procedure - Spliced AASHTO I-Girder - 2 Spans - (Requirements 2.B, 2.C, 2.E, 2.F, 2.G)

Figure 4.9 illustrates a 2-span I girder spliced within the spans and over the pier. On the Contract Drawings:

- Take into account longitudinal gradient, if any, and establish intended direction of grouting.
- Orient end anchors (A and G) so that grout injection and evacuation vent is at top – show on Plans.
- Determine which location is at lowest point of profile and show injection vent (in this example, point B). Because, in this case, the profile change in the depth of the spliced I-Girder is significant (i.e. greater than 20 inches (0.5m)) grout must be injected from low point. If two or more low points are at same elevation, then select one as injection point.
- Provide vent at crest (D) and at 3 to 6 feet (1 to 2m) beyond crest (at C and E) in both directions (to avoid potential confusion between work at precast plant and site).
- Provide drain vents at other low points (B and F).
- Provide grout outlet vent at end anchor (G).
- Show direction of grouting.
- Show sequence of closing vents.

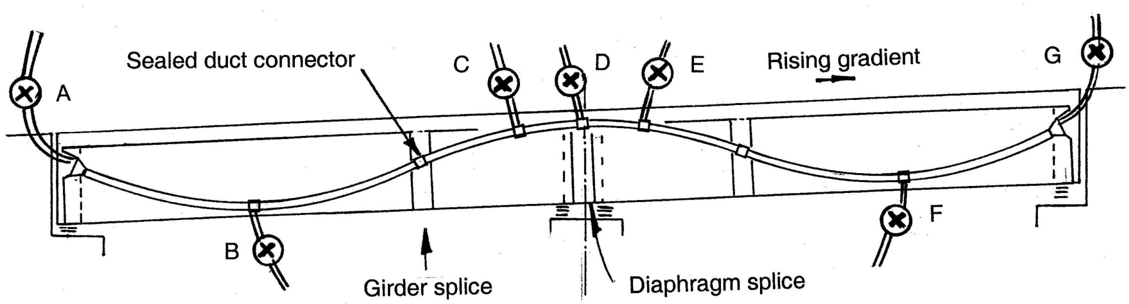

Figure 4.9 – Grouting Details for a 2 span spliced girder system

2.8 Grouting Procedure - Spliced Bulb-T or AASHTO Girder – 4-Spans – (Requirements 2.B, 2.C, 2.E, 2.F, 2.G)

Figure 4.10 illustrates a 4-span Bulb-T / I-girder spliced over the piers. On the Contract Drawings:

- Take into account longitudinal gradient, if any, and establish intended direction of grouting.
- Orient end anchors (A and O) so that grout injection and evacuation vent is at top – show on Plans.
- Determine which location is at lowest point of profile and show injection vent (in this example, point B). Because, in this case, the profile change in the depth of the spliced I-Girder is significant (i.e. greater than 20 inches (0.5m)) grout must be injected from low point. If two or more low points are at same elevation, then select one as injection point.
- Provide vent at all crests (D, H, L) and at 3 to 6 feet (1 to 2m) beyond crests (at C, E, G, I, K and M) in both directions (to avoid potential confusion between work at precast plant

and site. Although it is only necessary, in theory, to install outlet vents at the high points and on the downstream side of each crest, in order to avoid confusion and risk of mistake (such as turning girder end for end) during erection, it is prudent to install vents on both sides of a crest – at 3 to 6 feet (1 to 2m) from high point.).
- Provide drain vents at all other low points (B, F, J and N).
- Provide grout outlet vent at end anchor (O).
- Show direction of grouting.
- Show sequence of closing vents.

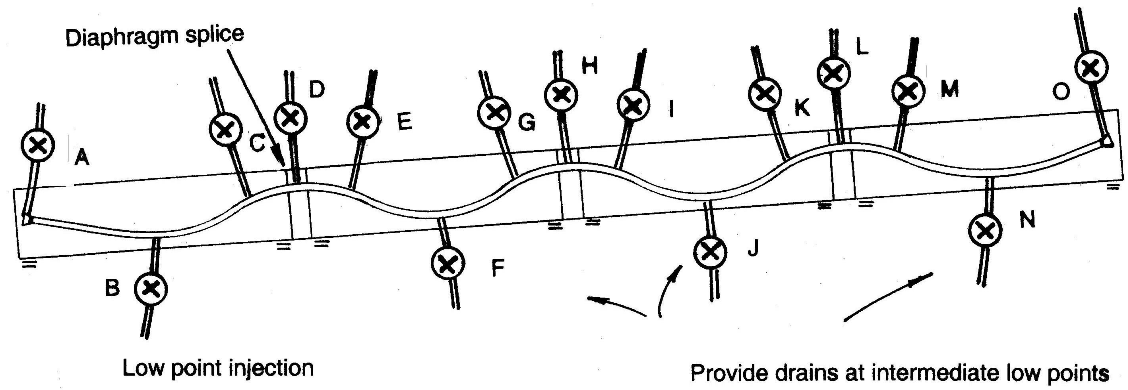

Figure 4.10 – Grouting Details for a 4 span spliced girder system

2.9 Grouting Procedure – Cantilever and Drop-in Spliced I-Girder - 3-Spans - Requirements 2.B, 2.C, 2.E, 2.F, 2.G)

Figure 4.11 illustrates a 3-span variable depth, cantilever and drop-in spliced Bulb-T / I-girder. On the Contract Drawings:

- Take into account longitudinal gradient, if any, and establish intended direction of grouting.
- Because, in this case, the profile change in the depth of the spliced I-Girder is significant (i.e. greater than 20 inches (0.5m)) grout must be injected from low point.
- 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 (e.g. B and F), then select one as injection point (B).
- Orient end anchors (A and L) so that grout injection and evacuation vent is at top – show on Plans.
- Provide vent at crests (D and I) and at 3 to 6 feet (1 to 2m) from crests (at C, E, H and J) in both directions (to avoid potential confusion between work at precast plant and site. Although it is only necessary, in theory, to install outlet vents at the high points and on the downstream side of each crest, in order to avoid risk of mistake (such as turning girder end for end) during erection, it is prudent to install vents on both sides of a crest – at 3 to 6 feet (1 to 2m) from high point.).
- Provide drain vents at all other low points (B, F, G and K).
- Provide grout outlet vent at end anchor (L).

- Show direction of grouting.
- Show sequence of closing vents.

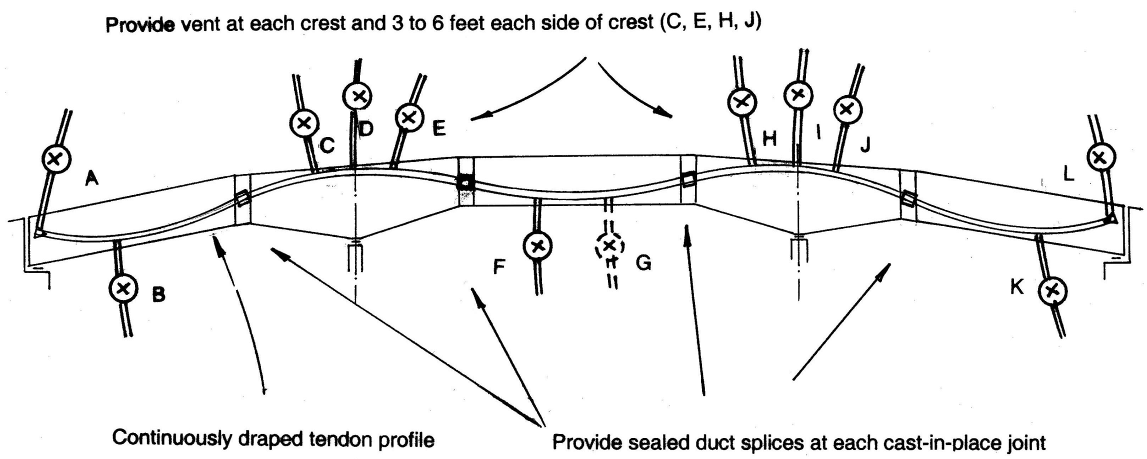

Figure 4.11 – Grouting Details for a 3 span, drop-in and spliced girder system

2.10 Grouting – Pressure Head in Long Tendons in Bridges on Gradient

On a long, continuous span superstructure, with long tendons extending from one end of a unit to another, longitudinal gradient will make a difference to the pressure required for grout injection. Also, the longitudinal gradient may affect the tendency for bleed, even with the new, pre-bagged, grouts to Section 938 of the FDOT Standard Specification. Therefore, for long gradients or significant elevation differences, additional precautions may be needed.

Example Increase in Pressure for Long Gradient – Example for 4 spans of 140 feet Bulb-T:

Longitudinal Gradient (%)	Rise Feet	Approximate Max Head (Ft)	Approximate Extra Pressure (psi) above Horiz case
0	0	6	0
2	11	17	11
4	22	28	23
6	34	40	35

Typically, grout is injected at approximately 75 psi with a limit of 150 psi. As such, extra pressures on the order of magnitude shown in the example above would not greatly impact grouting. The following precautions are needed to mitigate additional bleed water in these cases:

(a) Lock-off under pressure not exceeding 30 psi – extra pressure induces more bleed, even with low bleed grouts. Also, it induces extra hoop tension in duct walls. In the case of internal ducts in plastic pipes, the tension is transmitted locally to the concrete. The effect is controlled by reinforcing (such as web stirrups and duct support ties) and is, by practice, disregarded in design analyses.

(b) Provide stand-pipes at high points. These may be simple extensions of the outlet vents by a few feet (3 to 4 feet) to be able to monitor any expelled bleed water.

(c) Use low-bleed grout – per Standard Specification 938.

(d) Grout mix may contain a water reducing agent, but not a retarding agent since it is desirable that the grout take an initial set as soon as possible before any appreciable bleed can occur – commensurate with the length of tendon and quantity of grout to be injected. (This is unless the grout has been specifically formulated for little or no bleed under the anticipated additional pressure of the bridge grade.)

2.11 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 4.12 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.

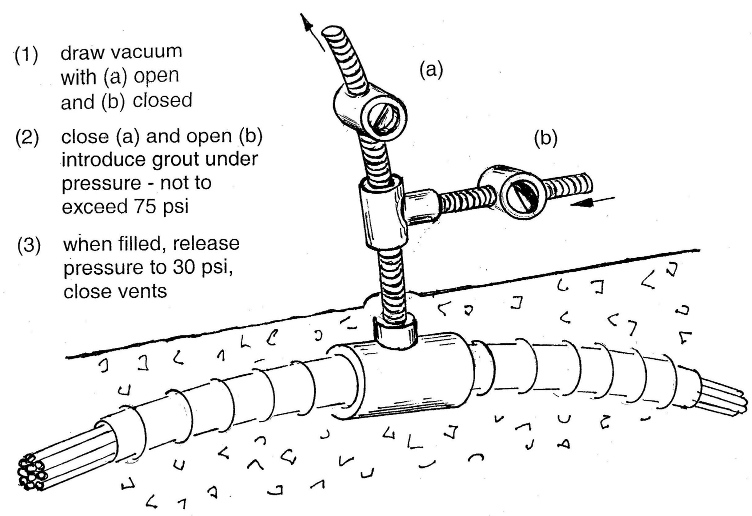

Figure 4.12 – Details of Vacuum Grouting Connections

(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”)

Strategy 3 – Multi-Level Anchor Protection

Significant corrosion to post-tensioning tendons in Florida has resulted from lack of adequate protection at anchorages. In the past, tendons at expansion joint ends of continuous span bulb-tee bridges were anchored in block-outs in the top of the girders in order to facilitate installation and stressing. The block-outs were then filled with deck concrete. This practice left some anchors susceptible to seepage of water at shrinkage cracks that inevitably developed in the slab around the pour-backs, and at transverse shrinkage cracks in the slab itself. Deck slab cracking near the expansion joints was enhanced by the reduction in precompression in this area resulting from the distribution of anchorages along the beam.

To help mitigate this and other corrosion issues, Strategy 3 requires that all anchors 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 precast spliced I-girder construction, relevant information (such as dimensions, angles, sizes, cover etc. for anchor pockets, blisters or block-outs) must also be integrated into the Shop Drawings 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. Also - 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.

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

3.5 Bulb-T and I-Girders, Spliced over Intermediate Piers (Requirement 3.B)

The preferred solution is to minimize block-outs and pour-backs in the top deck slab and to anchor all tendons at the ends of the girders where they provide more effective prestress for shear and flexure and can be protected by the detail shown in Figure 4.13. However, where this is not possible, some tendons (up to 50%) may be anchored in the top, and protected by the detail shown in Figure 4.14, with all other tendons anchored at the ends.

3.6 Cantilever and Drop-in Spliced I-Girders (Requirement 3.B)

This type of structure is typically used for three-span channel crossings, and as a result has significant lengths of approach span bridge on either side of the main unit. Construction of these bridges can usually be staged to provide access in the adjacent approach spans for placing and stressing full length tendons in the 3-span unit. Consequently, there is no need for tendons to anchor in the top of the girders. In this case, the preferred solution can be used as shown in Figure 4.13.

3.7 End anchorages (Requirement 3.B)

Arrange the end anchors in a group in the end of the girder. Since the concrete at the ends is exposed to the environment, the four levels of protection consist of:

- Grout.
- Permanent cap.
- Pour-back to encapsulate cap and anchor plate.
- Encase girder end within reinforced diaphragm (Figure 4.13).

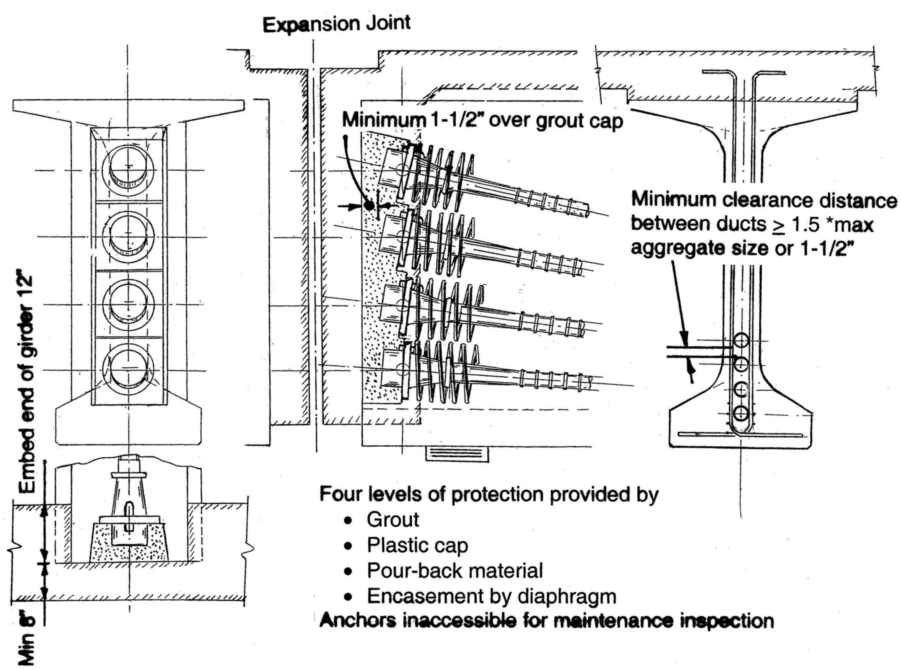

Figure 4.13 – Anchor protection details at end anchorages

Specific requirements for end anchors 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.

- Recess in end of girder for anchor head and cap.
- Concrete surfaces of recesses and pour-back substrates be cleaned and roughened prior to casting pour-backs.
- Encapsulate anchor and grout-cap in pour-back 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 and edges of anchor plate of 1-1/2 inch.
- For an individual anchor in a recess, surface of pour-back be even with adjacent face of I-girder 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 (i.e. screw coupled rebar) 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.
- Encasement of end of girder in concrete diaphragm, with at least 4 inches concrete over the end of the girder and at least 9 inches embedment of the girder into the diaphragm.
- At expansion joint, reinforced diaphragm is properly formed and cast to encapsulate the end of the girder.
- An appropriate joint spacer material (e.g. expanded polystyrene or similar) is used where joint is between continuous units with one diaphragm cast against the other.

3.8 Top Anchorages (Requirement 3.B)

Since the concrete at the ends is exposed to the environment, the “four-levels” of protection comprise:

- Grout.
- Permanent cap.
- Pour-back to encapsulate cap and anchor plate.
- Structural deck slab (seal construction joint with methyl-methacrylate) (Figure 4.14).

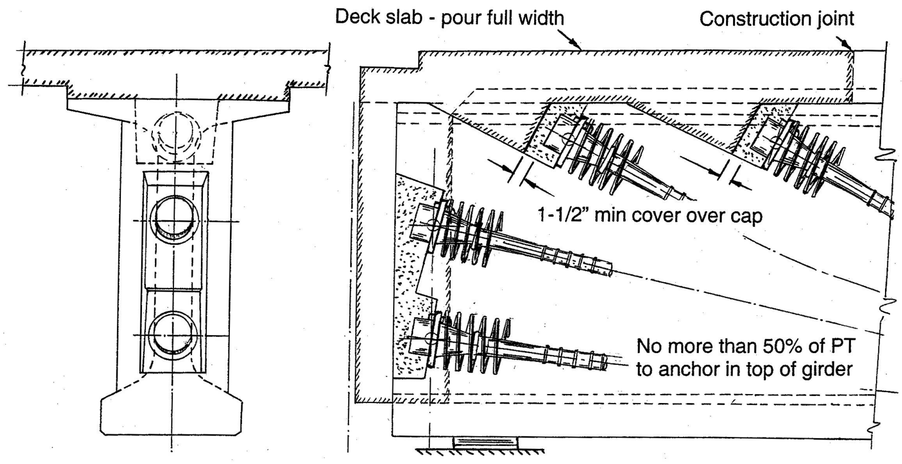

Figure 4.14 – Anchor protection details at top anchorages

Specific requirements for top anchors 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.
- Recess in *top* of girder for anchor head and cap.
- Concrete surfaces of recesses and pour-back substrates be cleaned and roughened prior to casting pour-backs.
- Encapsulate anchor and grout-cap in pour-back of an approved, high-bond, low-shrink, sand-filled epoxy grout selected from FDOT QPL.
- Pour-back to provide minimum cover over cap and edges of anchor plate of 1-1/2 inch.
- Fill remainder of recess with deck slab concrete in continuous full width pour.
- Seal top joint of deck slab with sealer (i.e. methyl methacrylate).

3.9 Temporary Protection during Construction (Requirement 3.C)

During construction, all post-tensioning ducts and tendons shall be temporarily sealed or capped to prevent ingress of water, corrosive agents or site debris. Specifically, 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

Spliced I-girder bridges do not have any interior open cells like segmental bridges, voids like voided slabs or cells like cellular boxes. Consequently, there are no interior voids that need to be made watertight. Nevertheless, it is essential that the internal tendons be fully grouted and that there are no voids in or around the longitudinal post-tensioning ducts that can serve as avenues for the intrusion of water or corrosive agents. The integrity of the post-tensioning system in spliced I-girder bridges is attained through the use of the proper ducts, proper tendon installation and grouting.

4.1 Deck Slab (Requirements 4.A, 4.D and 1.B)

Require all top surface joints at pour-backs to be sealed with an approved penetrating sealer (methyl-methacrylate) after grinding and grooving. (Sealing not required when an epoxy grout pour-back is used.)

4.2 Forming and Filling Temporary Holes in Top Slabs (Requirement 4.C)

As far as possible minimize the number of temporary holes through the top slab for any purpose. Avoid placing holes near permanent post-tensioning anchors where any leaks might drain or drip directly onto anchor heads or external duct connectors. Fully fill and seal all holes after use. 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 – make sure that holes are properly prepared, filled and sealed after use.
- CEI - check that holes are properly prepared, 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) No pipe of any kind (plastic, steel, ribbed or plain) to be used 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 the filled holes.
(8) Where temporary holes pass through the full depth of structure (e.g. diaphragms) – make appropriate allowance and adjusted details be made for local geometry, super-elevation, grade and possible interference with other components or tendons.

4.3 Temporary Access Holes (Requirement 4.C and D)

If temporary access holes through the deck slab are needed, then use only tapered sides (top wider than bottom), reinforce and fill in accordance with the details on the Contract Drawings or approved Shop Drawings. 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):

- Locate to avoid tendons and anchors.
- Locate to avoid possibility for water to drip onto anchors or components.
- Locally design slab 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 epoxy grout.
- 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.

Strategy 5 – Multiple Tendon Paths

5.1 Multiple Tendon Paths (Requirement 5.A)

Longitudinal post-tensioning tendons in spliced girders typically run the full length of the continuous superstructure unit and drape in the webs to provide required eccentricities. These tendons are not easily inspected and cannot be removed or replaced. Redundancy in these bridges is a function of the integrity of the deck slab, the number of girders per span and the number of tendons per girder. If a tendon in one girder is lost due to corrosion, adjacent girders will, within limits, carry the load not resisted by the damaged girder.

This strategy shall be met with the following requirements:

- Provide a minimum of 3 girder lines per bridge.
- Provide a minimum of 3 post-tensioning tendons per girder.
- Do not use a tendon size greater than 9-0.6 inch diameter strands or 12-0.5 inch diameter strands for standard beam shapes without appropriate modifications to web thickness.

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

In addition to that afforded by the grout and duct, the cast-in-place deck slab contributes to corrosion protection at crests of longitudinal post-tensioning tendons in precast I-girders spliced over interior piers. Also, the continuous mild reinforcing over the piers and the pre-tensioning strands at mid-span of the girders contribute 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, spliced I-girder bridges shall satisfy the following requirements:

- Consider long-term conditions only – i.e. after all PT losses and concrete shrinkage and creep redistribution have occurred.
- Consider only the section over each interior pier.
- For each of these sections only, assume, 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)

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. Details for this post-tensioning shall be such that the 10 percent provisional prestressing force (of all permanent tendons) closely follows the center of gravity of the 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.