Florida Department of Transportation

STATE OF FLORIDA • DEPARTMENT OF TRANSPORTATION

New Directions for Florida Post-Tensioned Bridges

Volume 9 of 10: Condition Inspection and Maintenance of Florida Post-Tensioned 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 will be changing policies and procedures to ensure the long-term durability of post-tensioning tendons. The background to these revised policies and procedures is presented in this study entitled, *New Directions for Florida Post-Tensioned Bridges*. The study will be presented in five volumes, with each volume focusing on a different aspect of post-tensioning.

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.

Volume 2: Design and Detailing of Post-Tensioning in Florida Bridges applies the five-part strategy presented in Volume 1 to the design of post-tensioned 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 this volume.

Volume 3: Construction Inspection of Florida Post-Tensioned Bridges addresses the five-part strategy for the various types of post-tensioned bridges in Florida, but from the perspective of CEI. The various types of inspections required to fulfill the five-part strategy and checklists of critical items are presented.

Volume 4: 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 5: 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 – Condition Inspection and Maintenance of Florida Post-Tensioned Bridges

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Chapter 1 – Introduction

1.1 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.

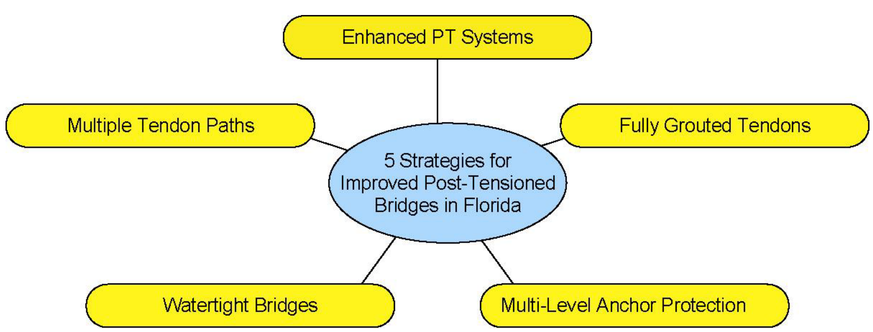


Figure 1.1 – Five-part strategy for more durable post-tensioned bridges in Florida.

Volume 1: Post-Tensioning in Florida Bridges presents the development of the five-part strategy for more durable post-tensioned bridge in Florida. This Volume applies these strategies to the condition inspection and maintenance of the different post-tensioned bridges in Florida.

In preparing this Volume, consideration was given to various means of inspecting tendons from simple visual to non-invasive (non-destructive) and invasive methods. Refer to Appendix B and Table B.1 for an overview and subjective assessment of 15 inspection methods. Refer to Appendix A for a review of 31 types of cracks that can affect post-tensioning tendons.

This Volume focuses on the proper use of current and proven technology for inspection and repair and not necessarily the panoply of possible high-technology methods or new materials (for example, coated strands, artificial fibers or exotic filler materials such as resins or gels) that are being developed and have yet to be established.

However, because defects may exist and corrosion may proceed with no visual indication whatsoever, if after a number of years of service (say ten) there is still no visual evidence of defects or corrosion, it may be necessary to perform an invasive inspection on a representative sample (at most 5%) of apparently sound tendons or anchors. This would be part of an in-depth inspection specifically scheduled for the purpose. The need for this inspection should be determined by the Maintenance Engineer. (It is recommended that such inspection be scheduled and budgeted according to the needs of each District.) Even though each routine biennial inspection will not necessarily include a complete inspection of the post-tensioning system, the Inspector should always keep a heightened sense of awareness and be vigilant for any signs of corrosion.

Also, although the up-grading of old bridges up to new standards is a worthy goal, it is also an issue of programming and funding that becomes a matter of scheduling maintenance forces and cost-effectively applying limited resources. It is not addressed in this Volume. For example, the installation of drainage troughs to expansion joints would improve watertight-ness, but can only be done during a major retrofit. However, depending upon the bridge - a more direct and cost effective means of improving watertight-ness night be, for example, to simply seal any leaky joints between precast-segments using methyl methacrylate or epoxy injection while postponing installation of expansion joint drainage troughs to a subsequent occasion.

Unlike the previous Volume 2 “Design” and Volume 3 “Construction” (CEI) the approach in Volume 4 “Maintenance Inspection” is different.

Maintenance inspection is based upon the need to identify deficiencies and their impact in order to and carry out appropriate repairs or other action. Although the combination of the possible variety of bridge (superstructure and substructure) types and post-tensioning types is large, inspection, assessment and repair procedures are relatively few and generally common to all bridge and tendon types. Furthermore, deficiencies (e.g. mainly grout voids, loss of tendon and anchor protection, and water seepage that lead to corrosion) are generic to the type of post-tensioning (i.e. internal or external) and corresponding details. In turn, these are generic to the type of bridge.

As regards inspection, some non-invasive inspection methods (such as impact-echo or ultra-sound) may verify regions where grout voids are suspected within a particular type of tendon or bridge or may indicate other defects such as cracks or spalls. However, very few non-invasive methods can effectively detect corrosion and all are relatively expensive. Some new medium to high-tech inspection methods (e.g. magnetic flux exclusion or vibration methods for external tendons) show promise (Appendix B). However – the most cost effective methods that offer good confidence for most situations are visual – namely visual inspection and examination using a bore-scope.

In any case, it is necessary to verify suspected corrosion by invasive means – i.e. by drilling into grout ports or ducts and using a bore-scope to examine the tendon (strands) at close range.

Consequently, for inspection the cost-effective approach relies upon visual inspection for symptoms followed by appropriate non-invasive methods, backed up by selective, invasive inspection by bore-scope at locations of suspected voids within the length of the tendon or at anchors.

Thus, the approach to inspection involves:

- An examination of the records
- A visual inspection to reveal or verify the type of superstructure
- The type of structure indicates the method of construction
- The method of construction indicates the type of tendons and details
- The tendons and details indicate the type of evidence of deficiencies to look for
- Field evidence is sought – visually at first
- Evidence is then supported by appropriate non-invasive methods
- Defects, if any, are verified by selective but limited, invasive methods (e.g. borescope of internal tendons or removal of portions of damaged duct from external tendons or borescope inspection of anchors)

The findings from the invasive (borescope) inspection are assessed as in regard to significance and seriousness (e.g. the number of strands or wires that have been lost in any given tendon and in the structure as a whole) to determine if the level of prestress is satisfactory. (Initially, acceptability is based on a simple estimate of the percentage of wires (or PT) effectively lost.)

- If there are no defects, or none of significance, simple repairs are made (such as grouting voids and sealing leaks) also including repairs to any defects caused by invasive inspection.
- If the level of prestress is satisfactory, then appropriate action is then taken to repair the structure (including defects caused by invasive inspection).
- If it is not satisfactory, then, in consultation with the Department, a structural analysis is necessary to determine the adequacy of the structure and the need to add or replace tendons. (This may involve a load rating based upon the estimated remaining post-tensioning after discounting that effectively lost to corrosion or other appropriate structural analyses)
- Subsequent action (i.e. rehab or replace) can then be evaluated.

In this Volume, the approach to inspection is described by flow charts. An initial chart (Flowchart 1.1) is provided to help to identify the bridge type (by superstructure) and probable post-tensioning based only upon a visual examination – which may be helpful in the absence of drawings or records. A set of tables (Tables 1.1, 1.2, 1.3 and 1.4) lists the features and type of evidence to look for to identify the type of bridge (superstructure and substructure), the type of post-tensioning and likely types of deficiencies. To identify a bridge and post-tensioning type, see Chapter 1, Sections 1.2 and 1.3

The process of inspection and assessment itself follows a series of “Inspection” flowcharts (in Chapter 2) – according to the five key strategies, namely:

Strategy #1	Enhanced Post-Tensioning
Strategy #2	Fully Grouted Tendons
Strategy #3	Multi-Level Anchor Protection
Strategy #4	Watertight Structures
Strategy #5	Multiple Tendon Paths

Each flowchart identifies specific “Inspection Procedures” (Chapter 2), “Assessment Procedures” (Chapter 3) and “Repair Procedures” (Chapter 4) to be used for making decisions and taking appropriate action.

The identification and assessment of the significance of deficiencies (such as grout voids and corrosion of the post-tensioning) is addressed in the “Inspection Procedures” and the “Assessment Procedures” backed up by Tables identifying various “visual evidence” appropriate to each type of structure and post-tensioning. The “Repair Procedures” in Chapter 4 are broadly arranged according to five key strategies.

Cracks are important if they breach post-tensioning ducts and allow contaminants to attack the tendons. However, the subject of cracking in structures is very broad and the origins of cracks vary with structure type, design and construction practices and material and environmental conditions. In so far as cracks affect post-tensioning – and vice-versa – a separate discussion covering 31 cases of various types of cracks most commonly encountered in post-tensioned bridges is included in Appendix A.

1.2 Identification of Bridge Type and Post-Tensioning

The first task of any inspection is to identify the bridge type and the type of post-tensioning it contains.

A bridge type is described by the type of superstructure and method of construction. The latter usually determines the type of post-tensioning.

This section applies to all types of post-tensioned bridges – whether of continuous spans or simply supported. However, it does not apply to non-PT (i.e. reinforced concrete only) structures.

1.2.1 Existing Records

First, make reference to all existing records and information on Plans, Shop Drawings, previous inspection reports and so forth to glean as much information as possible concerning

- The type of superstructure and how it was constructed
- The type of longitudinal post-tensioning in the superstructure (for example, internal or external tendons, in the top and bottom slabs or webs)
- The type of transverse post-tensioning in the superstructure (if any)
- The type of substructure (for example - cast-in-place or precast)

- If the substructure contains post-tensioning – then what type, internal or external tendons - or both and where is it located, is it lateral or vertical?

Considerable information that cannot be gleaned from existing records – or where no existing records exist – can be deduced solely from a visual examination of the structure – by following the procedure below.

1.2.2 Application of Post-Tensioning and Super-Structure Type

The application of post-tensioning to structure types is falls into the following categories.

Longitudinal PT of Superstructures

Precast I-girders of all types are prefabricated using pre-tensioning strands installed in a long-line casting bed at the casting yard even if they are later to have draped internal post-tensioning tendons installed in the bridge. Precast concrete planks and double-T's are also pre-tensioned at the factory. These are the only precast components that are longitudinally pre-tensioned prior to construction (Table 1.2).

Superstructure types and typical longitudinal post-tensioning tendons include:

- Precast segmental balanced cantilever (usually internal of multiple strands*)
- Precast segmental span-by-span (usually external of multiple strands**)
- Spliced I-girders (internal of multiple strands)
- Cast-in-place balanced cantilever (usually internal of multiple strands*)
- Cast-in-place on falsework, including
  - Solid slab (internal of strands)
  - Voided slab (internal of strands)
  - Cellular box (usually internal of multiple strands)

(* some external tendons may also be used in cantilever bridges)
(** some internal tendons may be found in span-by-span bridges – mostly in a longer span of the main span unit (msu) where erection is partially in cantilever.)

PT bars may be used in some applications in the above structures instead of strands. However, the most common use of PT bars is as temporary PT for construction purposes – such as for precast-segmental cantilever construction of for repair or rehabilitation. In some cases, temporary PT bars may be left in the structure, either stressed or not. However, if they are in internal ducts, they must be grouted. Also, any temporary ducts used for erection should also be filled with grout at the end of construction.

Longitudinal post-tensioning in superstructures is summarized in Table 1.2 - more detailed features of the various post-tensioning tendons are as follows:

(1) Cantilever tendons anchored in recesses to the top slab / web

Applies to

- Precast segmental balanced cantilever (pre 2001)
- Main span unit (msu) of span-by-span built in modified cantilever (pre 2001)
- Cast-in-place segmental balanced cantilever (pre and post 2001)

Tendons are located

- Internal to top slab (usually in one row – may be in two rows in big bridge)
- In a group over or near to each side of each web
- Tendons are spaced laterally at intervals of 7 to 10" (approx)
- Number of tendons is at maximum over an internal pier
- Tendons step laterally from one duct location to another at each segment joint

Cantilever tendons extend from anchor (in recess initially open to top surface and later filled with concrete) on one side of pier to a similar location at a similar distance on the other side of pier.

Anchor recesses in the top slab are at the transverse joints between segments – and should be identifiable by the presence of a small shrinkage (separation) cracks around pour-back in earlier structures built prior to these new strategies (2001).

(2) Cantilever tendons face-anchored in a recess within top slab

Applies to

- Precast segmental balanced cantilever (pre 2001 and post 2001)
- Main span unit (msu) of span-by-span built in modified cantilever (pre and post 2001)
- Cast-in-place segmental balanced cantilever (pre and post 2001)

Tendons are located

- Internal to top slab (usually in one row – may be in two rows in big bridge)
- In a group over or near to each side of each web
- Tendons are spaced laterally at intervals of 7 to 10" (approx)
- Number of tendons is at maximum over an internal pier
- Tendons step laterally from one duct location to another at each segment joint

Cantilever tendons extend from a face-anchor (in a recess completely below and not open to the top surface) on one side of pier to a similar location at a similar distance on the other side of pier.

Anchor recesses in the top slab are at the transverse joints between segments – but, being completely covered by segment concrete – they cannot be seen from the surface of the finished bridge if built properly according to the new strategies post (2001). Face anchors in recesses are intended to be located entirely within the depth of the top slab haunch at the web so that ducts do not have to cross through the plane of web rebar. This simplifies detailing and construction at the expense of a little extra concrete to attain cover.

(3) Cantilever tendons anchored in blisters at top slab / web

Applies to

- Precast segmental balanced cantilever (pre and post 2001)
- Main span unit (msu) of span-by-span built in modified cantilever (post 2001)
- Cast-in-place segmental balanced cantilever (post 2001)

Tendons are located

- Internal to top slab (usually in one row – may be in two rows in big bridge)

- In a group over or near to each side of each web
- Tendons are spaced laterally at intervals of 7 to 10” (approx)
- Number of tendons is at maximum over an internal pier
- Tendons step laterally from one duct location to another at each segment joint

Cantilever tendons extend from anchor blister in top of segment on one side of pier to a similar location at a similar distance on the other side of pier

Anchor blisters are inside the box section at the intersection of the underside of the top slab and web.

Anchor recesses should be identifiable by presence of a small shrinkage (separation) cracks around pour-back (in structures prior to 2001)

(4) Continuity PT anchored in blisters at top or bottom

Applies to

- Precast segmental balanced cantilever (pre 2001)
- Main span unit (msu) of span-by-span built in modified cantilever (pre 2001)
- Cast-in-place segmental balanced cantilever (pre and post 2001)

Tendons are located

- Internal to top slab (usually in one row)
- In top slab, in a group over or near to each side of each web
- In bottom slab, in a group near each side of each web
- Should be more bottom continuity tendons than top ones (may be no top ones)
- Tendons are spaced laterally at intervals of 7 to 10” (approx)
- Number of continuity tendons is maximum through a midspan closure of an interior span or near the end of an end span of a continuous span unit
- Tendons step laterally from one duct location to another at each segment joint

In interior spans, continuity tendons extend from an anchor blister in the span on one side of the midspan closure to a similar blister on the other side of the closure.

In end spans, continuity tendons extend from an anchor blister in the span to an anchor in the end face of the end diaphragm at the expansion joint

(5) Draped tendons in web (with perhaps faint image of ducts on surface)

Applies to

- Precast I girders
- Usually spliced and continuous (but could be simply supported)

Tendons are located

- Internal to the web
- Usually in two to four ducts
- Follow profile that drapes down from end anchor to bottom flange then rises to crest over interior pier supports

- Ducts are usually circular, galvanized steel in bridges (pre 2001)
- Some ducts are vertically elongated galvanized oval section (Edison and Choctawhatchee) – discontinued oval ducts after Edison
- Ducts post 2001 should be circular and of (plastic)

Anchors are located
- In anchor blocks at ends of girders at expansion joints
- In top of anchor blocks in recesses into top of girder under the top deck slab (anchor blocks extend several feet along girder from end at expansion joint)

Anchor recesses in top of girders were left open during construction and sometimes until after the deck slab had been cast, leaving a recess in the slab that was later filled with concrete

Anchor recesses should be identifiable by presence of a small shrinkage (separation) cracks around pour-back in deck slab (in structures prior to 2001)

(6) Draped internal tendons

Applies to
- Solid slabs cast-in-place on falsework
- Voided slabs cast-in-place on falsework
- Cellular boxes cast-in-place on falsework

Tendon locations
- In solid slabs – usually at regular intervals across width of deck
- In voided slabs – usually at locations of webs between voids
- In cellular boxes – usually inside webs – but occasionally, some tendons may be in the bottom slab

Anchors are located
- Solid slabs – in ends at expansion joints
- Voided slabs – in ends at expansion joints
- Cellular boxes – usually at ends in anchor blocks or diaphragms at expansion joints – but occasionally, some tendons may anchor in blisters on interior of box

Anchors at ends of solid (and voided) slabs would be under pour-backs in recesses or blockouts at the expansion joints. Any such anchor recesses should be identifiable by presence of a small shrinkage (separation) cracks around pour-back (in structures prior to 2001)

(7) Temporary post-tensioning bars (longitudinal and internal to concrete)

Applies to
- Precast segmental balanced cantilever (pre and maybe post 2001)
- Main span unit (msu) of span-by-span built in modified cantilever (ditto)

Temporary PT bar locations
- Internal to top slab
- Usually 2 to 4 locations at widely spaced intervals
- Internal to the bottom slab

- Possible at center or near bottom of each web or in bottom of web at corners

Temporary PT bars were used for erection of segments and were intended to be removed. However, they may have been left in place in the ducts either stressed or not stressed.

Anchors for temporary PT bars are typically on the end or recessed into the end face of cantilever segments, remote from pier on which the cantilever rests

Anchor recesses should be identifiable by presence of a small shrinkage (separation) cracks around pour-back (in structures prior to 2001)

(8) Permanent Internal PT bar (original design and construction**)**

Applies to
- Precast segmental balanced cantilever (pre and post 2001)
- Main span unit (msu) of span-by-span built in modified cantilever (post 2001)
- Cast-in-place segmental balanced cantilever (post 2001 - maybe)
- Cellular box – maybe

Tendon locations:

- In precast segmental cantilever or span-by-span, likely location is in top slab near wing tip of a wide box section
- Most probably at expansion joint ends of continuous units
- Similar use could be made in cast-in-place cantilever construction
- It is technically feasible, but unlikely, that this would be needed or used in cellular boxes – perhaps those with a wide section or special need

Anchors would be in recesses in top slab, back-filled with concrete

Anchor recesses should be identifiable by presence of a small shrinkage (separation) cracks around pour-back in structures prior to 2001 (in subsequent applications there should be no such shrinkage cracks).

(9a thru 9d) External PT in HDPE pipe ducts

Applies to
- Precast segmental span-by span structures (pre and post 2001)
- Precast segmental balanced cantilever – occasional
- Cast-in-place balanced cantilever – occasional
- Cellular box cast-in-place on falsework – occasional

PT tendon locations
- Tendons are external to the concrete but inside the hollow box section
- Deviate from anchor in diaphragm (either at end expansion joint or at internal pier) down inside webs and pass through deviator saddles
- Deviator saddles may be at multiple locations at corner of bottom slab and web with only one tendon deviating significantly in the vertical direction at each

- Alternatively, deviator saddles may be in deviator ribs at approximately 1/3 span from each end where several or all tendons deviate together

Anchors are located
- In diaphragms of end expansion joint segments
- In diaphragms of interior pier segments
- Occasionally, in deviator saddle block or rib
- Occasionally, in separate anchor blister (usually at corner of web/slab at top or bottom)

(10) Temporary PT bars – external with blisters

Applies to
- Precast segmental balanced cantilever (pre and post 2001)
- Main span unit of span-by-span built in modified cantilever (maybe - post 2001)
- Supplementary PT added to span-by-span or cantilever (pre and post 2001)

Temporary PT bar locations
- Underside of top slab in blisters
- Usually up to 6 locations under top slab (3 per blister per side of box)
- On top of bottom slab in blisters
- Possibly 2 locations at center or 1 at each side near bottom of each web
- PT bars may be a top, bottom or part way up webs and anchored in diaphragms and/or in deviators or ribs

Temporary PT bars are used for erection of segments and are intended to be removed. However, if they have been left in place in the ducts then it is an indication that they were either added during construction to make up for a PT deficiency (possibly in internal tendons) or late as a repair or supplementary PT.

Anchors for temporary PT bars (left in place) are on the ends of the furthest blisters through which the bars pass or on the faces of diaphragms or deviator ribs.

(11) External PT bar tendons added since built as repair or rehab

Applies to
- Precast segmental balanced cantilever (pre and post 2001)
- Precast segmental span-by-span (pre and post 2001)
- Main span unit of span-by-span built in modified cantilever (pre and post 2001)
- Spliced I-Girder (pre and post 2001)
- Cellular box cast-in-place on falsework (pre and post 2001)

(It is technically feasible, but very unlikely, that external PT bars would be used to longitudinally strengthen a precast prestressed concrete plank or double-T)

PT bar locations
- Bar tendons are usually straight
- Pass through holes in diaphragms, ribs or corbels (blisters)

- Corbels or blisters may have been part of original structure or may have been added (using dowelled-in rebar) as part of a repair

Anchors
- Anchors for external PT bars tendons are on the ends of the furthest corbels (blisters) through which the bars pass or on the faces of diaphragms or deviator ribs.

(12) External PT strand tendons added since built as repair or rehab

Applies to
- Precast segmental balanced cantilever (pre and post 2001)
- Precast segmental span-by-span (pre and post 2001)
- Main span unit of span-by-span built in modified cantilever (pre and post 2001)
- Spliced I-Girder (pre and post 2001)
- Cellular box cast-in-place on falsework (pre and post 2001)

(It is technically feasible, but very unlikely, that external strand tendons would be used to longitudinally strengthen a precast prestressed concrete plank or double-T)

PT bar locations
- Strand tendons are usually straight but may be draped
- Pass through holes in diaphragms, ribs or corbels (blisters)
- Corbels or blisters may have been part of original structure or may have been added (using dowelled-in rebar) as part of a repair

Anchors
- Anchors for external strand tendons are on the ends of the furthest corbels (blisters) through which the strand tendon passes or on the faces of diaphragms or deviator ribs.

Transverse PT of Superstructures

Certain superstructure types contain some type of transverse post-tensioning. In all cases, (except repairs) transverse post-tensioning is internal. The types of superstructure that may contain transverse post-tensioning tendons includes
- Precast prestressed concrete planks – for transverse connection (strands or bars)
- Cast-in-place slabs (either solid or voided) (usually strands, could be bars)
- Double T's – for transverse connection (strands)
- Deck slabs of box girders – precast or cast-in-place (usually up to 4*0.6" strands)
- Diaphragms – lateral PT of box girder pier diaphragms (usually multi-strands)
- Diaphragms or anchor blocks - vertical post-tensioning (usually PT bars)
- Webs of large box girders - vertical post-tensioning (usually PT bars)

1.2.3 Diagnostics Typical of Bridge Type

Various symptoms of deficiencies characteristic of a particular bridge type and post-tensioning system are listed in Table 1.3. This table may be used as an aid to help confirm the type of structure and post-tensioning. It is also used as the basis for visual examination and inspection of structures that follows in Chapter 2.

1.2.4 Substructure Post-Tensioning Applications

In general, substructures are mostly built of reinforced concrete with no post-tensioning. However, post-tensioning finds application in some circumstances – usually, it is for a special reason – for example to enable a straddle beam to span a greater distance than one made solely of reinforced concrete – or, for example – to facilitate erection using precast components. Various types of substructure associated with a particular type of superstructure is summarized in Table 1.4

It should be noted that prior to the implementation of these new "Strategies" (2001) the use of post-tensioning in substructures was basically un-restricted to environmental type – i.e. post-tensioning tendons extend into foundations in some coastal structures (e.g. Skyway) and the applications are of a special nature. Subsequent to these new strategies, post-tensioning will no longer be used below 12 feet above water level in aggressive coastal environments or below 5 feet above ground level in less aggressive (inland) locations with the exception that post-tensioning bars of at least 1-1/2" minimum diameter may be used in columns and footings in the latter situation. Bars are more massive than strands and are less susceptible to some corrosion characteristics and behavior of strand tendons (for example - no potential "wick action" through interstitial gaps between wires).

Lateral post-tensioning

Internal strand-tendons or bars are often necessary for:

- Hammerhead column – cantilever caps
- Straddle beams - simply supported atop columns
- Confinement of caps – to contain local concentrated bearing reactions

Lateral and vertical post-tensioning

Internal strand or bar tendons are used in

- Cantilever C-Piers (cap, column and footing)
- Portal frames (monolithic straddle bent)

Except that only bars may now be used (post 2001) in columns and footings below 5 feet above ground level in non-aggressive environmental (land) sites

Vertical post-tensioning

Internal strand and bar tendons have been and may (occasionally) continue to be used in special applications comprising:

- Hollow precast piers
- Precast I-section piers
- Hollow reinforced piers (service crack control)

1.3 Procedure to Visually Identify Bridge Type and Post-Tensioning

How then to determine the type of bridge and post-tensioning? Refer to records and / or use the following visual inspection procedure.

1.3.1 Information Available from a Visual Inspection

A bridge type is described by the type of superstructure and method of construction. The latter usually determines the longitudinal post-tensioning. However, once built, it is not always immediately clear what type of construction was used.

Visual inspection immediately identifies whether the superstructure is a box section, I-girder, double-T or some type of slab (solid, voided or precast plank).

Since there are, for example, several possibilities for box section construction (precast segmental, balanced cantilever, span-by-span, cast-in-place cantilever or cast-in-place on falsework) a superficial glance will not necessarily reveal the original method of construction – particularly if the exterior is coated with a class-V finish. Nevertheless, a close examination of the top of the deck or the interior of a box, for epoxy or dry-joints between segments will immediately reveal if it is precast segmental. If there are no such joints, then it must be cast-in-place (either segmental cantilever or a box cast-in-place on falsework).

With the exception of external tendons, visual inspection does not immediately reveal the type of longitudinal post-tensioning and its location. Internal post-tensioning is hidden from view within the concrete. (Occasionally, it is possible to make out the image of tendons draped internal to the web of a precast-I girder by a color contrast in the concrete surface, possibly the result of form effects and concrete vibration as the concrete passed the ducts in the webs.) Even so, the types of post-tensioning tendons and locations within the superstructure are characteristic of the type of bridge and construction method.

Consequently, knowing the type of bridge reveals the construction method. The construction method reveals what types of tendons to expect and where to look. The type of bridge and tendons, in-turn, indicates what type of potential deficiencies to look for.

Although a visual inspection cannot necessarily reveal potential deficiencies hidden within the concrete – such as grout voids in ducts or corrosion of tendons – the visual evidence of such deficiencies reveals itself in ways that are characteristic of the different types of bridges and tendons. Consequently, even visual evidence of deficiencies helps identify a type of bridge.

In summary, a visual inspection reveals the type of superstructure and likely method of construction. This reveals what type of tendons may be present and where to look. The type of bridge and type of tendons reveals what type of evidence of deficiencies to look for. Seeking that evidence will, in turn, re-confirm the type of bridge.

1.3.2 Visual Identification of Superstructure Type

1. Follow the visual inspection Flowchart 1 “Identify Bridge Type by Superstructure” to identify the bridge type and likely post-tensioning.
    - Flowchart 1.1 is based on the information in Tables 1.1 and 1.2

2. Refer to Table 1.1 “Identify Bridge Type – Superstructure” to check the result of following Flowchart 1.1
    - Different types of post-tensioned superstructure and their predominant features are given in Table 1.1

- Note that the information in the top three categories (A, B and C) of Table 1.1 is usually sufficient to identify the superstructure using Flowchart 1.1
- Information on the depth of the superstructure (E) and span lengths (F) in Table 1.1 is for general guidance in so far as it applies to bridge types and approximate ranges given

3. Confirm the type of post-tensioning by reference to Table 1.2 "Identify Superstructure Post-Tensioning"
   - Different longitudinal and transverse post-tensioning associated with each type of superstructure is given in Table 1.2

4. Table 1.3 offers guidance on the types of deficiencies according to the type of bridge. If necessary, use this to help verify the bridge and PT type also.
   - This table is not intended for definitive identification of bridge type, but it offers indirect verification

5. Use Table 1.4 to identify the substructure according to the superstructure type

1.3.3 Substructures – typical of superstructure type

The type of substructure most commonly associated with the various types of superstructure is given in Table 1.4

Note that some applications of substructure types (for example cantilever C-piers) have not necessarily been used in Florida but they have been used in other places – particularly in urban interchanges and viaducts. Consequently, these are included in anticipation of future needs. In the table, these are identified as a "feasible technique that has been or may be used".

Also, it is conceivable that some types of substructure not normally used in conjunction with a particular type of superstructure could, technically, find occasional application. These are identified as a "feasible technique (but probably not or rarely used)".

When the superstructure type, post-tensioning type and substructure type has been identified, proceed with the inspection according to each "Strategy" – See Chapter 2.

TABLE 1.1 - IDENTIFY BRIDGE TYPE - SUPERSTRUCTURE

IDENTIFY BRIDGE TYPE - SUPERSTRUCTURE

Use this table to help identify the type of superstructure
from the available information or visual evidence

? = reliable indicator
no = does not exist (or is no longer used)
n/a = not applicable
msu = main span unit (or longest span)
maybe = a feasible technique that has been or could be used
possible = a feasible technique (but probably not or very rarely used)

		Precast Segmental Balanced Cantilever		Precast Segmental Span-by-Span		Spliced I-Girder	CIP Segmental Balanced Cantilever	Cast-in-Place on Falsework			Precast Pre-tens Concrete Planks	Precast Pre-tens Double T's
		Pre 2001	Post 2001	Pre 2001	Post 2001			Solid Slab	Voided Slab	Cellular Box		
SUPERSTRUCTURE												
Visual - From Exterior - (Non-Cable Stay)												
A Shape of Superstructure Section												
Large trapezoidal or rectangular box		?	?	?	?	no	?	no	no	?	n/a	n/a
Longitudinal I-Girders approx 6 to 11 ft apart		no	no	no	no	?	no	no	no	no	n/a	n/a
Shallow depth, slab like superstructure		no	no	no	no	no	no	?	?	?	?	n/a
Precast double-T section		no	no	no	no	no	no	no	no	no	no	?
Visual - From Outside or Inside Accessible Box Superstructure												
B Transverse Joints Between Segments or Pours												
Epoxy Joints (at 8 - 12 ft o/c ±)		?	?	no	?	n/a	no	no	no	no	n/a	n/a
Epoxy Joints (at 14 - 18 ft o/c +)		no	no	no	?	n/a	no	no	no	no	n/a	n/a
Dry Joints (at 14 -18 ft o/c ±)		no	no	?	no	n/a	no	no	no	no	n/a	n/a
Longit. reinf. constn (cold) joints (at 12 - 20ft o/c ±)		no	no	no	no	n/a	?	no	no	no	n/a	n/a
Occasional longit. reinf. construction (Cold) Joints		no	no	no	no	no	no	?	?	?	n/a	n/a
Visual - From Exterior or Inside Superstructure												
C Cast-in-Place Closure Joints (transverse)												
Approx at midspan and approx 1 to 16 ft long		?	?	no	no	n/a	?	no	no	no	n/a	n/a
At each end of span and approx 6" to 1 ft long		no	no	?	?	no	no	no	no	no	n/a	n/a
At diaphragm over interior piers of continuous unit		no	no	no	no	?	no	no	no	no	n/a	n/a
At drop-in-span splice (at 1/4 to 1/3rd span)		no	no	no	no	?	no	no	no	no	n/a	n/a
Over interior pier or end of a unit (narrow cip joint)		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?
D Cast-in-Place Closure Joints (longitudinal)												
Joining interior wings of parallel boxes		?	?	no	?	n/a	?	n/a	n/a	?	n/a	n/a
Joining longitudinal PPC planks or Double-T's		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?
Visual - From Exterior or Available from Plans												
E Depth of Superstructure (approximate)												
Approach or low level slab 1 to 2 ft deep		no	no	no	no	no	no	?	no	no	?	no
Approach or low level slab 2 to 4 ft deep		no	no	no	no	no	no	no	?	?	no	?
Approach spans - constant depth 5 to 10 feet		?	?	?	?	?	?	n/a	n/a	?	no	no
Main Span Unit - constant depth 6 to 12 feet		?	?	?	?	no	?	n/a	n/a	?	no	no
Main Span Unit - variable depth 6 to 15 ft approx		?	?	?	?	?	?	n/a	n/a	?	no	no
Main Span Unit - variable depth over 15 ft approx		no	no	no	no	no	?	n/a	n/a	no	no	no
F Span Lengths (approximate)	approx range											
Approach or low level slab structure	< 40 feet	n/a	n/a	n/a	n/a	n/a	n/a	?	n/a	n/a	?	?
Approach structure / or slab	40 to 70 feet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?	n/a	?
Straight approach or ramp structure	60 to 150 ft	?	?	?	?	?	?	no	no	?	n/a	n/a
Curved approach or ramp structure	70 to 200 ft	?	?	no	no	n/a	?	no	no	?	n/a	n/a
Main Span or Longest Span	< 100 ft	?	?	?	?	?	?	?	?	?	n/a	n/a
Main Span or Longest Span	90 - 150 ft	?	?	?	?	?	?	n/a	n/a	?	n/a	n/a
Main Span or Longest Span	120 - 250 ft	?	?	msu	msu	msu	?	n/a	n/a	?	n/a	n/a
Main Span or Longest Span	250 to 400 ft	?	?	no	no	no	?	n/a	n/a	no	n/a	n/a
Main Span or Longest Span	> 400 ft	no	no	no	no	no	?	n/a	n/a	no	n/a	n/a

TABLE 1.2 - IDENTIFY SUPERSTRUCTURE POST-TENSIONING

IDENTIFY SUPERSTRUCTURE POST-TENSIONING

This table may be used to help identify the most probable type of post-tensioning in the structure to be inspected

Note: for structures that combine different construction methods use indicators as appropriate
(For example - a mostly span-by-span structure that contains a main span unit partly built in cantilever)

? = reliable indicator
no or none = does not exist (or is no longer used)
n/a = not applicable
msu = main span unit (or longest span)
maybe = a feasible technique that may have been or could be used
possible = a feasible technique (but probably not or very rarely used)

	Precast Segmental Balanced Cantilever		Precast Segmental Span-by-Span		Spliced I-Girder	CIP Segmental Balanced Cantilever	Cast-in-Place on Falsework			Precast Pre-tens Concrete Planks	Precast Pre-tens Double T's
	Pre 2001	Post 2001	Pre 2001	Post 2001			Solid Slab	Voided Slab	Cellular Box		
Longitudinal Pre-Tensioned											
Prefabricated precast using strands	n/a	n/a	n/a	n/a	?	no	no	no	no	?	?
Longitudinal Post-Tensioning											
Internal PT											
1 Cantilever tendon anchored in recesses to top slab / web	?	no	msu	no	no	?	n/a	n/a	n/a	n/a	n/a
2 Cantilever tendon face-anchored in a recess within top slab	no	maybe	no	msu	no	maybe	n/a	n/a	n/a	n/a	n/a
3 Cantilever tendon anchored in blisters at top slab / web	?	?	msu	msu	no	?	n/a	n/a	n/a	n/a	n/a
4 Continuity PT anchored in blisters top or bottom	?	?	msu	msu	no	?	n/a	n/a	?	n/a	n/a
5 Draped in web (maybe feint image of ducts on surface)	n/a	n/a	n/a	n/a	?	no	n/a	n/a	n/a	n/a	n/a
6 Draped internal PT tendons	no	no	no	no	?	maybe	?	?	?	n/a	n/a
7 Temporary PT bars (stressed or not) left in ducts after constn	maybe	maybe	no	msu	no	maybe	n/a	n/a	n/a	n/a	n/a
8 Permanent internal PT bar (original construction)	?	?	no	msu	n/a	maybe	n/a	n/a	maybe	n/a	n/a
External PT - installed at time of construction											
9a PT in PE Pipes (connected to steel pipes)	no	?	?	?	no	maybe	no	no	maybe	no	no
9b PT anchors in diaphragms or ribs (when built)	no	?	?	?	no	maybe	no	no	maybe	no	no
9c Several deviator blocks at bottom web/slab per span	no	?	?	?	no	possible	no	no	maybe	no	no
9d Deviator ribs at approx 1/3 span	no	?	?	?	no	possible	no	no	maybe	no	no
10 Temporary PT bars (external into blisters or diaphragms)	?	?	msu	msu	no	n/a	no	no	n/a	n/a	n/a
External PT - added since built - as rehab or repair											
11 External PT bar tendon	?	maybe	?	maybe	?	maybe	no	no	?	possible	possible
12 External PT strand tendon	?	maybe	?	maybe	?	maybe	no	no	?	possible	possible
Transverse Prestress											
Transverse Pre-Tensioning											
Pre-tensioned strands to deck slab	none	maybe	? (c. 1980)	maybe	no	no	no	no	no	no	no
Internal Post-Tensioning (Typical)											
To top deck slab (up to 4 * 0.6 strands)	?	?	?	?	no	?	n/a	n/a	maybe	n/a	n/a
Lateral to diaphragms (multi-strands or bars)	?	?	?	?	maybe	maybe	n/a	n/a	?	n/a	n/a
Vertical to diaphragms (PT bars)	?	?	?	?	no	maybe	n/a	n/a	?	n/a	n/a
Vertical to webs (PT bars)	no	maybe	no	maybe	no	maybe	n/a	n/a	possible	n/a	n/a
Transverse to solid slab	n/a	n/a	n/a	n/a	n/a	n/a	maybe	n/a	n/a	n/a	n/a
Internal to PPC Planks and Double T's											
Strands (possibly up to 4*0.6")	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?
PT bars	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	no
External PT - added since built - as rehab or repair											
Vertical strands to web	?	possible	possible	possible	n/a	possible	n/a	n/a	possible	n/a	n/a
Vertical PT bars to web	possible	possible	possible	possible	n/a	possible	n/a	n/a	possible	n/a	n/a

TABLE 1.3 - DIAGNOSTICS TYPICAL OF BRIDGE TYPE (Visual Examination)

DIAGNOSTICS - TYPICAL OF BRIDGE TYPE
(May be used to assist in identification of bridge and PT type)
? = reliable indicator
no = no longer used
n/a = not applicable
msu = main span unit (or longest span)
? = Means either that there should not be or was not a problem before introduction of 2001 standards or there should not be any further symptoms after 2001 standards

	Precast Segmental Balanced Cantilever		Precast Segmental Span-by-Span		Spliced I-Girder	Cast-in-Place Segmental Cantilever		Cast-in-Place on Falsework			Precast Pre-tens Concrete Planks	Precast Pre-tens Double T's
	Built Pre 2001	Built Post 2001	Built Pre 2001	Built Post 2001		Built Pre 2001	Built Post 2001	Solid Slab	Voided Slab	Cellular Box (post 2001)		
#1 **ENHANCED POST-TENSIONING**												
External PT Ducts (holes / split ducts)	n/a	?	?	?	n/a	n/a	?	n/.a	n/a	?	n/a	n/a
#2 **FULLY GROUTED TENDONS**												
Longitudinal Post-Tensioning - Possible Grout Voids												
Internal PT - symptoms of incomplete grout												
Efflouresence and/or rust stains at/near internal PT ducts												
at match-cast joints	?	?	?	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
at closure pour joints	?	?	?	?	n/a	?	?	n/a	n/a	n/a	n/a	n/a
at construction joints with longitudinal rebar	n/a	n/a	n/a	n/a	n/a	?	?	?	?	?	n/a	n/a
at transverse crack in slab	?	?	?	?	n/a	?	?	?	?	?	n/a	n/a
at duct splices at cip joints	?	?	?	?	?	?	?	?	?	?	n/a	n/a
at longit cracks along internal tendon path	?	?	?	?	?	?	?	?	?	?	n/a	n/a
at vertical or diagonal web cracks at ducts	?	?	?	?	?	?	?	n/a	n/a	n/a	n/a	n/a
External PT - symptoms of incomplete grout												
Efflouresence and/or rust stains at/near external PT ducts												
at PT duct splices or neoprene boots	?	?	?	?	n/a	?	?	n/a	n/a	?	n/a	n/a
Other symptoms of incomplete grout (int'l or ext'l PT)												
Efflouresence and/or rust stains												
at cracks at / near PT anchors in diaphragms	?	?	?	?	?	?	?	n/a	n/a	?	n/a	n/a
at cracks in PT anchor blocks / blisters	?	?	?	?	?	?	?	n/a	n/a	?	n/a	n/a
at honeycombe at / near PT anchor blocks	?	?	?	?	?	?	?	?	?	?	n/a	n/a
at honeycombe at / near PT ducts	?	?	?	?	?	?	?	?	?	?	n/a	n/a
Transverse Post-Tensioning - Possible Grout Voids												
Efflouresence and/or rust stains at/near internal PT ducts												
at end anchors or pour-backs	?	?	?	?	n/a	?	?	n/a	?	n/a	?	?
at longitudinal joints at or near transverse ducts	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?
#3 **ANCHOR PROTECTION - Typical of Bridge Type**												
Longitudinal Post-Tensioning												
Internal PT												
Anchors buried in recess in or under deck	?	?	n/a	n/a	?	?	?	n/a	n/a	n/a	n/a	n/a
External PT												
Anchors under pourbacks at expansion joints	?	?	?	?	?	?	?	?	?	?	n/a	n/a
#4 **WATERTIGHTNESS**												
Leaks (through deck slabs and pour-backs)												
At Transverse Joints between Segments or Pours												
at epoxy joints before 2001 standards	?	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a
at epoxy joints after 2001 standards	n/a	?	?	?	n/a	n/a		n/a	n/a	n/a	n/a	n/a
at dry joints between precast segments	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a
at transverse longit. reinf. construction joints	n/a	n/a	n/a	n/a	n/a	?		?	?	?	n/a	n/a
At Cast-in-Place Closure Joints												
at midspan closure segment or joint	?	?	n/a	n/a	n/a	?		n/a	n/a	n/a	n/a	n/a
at cip joint at end of each span	n/a	n/a	?	?	n/a	n/a		n/a	n/a	n/a	n/a	n/a
at pour-back in cip closure segment or joint	?	?	?	?	n/a	?		n/a	n/a	n/a	n/a	n/a
at diaphragm over interior piers of continuous unit	n/a	n/a	n/a	n/a	?	n/a		n/a	n/a	n/a	n/a	n/a
at drop-in-span splice (at 1/4 to 1/3rd span)	n/a	n/a	n/a	n/a	?	n/a		n/a	n/a	n/a	n/a	n/a
over interior pier or end of a unit in narrow cip joint	n/a	n/a	n/a	n/a	?	n/a		n/a	n/a	n/a	?	?
Other leaks												
through (filled) holes used for construction purposes	?	?	?	?	n/a	?		n/a	n/a	?	n/a	n/a
at / around block-outs for PT anchors in top slabs	?	?	?	?	n/a	?		n/a	n/a	?	n/a	n/a
at / around access holes poured back	?	?	?	?	n/a	?		n/a	n/a	?	n/a	n/a
at transverse cracks in cast-in-place deck slab	n/a	n/a	n/a	n/a	?	n/a		n/a	n/a	n/a	n/a	n/a
#5 **MULTIPLE TENDON PATHS**												
(Not an applicable diagnostic)												

TABLE 1.4 - IDENTIFY BRIDGE TYPE - SUBSTRUCTURE

IDENTIFY BRIDGE TYPE - SUBSTRUCTURE

Use this table to help identify the most probable type of post-tensioned substructure

? = reliable indicator
no / none = does not exist (or is no longer used)
n/a = not applicable
msu = main span unit (or longest span)
maybe = a feasible technique that has been or could be used
possible = a feasible technique (but probably not or very rarely used)

	Precast Segmental Balanced Cantilever		Precast Segmental Span-by-Span		Spliced I-Girder	Cast-in-Place Segmental Cantilever		Cast-in-Place on Falsework			Precast Pre-tens Concrete Planks	Precast Pre-tens Double T's
	Pre 2001	Post 2001	Pre 2001	Post 2001		Pre 2001	Post 2001	Solid Slab	Voided Slab	Cellular Box		
SUBSTRUCTURE												
Substructures typical of superstructure type												
Pile bents	n/a	n/a	n/a	n/a	?	n/a	n/a	?	?	n/a	?	?
Multiple RC columns with cap beam	n/a	n/a	n/a	n/a	?	n/a	n/a	?	?	n/a	?	?
Single RC column with hammerhead cap	n/a	n/a	n/a	n/a	?	n/a	n/a	?	?	n/a	possible	possible
Single RC column with cap (straight or flared) or wall pier	?	?	none	?	n/a	?	?	maybe	maybe	?	possible	possible
Single precast segmental PT column (rect or oval) and cap	none	maybe	?	maybe	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Single precast segmental PT column (I-section) and cap	none	maybe	?	maybe	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Post-Tensioned straddle beam on columns (or frame)	none	maybe	none	maybe	n/a	maybe	maybe	n/a	maybe	maybe	n/a	n/a
Post-Tensioned C-pier	none	maybe	none	maybe	n/a	maybe	maybe	n/a	maybe	maybe	n/a	n/a
Substructure Post-Tensioning (not repaired structures)												
Pile bents	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Multiple RC columns with cap beam	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Single RC column with hammerhead cap												
PT to to hammerhead (across width of bridge)	n/a	n/a	n/a	n/a	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Single RC column with cap (straight or flared) or wall pier												
Confinement PT to bearing reactions	?	?	?	?	n/a	?	?	n/a	n/a	n/a	n/a	n/a
Single precast segmental PT column (rect or oval) and cap												
Lateral confinement PT (bars) to bearings	none	?	?	?	n/a	o	o	n/a	n/a	n/a	n/a	n/a
Vertical Internal or External PT strand tendons inside column	none	o	?	o	n/a	none	o	n/a	n/a	n/a	n/a	n/a
Single precast segmental PT column (I-section) and cap												
Vertical PT bars internal to concrete	none	o	?	o	n/a	none	o	n/a	n/a	n/a	n/a	n/a
Post-Tensioned straddle beam on columns (or frame)												
Lateral (internal PT) to full width of straddle bent	none	maybe	none	maybe	maybe	none	maybe	n/a	n/a	maybe	n/a	n/a
Post-Tensioned C-pier												
Internal vertical and horizontal PT	none	maybe	none	maybe	maybe	none	maybe	n/a	n/a	maybe	n/a	n/a

FLOWCHART 1.1 - IDENTIFY BRIDGE TYPE BY SUPERSTRUCTURE

IDENTIFY BRIDGE TYPE BY SUPERSTRUCTURE (by visual examination)

Note: for further detail, refer to Chapter 1.2 "Identification of Bridge Type and Post-Tensioning"
and 1.3 "Procedure to Visually Identify Bridge Type and Post-Tensioning"

Table 1.1 - Identify Bridge Type - Superstructure
Table 1.2 - Identify Superstructure Post-Tensioning
Table 1.3 - Diagnostics Typical of Bridge Type
Table 1.4 - Identify Bridge Type - Substructure

BEGIN

is section rectangular or trapezoidal box?
- No → go to 6
- Yes → go to 1

			Probable Bridge Type		Confirmation by Longitudinal PT	
1	Have transverse construction joints (reinforced) spaced at 12 to 20 ft intervals ?	Yes ---->	Cast-in-Place Balanced Cantilever	-->	Are there internal continuity PT tendons anchored in blisters at top and bottom corners inside box section?	Yes --> STOP; No - Go back and try again
2	Are there no or only occasional transverse (reinforced) construction joints ?	Yes ---->	Cellular Box Cast-in-Place on falsework	-->	Are longitudinal PT tendons internal to concrete and anchored at ends (at expansion joints)	Yes --> STOP; No - Go back and try again
3	Are there dry (no-epoxy) joints between precast concrete segments ?	Yes ---->	Precast Segmental Span-by-Span built before 2001	-->	Are longitudinal PT tendons draped external to the concrete but inside the box and anchored in diaphragms?	Yes --> STOP; No - Go back and try again
4	Are there epoxy joints and a (6"-12") transverse cast-in-place closure joint at each end of span?	Yes ---->	Precast Segmental Span-by-Span built after 2001	-->	Are longitudinal PT tendons draped external (but may enter the bottom slab) and anchor in diaphragms	Yes --> STOP; No - Go back and try again
5	Are there epoxy joints between segments and a CIP closure at or near midspan ?	Yes ---->	Precast Segmental Balanced Cantilever	-->	Are there internal continuity PT tendons anchored in blisters at top and bottom corners inside box section?	Yes --> STOP; No - Go back and try again

From 1 to 2: ↓; from 2, 3, 4: No ↓; from 5: No ↓

You should not be here Go back and start over!

			Probable Bridge Type		Confirmation	
6	Is section made of I-Girders spaced at intervals of 6 to 11 ft ?	Yes ----->	Spliced I-Girder	-->	Are there cast-in-place splice joints either over the piers or at approx. 1/4 to 1/3 points of span?	Yes --> STOP; No - Go back and try again
7	Is Section a Double-T ?	Yes ----->	Precast prestressed Double-T with transverse PT	-->	Are there longitudinal cast-in-place (narrow) joints between double-T's (spans approx in range 40 to 70 ft)	Yes --> STOP; No - Go back and try again
8	Is structure slab-like, 15" to 20" deep with longitudinal narrow cip joints spaced at 3' to 5'?	Yes ----->	Precast prestressed concrete planks with transverse PT	-->	Spans range up to approx 40 ft	Yes --> STOP; No - Go back and try again
9	Is structure slab-like and in the range of 2 to 4 ft deep ?	Yes ----->	Voided Slab	-->	Spans range approx 40 to 70 ft	Yes --> STOP; No - Go back and try again
10	Is structure slab-like 16" to 24" deep with occasional (reinf) construction joints ?	Yes ----->	Solid Slab	-->	Spans range approx up to 40 ft	Yes --> STOP; No - Go back and try again

From 10: No ↓

You should not be here Go back and start over!

Chapter 2 – Inspection Procedures

Chapter 1 presented the need to maintain a good set of construction records for post-tensioned structures, along with photographic or video information, to help identify potential problem areas from one inspection to the next. In the absence of these records, a process was also presented in Chapter 1 to enable the type of structure and post-tensioning to be identified “visually” by reference to key features and characteristics of post-tensioned bridges found in Florida (Flowchart 1.1). These key features primarily focus on the superstructures (cross section types, typical span ranges and type of post-tensioning). Substructures vary according to the type of superstructure and site application. However, use of post-tensioning in substructures is limited to a relatively few types of applications that are a function of the site and environment or a consequence of the chosen construction method. In general, most substructures are of reinforced rather than post-tensioned concrete.

The initial identification of the type of structure and post-tensioning is paramount to the inspection process. All subsequent inspection procedures in this Chapter follow in sequence according to the five strategies developed to produce more durable post-tensioned bridges in Florida:

Section 2.1	Strategy #1	Enhanced Post-Tensioning
Section 2.2	Strategy #2	Fully Grouted Tendons
Section 2.3	Strategy #3	Multi-Level Anchor Protection
Section 2.4	Strategy #4	Watertight Structures
Section 2.5	Strategy #5	Multiple Tendon Paths

The first inspection procedure involves checking that the post-tensioning satisfies the intent of the criteria for “Enhanced Post-Tensioning Systems”. Inspection then proceeds according to each of the above, culminating with that for “Multiple Tendon Paths”. If a structure satisfies all the strategies then no further action such as repair, rehabilitation or the addition of extra post-tensioning is necessary. On the other hand, if the strategies are not satisfied then, appropriate action, based on engineering and economic principles, should be taken. It is important to remember that reviews of this nature do not necessarily address other aspects of Florida’s post-tensioned bridges. Each post-tensioned bridge should still be inspected on a regular (biennial) basis in accordance with the Departments inspection policy.

Even though each routine biennial inspection may not necessarily include a complete inspection of the post-tensioning system, the Inspector should maintain a heightened sense of awareness for any signs of corrosion, because defects may exist and corrosion may proceed with no visual indication whatsoever.

If there is no visual evidence of defects or corrosion after a number of years in service, it would be appropriate to perform a limited invasive inspection on a representative sample (at most 5%) of apparently sound tendons or anchors as part of a special “in-depth inspection” specifically scheduled for the purpose. The need for this “in-depth” inspection should be determined by the Maintenance Engineer based upon the history of the bridge and the performance of similar bridges of similar design and construction. (It is recommended that such inspection be scheduled and budgeted according to the needs per District.)

2.1 Enhanced Post-Tensioning Systems

This inspection procedure provides overall guidance to assess the integrity of existing post-tensioned bridges in relation to the new standards or "Strategies" for post-tensioned structures established in 2001.

It describes the types of deficiencies to look out for and offers direction for follow-up action such as further investigation or repair, by reference to other inspection, assessment and repair procedures within this document as appropriate.

The three levels of protection depend upon the type of structure and, particularly the post-tensioning tendon – primarily whether the tendon is internal or external to the concrete.

For internal tendons the three levels of protection are:

- Grout – a fully grouted tendon
- Duct – a continuous, impervious duct
- Cover – a sufficient thickness of sound concrete cover over the duct – or a well sealed joint between precast or cast-in-place segments

For external tendons (outside the concrete but within the interior of a hollow box structure) the three levels of protection are:

- Grout – a fully grouted tendon
- Duct – a continuous, impervious duct
- Cover – a surrounding watertight, well-drained box structure

2.1.1 Tendon Protection

From records, identify when the structure was built. If the structure was built prior to 2001, then the tendon protection system is most probably comprised of:

- Grout: Ordinary Portland cement grout mixed with water only with no special additives to reduce bleed of air or water. The grout probably contains voids. The location of the voids depends upon the type of tendon and tendon profile.

- Ducts for Internal Tendons: Ducts for longitudinal tendons are typically spiral wound galvanized steel. Ducts for transverse tendons are typically either spiral wound galvanized steel or HDPE plastic.

- Ducts for External, Longitudinal Tendons: HDPE (black plastic) schedule 40 pipe in external portion connected using a neoprene sleeve (boot) to steel duct – of schedule 40 steel pipe (usually galvanized) but might also be galvanized spiral wound duct in a few cases. These early external HDPE pipe ducts tend to split eventually (after some years) leaving the grout or strand exposed to the atmosphere inside the box structure.

- Concrete cover: Cover should be to FDOT criteria or standards at the time of construction.

- Epoxy joints between precast segments: Joints may have insufficient epoxy to create effective seal and may leak. This is evidenced by water stains on the undersides of the top and bottom slabs (for example see – Figure 1.12 Volume 1)

- Dry joints (no epoxy) between precast segments: Most joints leak due to ineffective seal strip in top slab joint. Dry joints were used only with external tendons that do not pass internally through a non-epoxy joint.

If the structure was built after 2001 then tendon protection should comprise:

- Grout: Special FDOT approved no-bleed, no-shrink, grout mixed with water. Grout includes additives to eliminate or very significantly reduce bleed of air or water and injected under carefully controlled conditions. The grout should not contain any significant voids.

- Ducts for Internal Tendons: Ducts for longitudinal and transverse tendons are HDPP plastic with sealed splices and joints.

- Ducts for External, Longitudinal Tendons: HDPE (black plastic pipe to ASTM D 3350 with a Hydrostatic Design Basis of 1600 psi and DR $\geq$ 17) external portion connected by neoprene sleeve to schedule 40 galvanized steel pipe embedded in concrete.

- Concrete cover: Cover should be to FDOT criteria or standards at the time of construction.

- Epoxy joints between precast segments: Joints must have sufficient epoxy to create an effective seal so as not to leak either water or grout. Epoxy is applied to both faces of precast segments at time of erection.

- Dry joints (no epoxy): This practice of using dry joints is no longer allowed in Florida. All joints between precast segments must have two-face epoxy application.

With the foregoing information, plan any new inspection with regard to the type of structure and type of post-tensioning.

2.1.2 Applicability

This procedure applies to all internal and external longitudinal superstructure tendons, transverse tendons and tendons in substructures for the various types of post-tensioned bridges used in Florida

2.1.3 Procedure

Use the following procedure to assess the post-tensioning system:

- Retrieve records and examine the post-tensioning details of the as-built bridge. Special attention should be given to note the corrosion protection system that was used at the time of construction.

- Follow Flow Chart 2.1 for Enhanced Post-Tensioning and perform field verification of the post-tensioning in the structure. Examine the structure and the post-tensioning tendons in particular for any deficiencies that could breach the integrity of the existing corrosion protection system. Refer also to Appendix A for cracks that might affect the tendons

- Verify whether or not the corrosion protection system is in compliance with the new (2001) requirements for three levels of corrosion protection. If it is not then repair, rehabilitation or even extra tendons might be needed - all according to various Repair Procedures of Chapter 4

- Prepare a photographic or video record of the field investigation.

Breaches of the above required three levels of protection commonly arise from:

- Improperly sealed joints between precast segments (e.g. Figure 1.12 Volume 1)
- Improperly sealed joints between cast-in-place segments or portions of structures
- Shrinkage cracks between different pours of concrete (e.g. in deck slabs on spliced I-girder bridges)
- Shrinkage cracks to pour-backs to anchor or access block-outs, or of concrete filler to holes used for attaching lifting devices during construction, etc
- Honeycombed concrete – particularly around ducts and congested anchorage zones (In most casts, honeycombed concrete is either rejected or repaired during construction)
- Damaged or discontinuous ducts - prior to these new strategies (2001):
  - Internal ducts stopped each side of segment joints in precast segmental bridges and most longitudinal internal ducts in all bridges comprised galvanized spiral wound steel with impervious seams.
  - External tendons – some cases, High Density Polyethylene Pipe ducts for external tendons had thin walls, material of lower strength and properties sometimes susceptible to changes in temperature that led, over time, to longitudinal splits. In addition, in an obvious attempt to check that the ducts were full of grout, many external tendon pipes had been deliberately punctured with nails. These left holes, which although plugged by a nail or filler, allowed water to penetrate and create a local corrosion spot. The punctures also encouraged more splits. Consequently, such practice is no longer allowed. In addition, new HDPE pipes must be to a higher thickness and quality. Otherwise, external tendon systems offer significant benefit for ease of maintenance inspection and can be easily replaced in the event of a damaged or corroded tendon. Greater use of external as opposed to internal tendons is encouraged in future.
- Cracks (induced by various means – some structural) that breach the concrete cover to the ducts. Cracks are significant not only to the potential breach of the protection to the tendons, but also to the general structural integrity and performance. They arise from a variety of sources and have many different implications.

  The subject of cracks is extensive and cannot be comprehensively addressed in this relatively short introductory procedure for the inspection of bridges. Consequently, an entire section on cracking in structures is provided in Appendix A. The reader is encouraged to examine this Appendix to become familiar with the types of cracks that seem to occur most often - particularly in post-tensioned concrete superstructures.

2.2 Fully Grouted Tendons (Evidence of Incomplete Grout or Corrosion)

This procedure involves the identification of tendon locations, visual inspection for evidence of grout voids, determination if that evidence is significant as regards indicating a void and the assessment of the likelihood of grout voids in the tendons. Also given is an indication of the possible follow-up action such as further investigation of possible corrosion and / or repair.

2.2.1 Existing Records

This procedure applies to all internal and external tendons in all post-tensioned bridges types.

It is assumed that the type of structure and type of post-tensioning has already been identified using preparatory procedures:

Chapter 1.2 - ***Identification of Bridge Type and Post-Tensioning***
Chapter 1.3 - ***Procedure to Visually Identify Bridge Type and Post-Tensioning***

2.2.2 Procedure

Identify on the structure, the locations of the post-tensioning tendons and their anchors - if necessary, plot and mark locations of tendons on the structure for record, photographic or video record and reference.

Follow Flowchart 2.2 “Fully Grouted Tendons” and perform visual inspection (at close range) for evidence of incomplete grouting referring to the evidence for the type of structure and type of post-tensioning listed in:

Table 2.1 – Evidence of Incomplete Grout – Superstructures - Longitudinal PT
Table 2.2 – Evidence of Incomplete Grout – Superstructures - Transverse PT
Table 2.3 – Evidence of Incomplete Grout – Substructures

Compare current inspection with records, photographs and video from previous inspections to determine if evidence is static or getting worse.

Note and record any changes – such as the appearance of efflorescence (for example, Figure 2.1) or an intensifying rust stain or both (for example, Figure 2.2) – so that the need for further detailed inspection and appropriate action can be assessed and taken (below).

In making comparisons from one inspection to another, it is important to know what the structure looked like originally, just after completion. For example, in some cases, when anchorages or reinforcement remained exposed in precast components during storage, rain will have made rust stains on the concrete. Rust stains may also arise from the use of steel forms. Consequently, all such stains must first be identified and eliminated as evidence of long-term corrosion of any post-tensioning.

If there is doubt, then either photograph (in color) the stains or efflorescence and mark and date their extent on the part of the structure at one inspection and then look for changes at the next. Alternatively, clean off the stains *at the first inspection* and examine the area for any returning evidence at the next inspection.

Figure 2.1 – Efflorescence (example - from cracks through a deck slab)

Figure 2.2 – Efflorescence and rust emanating from defect along tendon path in a web

If this is the first inspection or if no previous records, photographs or video are available for comparison then make appropriate records during this inspection.

It is necessary to decide on the basis of the evidence, if there are any grout voids.
This depends upon the significance of the evidence – particularly visual evidence.

Visual evidence (i.e. efflorescence and / or rust stains) is significant if it is easily noticed and is visibly different (worse) than previous records. It is also significant if there is visible water flow or seepage during or after rain when associated with other evidence.

However, first, it is important to eliminate the possibility of false visual evidence – in particular, old rust stains from storage or construction and decide if the stain should be counted as significant evidence or not for the current inspection and assessment – as follows:

- If a rust stain has appeared or re-appeared since a previous inspection when it is known for certain that there was no stain or the stain had previously been cleaned off, then count the rust stain as significant for the current assessment.

- If it is not known that a rust stain is new and yet it appears to come from a source such as an active leak in a tendon or at an anchor and, particularly if it is associated with efflorescence at the same location, then count the stain as significant for the current assessment.

- If it is not known that a rust stain is new and there appears to be no associated efflorescence, then make a record of the fact for this inspection. If this is the first inspection then record the location, extent and color intensity by photograph or video for future reference. Then, only if this is the first inspection, clean off* rust stain and any efflorescence. Do not count the rust stain as significant for the current assessment.

(*To clean off a rust stain or efflorescence, use wire brushing or very light sand-blasting and wash with water. Alternatively, use an approved rust-stain remover or an approved detergent for removing efflorescence according to FDOT QPL.)

2.2.3 Assess Significance of Visual Inspection and Follow-Up

Using the above criteria for the significance of the visual evidence, and using the guide from Tables 2.1, 2.2, 2.3 for the type of structure and type of tendon then, for the current inspection, the indications of a grout void are assessed thus:

(A) If any one of the visual items ((a) through (l)) (in these tables) is noticed it is a sign of a possible grout void. Re-examine the area closely to be sure of the visual evidence and make a record for future inspection and assessment.

Follow-up action - no further action is necessary for this inspection. However, if this is the second (or later inspection) after the first discovery this one item and if there is no change for the worse – then drill an inspection port, (check with borescope to make sure strand are OK) and grout any void using vacuum grouting.

(B) If two or more of the items ((a) through (l)) (in these tables) are noticed within one tendon or within a group of tendons at a location in the structure and if there is efflorescence (but not rust) then a grout void is very probable.

Follow up action during this inspection - check the evidence and make a visual inspection of the associated anchors for loss of protection or water seepage or leaks.

If the tendon is an internal tendon in a deck slab, bottom slab or web, simple sounding techniques - using light taps with a hammer or dragging a chain across the surface – may be used to sound for hollowness to confirm presence of voids (i.e. items (n) and (o) of Table 2.1). Note that such simple sounding is not fully reliable and only offers an indication.

If the tendon is external simple tapping of the duct may reveal the presence of grout voids by a hollow sound (item (p)). However, this is far from reliable.

Further investigation – perform invasive investigation using a bore-scope to check if there is a void and if the tendon is coated with grout. This may be done as part of this current inspection or may be carried out at a separate, later time. (Also, a pressure test may be appropriate to verify the volume of the grout void – but this could be done as part of the grouting repair.)

If there is no evidence of corrosion of the tendon, then fill voids with grout and seal all ports and vents. Restore any anchor protection. If the tendon is in the deck and if deemed necessary, seal the deck using the appropriate procedures.

(C) If rust stains coming from a tendon or group of tendons are associated with efflorescence at that location then there is a grout void and the tendon itself might be corroding (Figure 2.2). Corrosion products can also come from internal metal ducts or rebar, particularly at honeycombed areas. However, the tendon may not have corroded sufficiently to have failed or be considered lost.

Further investigation: perform further invasive investigation using a bore-scope to confirm the voids and degree of corrosion of the tendons.

2.2.4 Corrosion

Assess evidence for corrosion with respect to the allowable limit found by following Flowchart 3.1 “Evaluate Corrosion” and the Assessment Procedures:

3.1 ***Assess Internal Tendon (at location in length)***
3.2 ***Assess External Tendon (at location in length)***
3.3 ***Assess Tendon at Anchor (Internal or External)***
3.4 ***Assess Overall Level of prestress***

If the corrosion of the tendon (loss of wires) is less than the acceptable limit, then fill voids with grout and seal all ports and vents. Restore any anchor protection. If the tendon is in the deck and if deemed necessary, seal the deck using the appropriate procedures (as necessary).

If the overall global corrosion condition is satisfactory (according to 3.4), then determine the repair procedure to use for grouting anchor and tendon given according to the above assessment procedures. Then grout tendon voids and any anchor voids and restore anchor protection using the appropriate repair procedures (as necessary).

If the corrosion of the tendon is greater than the acceptable limit (according to 3.4) it may be necessary to carry out further investigation. This is optional and depends on the evidence. In any case, it will be necessary to expedite a structural analysis to determine the need to add supplementary PT or replace tendons. Refer to Engineer.

2.2.5 Repair Procedures

Use the following Repair Procedures to make repairs to invasive inspection ports.

Grouting Procedures:

4.8 Inject Grout to Fill a Long Void in an Internal Duct
4.9 Vacuum Inject Grout into Local Void of Internal Tendon
4.10 Vacuum Inject Grout at an Anchor
4.11 Grout Multiple Duct Voids with Cross Communication
4.12 Seal Grout Ports and Vents

Anchor Protection Procedures:

4.13 Restore Anchor Protection (to Directly Accessible Anchors)
4.14 Locally Repair Anchor Protect

2.3 Anchor Protection

This procedure involves the inspection of post-tensioning anchors for evidence of loss of anchor protection (also grout voids) and determination if that evidence is significant. Also included is an indication of the possible follow-up action such as further investigation and/or repair.

2.3.1 Applicability

This procedure applies to all internal and external tendons in all post-tensioned bridges types.

It is assumed that the type of structure and type of post-tensioning has already been identified using preparatory procedures:

Chapter 1.2 - ***Identification of Bridge Type and Post-Tensioning***
Chapter 1.3 - ***Procedure to Visually Identify Bridge Type and Post-Tensioning***

2.3.2 Procedure

Identify on the structure, the locations of the post-tensioning tendons and their anchors - if necessary, plot and mark locations of tendons on the structure for record, photographic or video record and reference.

Follow Flowchart 2.3 “Anchor Protection” and perform visual inspection (at close range) for evidence of loss of anchor protection with reference to the evidence for the type of structure and type of post-tensioning listed in:

Table 2.4 – Anchor Protection – Superstructures	- Longitudinal PT
Table 2.5 – Anchor Protection – Substructures	- Transverse PT
Table 2.6 – Anchor Protection – Substructures	- Lateral and Vertical PT

Compare current inspection with records, photographs and video from previous inspections to determine if evidence is static or getting worse.

Note and record any changes – such as an intensifying rust stain and the appearance or growth of efflorescence – so that the need for further detailed inspection and appropriate action can be assessed as appropriate (below).

In making comparisons from one inspection to another, it is important to know what the structure looked like originally, just after completion. For example, in some cases, when anchorages or reinforcement remained exposed in precast components during storage, rain will have made rust stains on the concrete. Rust stains may also arise from the use of steel forms. Consequently, all such stains must first be identified and eliminated as evidence of long-term corrosion of any post-tensioning.

If there is doubt, then either photograph (in color) the stains or efflorescence and mark and date their extent on the part of the structure at one inspection and then look for changes at the next. Alternatively, clean off the stains *at the first inspection* and examine the area for any returning evidence at the next inspection.

If this is the first inspection or if no previous records, photographs or video are available for comparison then make appropriate records during this inspection. Remove rust stains if this is the first inspection before making the photographic or video record.

2.3.3 Assessment of Anchor Protection

It is necessary to decide, on the basis of the evidence, if there is a significant loss of anchor protection. Refer to Tables 2.4, 2.5, 2.6 and select which of the indicators applies, if any, to a given anchor and then assess as follows:

- If there is only one of the reliable indicators (items (a) through (h) in Tables 2.4, 2.5, and 2.6) for evidence of loss of anchor protection, and providing that there is no other visual evidence (items (i) through (l)), that might indicate loss of grout or corrosion of the tendon, then clean and repair local anchor protection. Follow Repair Procedure: **4.14 - *Locally Repair Anchor Protection.***

- If there are two or more of the reliable indicators (items (a) through (h)) for evidence of loss of anchor protection – but with no other visual evidence that might indicate loss of grout or corrosion of the tendon (i.e. items (i) through (l));

  Or,

If there is one or more of the reliable indicators (items (a) through (h) for loss of anchor protection and if there is one or more "other visual evidence" (items (i) through (l));

Or,

If there is otherwise significant evidence for a possible grout void as indicated by Inspection Procedure 2.2 "Fully Grouted Tendons" for evidence of incomplete grout or corrosion (Flowchart 2.2) and Tables 2.1, 2.2, 2.3:

Then, perform an invasive (borescope) examination and assess any corrosion as detailed in the following section.

2.3.4 Assess Tendon at Anchor

- Remove anchor protection and pour-back (if possible) to expose anchor or create an inspection port at the anchor by drilling. (Follow Repair Procedure: **4.6 - *Create Grout Port or Inspection Port at Anchor***)

- Perform a bore-scope inspection for grout void and or corrosion of tendon

- Assess evidence for corrosion – (Follow Assessment Procedure: **3.3 - *Assess Tendon at Anchor* (Internal or External)).**

- Assess overall integrity level of prestress with regard to the allowable limits for loss to corrosion given in Inspection and Assessment Procedure: **3.4 - *Assess overall integrity of level of prestress*).**

- If the loss to corrosion is less than the allowable limit, then determine which procedure to use for grouting anchor by reference to Section 3.3 ***Assess Tendon at Anchor.*** Grout anchor and tendon, seal grout ports and vents and restore anchor protection by following the appropriate Repair Procedures (below)

- If the loss to corrosion is greater than the allowable limit, then have a qualified Engineer (PE) examine results

- If the Engineer determines that the loss to corrosion is acceptable, then proceed with grouting, seal of ports and vents and restoration of anchor protection.

- If the Engineer determines that the loss to corrosion is not acceptable, then he may decide to pursue further corrosion investigation or expedite a structural analysis to determine the need to add or replace tendons and then implement the necessary repairs.

2.3.5 Repair Procedures

Use following repair procedures detailed in Chapter 4, as necessary.

Grouting Procedures:

4.8 Inject Grout to Fill a Long Void in an Internal Duct
4.9 Vacuum Inject Grout into Local Void of Internal Tendon
4.10 Vacuum Inject Grout at an Anchor
4.11 Grout Multiple Duct Voids with Cross Communication
4.12 Seal Grout Ports and Vents

Anchor Protection Procedures:

4.13 Restore Anchor Protection (to Directly Accessible Anchors)
4.14 Locally Repair Anchor Protection

2.4 Watertight Structures

This procedure is to guide the inspection for evidence of water leaks and to determine the appropriate repair procedures.

2.4.1 Applicability

- All post-tensioned structures
- All types of post-tensioning
- Superstructure and substructure

2.4.2 Procedure

Follow the Flow Chart for each type of structure and refer to Tables 2.7 and 2.8 for evidence of water leaks associated with various types of superstructure and substructure respectively.

Implement repairs as indicated in the Flowchart for each type of structure.

Repair action is based upon the general Strategy #4 that structures must be watertight and well drained in order to prevent leaks into tendons, anchors or components that might lead to corrosion of the post-tensioning.

Appropriate repairs involve:

- Sealing of joints – whether between precast segments or ordinary reinforced construction joints
- Sealing of cracks that arise from various causes (see Appendix A)
- Cleaning or installing new drains to prevent water accumulating inside hollow structures Sealing of surfaces
- Installing drip flanges or weather baffles at expansion joints (and, when necessary, the replacement of leaky expansion joint devices) as necessary.

2.5 Inspect for Multiple Tendon Paths

Purpose of this procedure is to determine if an existing structure satisfies the new criteria (2001) for multiple tendon paths. This procedure should be carried out by a qualified Registered Engineer, experienced in the design and construction of post-tensioned bridges.

2.5.1 Applicability

This inspection is applicable to all post-tensioned bridges.

2.5.2 Procedure

- Retrieve records and examine the post-tensioning details of the as-built bridge. Special attention should be given to the number, type, and size of the post-tensioning tendons in the bridge.
- Follow Flow Chart 2.10 for Multiple Tendon Paths and perform field verification of the structure.
- Compare the available records information with the field verification to finalize the assessment of the post-tensioning layouts.
- Compare the post-tensioning layouts to “Strategy” (#5) for Multiple Tendon Paths of **Volume 2 - Design and Detailing of Post-Tensioning in Florida Bridges**.
- If the existing post-tensioning layouts do not meet the Volume 2 requirements, consult with the FDOT Structures Design Office to determine if the structure should be retrofitted with additional post-tensioning.

TABLE 2.1 EVIDENCE OF INCOMPLETE GROUT SUPERSTRUCTURES - Longitudinal PT

SUPERSTRUCTURES - LONGITUDINAL PT — **Superstructure Types**

Detection of grout voids / corrosion

n/a = not applicable or not appropriate
? = reliable indicator
o = tentative indicator / not always suitable methoc concrete may be too massive to give result - etc

	Precast Balanced Cantilever		Precast Span-by-Span		Spliced I-Girder with Cast-in-Place Deck		CIP BC		Cast-in-Place on Falsework			
									Solid Slab	Voided Slab	Cellular Box	
TENDON TYPE =	Internal	External	Internal	External	Internal	External (repair)	Internal	External	Internal	Internal	Internal	External
Visual evidence of incomplete grouting - look for Efflorescence and / or Rust Stains or water leaks												
a at match-cast joints at or near internal PT ducts	?	n/a	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
b at closure pour joints at or near internal PT ducts	?	n/a	?	n/a	n/a	n/a	?	n/a	n/a	n/a	n/a	n/a
c at construction joints with rebar at or near internal PT ducts	n/a	n/a	n/a	n/a	n/a	n/a	?	n/a	?	?	?	n/a
d at cracks in slabs at or near internal PT ducts	?	n/a	?	n/a	n/a	n/a	?	n/a	?	?	?	n/a
e at external PT duct splices or boots	n/a	?	n/a	?	n/a	?	n/a	?	n/a	n/a	n/a	?
f at internal PT duct splices at cast-in-place joints	?	n/a	?	n/a	?	n/a	?	n/a	?	?	?	n/a
g at longitudinal cracks along internal PT tendon path	?	n/a	?	n/a	?	n/a	?	n/a	?	?	?	n/a
h at vertical or diagonal web cracks at ducts	?	n/a	?	n/a	?	n/a	?	n/a	n/a	n/a	?	n/a
i at cracks at or near PT anchors in diaphragms	?	?	?	?	?	?	?	?	n/a	n/a	?	?
j at cracks in PT anchor blocks or blisters	?	?	?	?	?	?	?	?	n/a	n/a	?	?
k at honeycomb concrete at or near PT anchor blocks	?	?	?	?	?	?	?	?	?	?	?	?
l at honeycomb concrete at or near PT ducts	?	?	?	?	?	?	?	?	?	?	?	?
Other evidence - look for												
m Water leaks indicating cross-grout communication at joints	?	n/a	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evidence by Simple Souding Techniques*												
n Hollow sound when lightly tap surface at tendon locations	o	n/a	o	n/a	o	n/a	o	n/a	n/a	n/a	o	n/a
o Hollow sound when drag a chain across top surface	o	n/a	o	n/a	n/a	n/a	o	n/a	n/a	n/a	o	n/a
p Hollow sound when lightly tap external duct	n/a	o	n/a	o	n/a	o	n/a	o	n/a	n/a	n/a	o
(*these are only indications - not fully reliable methods)												
Evidence by Sound Instrumentation Methods												
q Ultrasonic - to reveal delamination or spall (not grout void)	?	n/a	?	n/a	?	n/a	?	n/a	n/a	n/a	o	n/a
r Ultrasonic - to reveal grout void	o	n/a	o	n/a	o	n/a	o	n/a	n/a	n/a	o	n/a
s Impact echo - to reveal void not corrosion. NG with plastic duct	?	n/a	?	n/a	?	n/a	?	n/a	o	n/a	o	n/a
Evidence by Vibration Measurement and Analysis												
t grout void - measure / analyze frequency of vibration of external PT	n/a	?	n/a	?	n/a	o	n/a	?	n/a	n/a	n/a	?
u corrosion - fracture of wires or loss of force	n/a	?	n/a	?	n/a	o	n/a	?	n/a	n/a	n/a	?
Evidence by Magnetic Flux Exclusion - Detect Corrosion												
v External tendons only - can access about 75 to 85% of length of exposed ducts - can detect corrosion defects	n/a	?	n/a	?	n/a	?	n/a	?	n/a	n/a	n/a	?

TABLE 2.2 EVIDENCE OF INCOMPLETE GROUT - SUPERSTRUCTURES - Transverse PT

SUPERSTRUCTURES - TRANSVERSE PT

Detection of grout voids / corrosion

n/a = not applicable or not appropriate
? = reliable indicator
o = tentative indicator / not always suitable method / concrete may be too massive to give result - etc

	Deck slab of Precast Segmental Box	Deck slab of CIP Segmental Box	Trans PT to diaphragm of seg box	Trans PT to diaphragm I-girders	Vertical PT to diaphragm of seg box	Vertical PT to diaphragm of seg box	Vertical PT to webs of seg box	Vertical PT to webs of seg box	CIP on Falsework Transverse (horizpntal) PT solid slab	voided slab	cellular box deck slab	Precast PS Conc Plancks	Trans PT to Double T's
Tendon Type =	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal
Visual evidence of incomplete grouting - look for Efflorescence and / or Rust Stains or water leaks													
a at match-cast joints at or near internal PT ducts	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
b at closure pour joints at or near internal PT ducts	?	?	n/a	n/a	n/a	n/a	n/a	n/a	?	?	?	?	?
c at construction joints with rebar at or near internal PT ducts	?	?	n/a	n/a	n/a	n/a	n/a	n/a	?	?	?	?	?
d at cracks in slabs at or near internal PT ducts	?	?	n/a	n/a	n/a	n/a	n/a	n/a	?	?	?	?	?
e at external PT duct splices or boots	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
f at internal PT duct splices at cast-in-place joints	?	?	n/a	n/a	n/a	n/a	n/a	n/a	?	?	?	?	?
g at longitudinal cracks along internal PT tendon path	?	?	?	?	?	?	?	?	?	?	?	?	?
h at vertical or diagonal web cracks at ducts	n/a	n/a	?	?	?	?	?	?	n/a	n/a	n/a	n/a	n/a
i at cracks at or near PT anchors in diaphragms	?	?	?	?	?	?	?	?	?	?	?	?	?
j at cracks in PT anchor blocks or blisters	?	?	?	?	?	?	?	?	?	?	?	?	?
k at honeycomb concrete at or near PT anchor blocks	?	?	?	?	?	?	?	?	?	?	?	?	?
l at honeycomb concrete at or near PT ducts	?	?	?	?	?	?	?	?	?	?	?	?	?
Other evidence - look for													
m Water leaks indicating cross-grout communication at joints	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?
Evidence by Simple Souding Techniques*													
n Hollow sound when lightly tap surface at tendon locations	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
o Hollow sound when drag a chain across top surface	o	o	n/a	n/a	n/a	n/a	n/a	n/a	o	n/a	o	o	o
p Hollow sound when lightly tap external duct	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(*these are only indications - not fully reliable methods)													
Evidence by Sound Instrumentation Methods													
q Ultrasonic - to reveal delamination or spall (not grout void)	o	o	n/a	n/a	n/a	n/a	o	o	o	o	o	n/a	n/a
r Ultrasonic - to reveal grout void	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
s Impact echo - to reveal void not corrosion. NG with plastic duct	o	o	n/a	n/a	n/a	n/a	o	o	o	o	o	o	o
Evidence by Vibration Measurement and Analysis													
t grout void - measure / analyze frequency of vibration of external PT	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
u corrosion - fracture of wires or loss of force	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evidence by Magnetic Flux Exclusion - Detect Corrosion													
v External tendons only - can access about 75 to 85% of	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
length of exposed ducts - can detect corrosion defects	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

TABLE 2.3 - EVIDENCE OF INCOMPLETE GROUT - SUBSTRUCTURE

SUBSTRUCTURE

Lateral and Vertical Post-Tensioning

Precast and Cast-in-Place Construction

n/a = not applicable or not appropriate
? = reliable indicator
o = tentative indicator / not always suitable method
concrete may be too massive to give result - etc

		Lateral PT			Lateral and Vertical PT				Vertical PT			
	Tendon Type =	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	External	Internal	Internal
		Hammerhead	Straddle Beam	Cap Confinement	Cantilever C-Pier		Portal Frame (Monolithic Straddle)		Precast Hollow Box	Precast Hollow Box	Precast I-Section	Hollow Reinforced
					Lateral PT	Vertical PT	Lateral PT	Vertical PT				
Visual evidence of incomplete grouting - look for Efflorescence and / or Rust Stains or water leaks												
a	at match-cast joints at or near internal PT ducts	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?	?	n/a
b	at closure pour joints at or near internal PT ducts	n/a	?	n/a	n/a	n/a	?	?	n/a	n/a	n/a	n/a
c	at construction joints with rebar at or near internal PT ducts	?	?	n/a	?	?	?	?	n/a	n/a	n/a	?
d	at cracks in slabs at or near internal PT ducts	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
e	at external PT duct splices or boots	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	n/a	n/a
f	at internal PT duct splices at cast-in-place joints	?	?	n/a	?	?	?	?	?	n/a	?	?
g	at longitudinal cracks along internal PT tendon path	?	?	n/a	?	?	?	?	?	n/a	?	?
h	at vertical or diagonal web cracks at ducts	?	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
i	at cracks at or near PT anchors in diaphragms	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
j	at cracks in PT anchor blocks or blisters	?	?	?	?	?	?	?	?	?	?	?
k	at honeycomb concrete at or near PT anchor blocks	?	?	?	?	?	?	?	?	?	?	?
l	at honeycomb concrete at or near PT ducts	?	?	?	?	?	?	?	?	?	?	?
Other evidence - look for												
m	Water leaks indicating cross-grout communication at joints	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	n/a	n/a	n/a
Evidence by Simple Souding Techniques*												
n	Hollow sound when lightly tap surface at tendon locations	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
o	Hollow sound when drag a chain across top surface	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
p	Hollow sound when lightly tap external duct (*these are only indications - not fully reliable methods)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evidence by Sound Instrumentation Methods												
q	Ultrasonic - to reveal delamination or spall (not grout void)	o	o	o	o	o	o	o	o	n/a	o	o
r	Ultrasonic - to reveal grout void	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
s	Impact echo - to reveal void not corrosion. NG with plastic duct	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evidence by Vibration Measurement and Analysis												
t	grout void - measure / analyze frequency of vibration of external P	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
u	corrosion - fracture of wires or loss of force	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Evidence by Magnetic Flux Exclusion - Detect Corrosion												
v	External tendons only - can access about 75 to 85% of length of exposed ducts - can detect corrosion defects	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

TABLE 2.4 - ANCHOR PROTECTION - Superstructures - Longitudinal Post-Tensioning

SUPERSTRUCTURES
Longitudinal PT

n/v = should not be visible without removal of concrete
n/a = not applicable
* = hollow structures must be watertight and well drained
? = reliable indicator
o = tributory concern or secondary indicator

	Precast Segmental Balanced Cantilever					Precast Segmental Span-by-Span (Internal tendons may be in main span (cantilever) unit or in typical span in some cases)					Spliced I-Girder with Cast-in-Place Deck			Cast-in-Place Balanced Cantilever					Cast-in-Place on Falsework Solid Slab	Voided Slab	Cellular Box			
Tendon Type =	Internal	Internal	Internal	External	External	Internal	Internal	Internal	External	External	Internal	Internal	External	Internal	Internal	Internal	External	External	Internal	Internal	Internal	Internal	External	External
Anchor Type =	anchor inside hollow* box	anchor at expansion joint	face anchor at segment joint	anchor inside hollow* box	anchor at expansion joint	anchor inside hollow* box	anchor at expansion joint	face anchor at segment joint	anchor inside hollow* box	anchor at expansion joint	End anchors	Top anchors (under deckslab)	(repair)	anchor inside hollow* box	anchor at expansion joint	face anchor at segment joint	anchor inside hollow* box	anchor at expansion joint	anchor under exposed surface	anchor under exposed surface	anchor inside hollow* box	anchor at expansion joint	anchor inside hollow* box	anchor at expansion joint
Visual inspection for evidence of deterioration or loss of anchor protection																								
Anchor Components																								
a Exposed anchor plate or part thereof	?	?	n/v	?	?	?	?	n/v	?	?	n/v	n/v	?	?	?	n/v	?	?	n/v	n/v	?	?	?	?
b Exposed wedge plate or part thereof	?	?	n/v	?	?	?	?	n/v	?	?	n/v	n/v	?	?	?	n/v	?	?	n/v	n/v	?	?	?	?
c Exposed wedges and strands	?	?	n/v	?	?	?	?	n/v	?	?	n/v	n/v	?	?	?	n/v	?	?	n/v	n/v	?	?	?	?
d Exposed nut and PT bar	?	?	n/v	?	?	?	?	n/v	?	?	n/v	n/v	?	?	?	n/v	?	?	n/v	n/v	?	?	?	?
Pourback to anchorhead																								
e Missing part or all of pourback	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
f Separation/shrinkage of pourback from substrate	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
g Cracks or spalls in pourbacks	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
h Missing epoxy-coal-tar coating to pourback	?	?	n/a	?	?	?	?	n/a	?	?	n/a	n/a	?	?	?	n/a	?	?	n/a	n/a	?	?	?	?
Other visual evidence																								
Efflorescence and / or rust stains or water leaks																								
i at cracks at / near PT anchors in diaphragms	?	?	n/a	?	?	?	?	n/a	?	?	?	?	?	?	?	n/a	?	?	n/a	?	?	?	?	?
j at cracks in PT anchor blocks / blisters	?	?	n/a	?	?	?	?	n/a	?	?	?	?	?	?	?	n/a	?	?	?	?	?	?	?	?
k at honeycomb at / near PT anchor blocks	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
l from under pourback at anchor	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Other tributory concerns																								
m Cracks in anchor blocks or local anchor zones	o	o	o	o	o	o	o	o	o	o	?	?	?	o	o	o	o	o	?	?	o	o	o	o
n Cracks in Diaphragms	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	n/a	o	o	o	o	o
Anchor Protection																								
Requirements for New Construction																								
Strategy requires four "levels" of protection																								
Technique that constitutes one "Level" of protection:																								
1 Grout - fully filled anchor head and cap	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
2 Permanent non-metallic (plastic) cap	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
3 Concrete cover or epoxy sealed joint			?					?								?								
4 Encapsulating pourback sand-filled epoxy grout		?	?		?		?	?		?	?	?	?		?	?		?	?	?		?		?
5 Elastomeric Seal Coat	?	?		?	?	?	?		?	?			?	?	?		?	?	?	?	?	?	?	?
6 Seal with Methyl Methacrylate																								
7 Permanent reinf concrete traffic barrier over top																								
8 Surrounding hollow, watertight drained structure	?			?		?			?					?			?				?		?	
9 Encapsulating end diaphragm of reinf concrete											?													
10 Continuous, reinforced deck slab over top												?												
Accessibility of Anchors for Maintenance Inspection																								
The following is a general guide - individual bridges may differ.																								
? Would it be necessary to remove pour-back to inspect anchor																								
(i) For anchors to pre-2001 methods? ** (yes or no)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
(ii) For anchors to post 2001 methods? ** (yes or no)	no	yes	yes	no	yes	no	yes	yes	no	yes	yes	yes	yes	no	yes	yes	no	yes	yes	yes	no	yes	no	yes
? Even though not recommended, would it be necessary to remove structural concrete to gain access to inspect anchor?	no	no	yes	no	no	no	no	yes	no	no	yes	yes	no	no	no	yes	no	no	yes	yes	no	no	no	no
? Is anchor considered "Directly Accessible" (yes or not)	yes	yes	not	yes	yes	yes	yes	not	yes	yes	not	not	yes	yes	yes	not	yes	yes	not	not	yes**	yes**	yes**	yes**
Note - this is only a general guide - individual cases may differ																								
** = It is presumed that there is sufficient access space for a person to get to the anchorage in order to inspect it - this may not be possible in all cases																								

TABLE 2.5 - ANCHOR PROTECTION - Superstructures - Transverse Post-Tensioning

SUPERSTRUCTURES **Transverse PT**	Deck slab of Precast Segmental Box	Deck slab of CIP Segmental Box	Trans PT to diaphragm of seg box	Trans PT to diaphragm I-girders	Vertical PT to diaphragm of seg box PC or CIP	Vertical PT to diaphragm of seg box PC or CIP	Vertical PT to webs of seg box PC or CIP	Vertical PT to webs of seg box PC or CIP	CIP on Falsework Transverse (horizontal) PT solid slab	voided slab	cellular box deck slab	Precast PS Conc Plancks	Trans PT to Double T's
Tendon Type =	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal
Anchor Type =	anchor under exposed surface	anchor under exposed surface	anchor under exposed surface	anchor under exposed surface	TOP anchor under exposed surface	BTM anchor under exposed surface	TOP anchor under exposed surface	BTM anchor under exposed surface	anchor under exposed surface	anchor under exposed surface	anchor under exposed surface	anchor under exposed surface	anchor under exposed surface
n/v = should not be visible without removal of concrete													
n/a = not applicable													
* = hollow structures must be watertight and well drained													
? = reliable indicator													
o = tributory concern or secondary indicator													
Visual inspection for evidence of deterioration or loss of anchor protection													
Anchor Components													
a Exposed anchor plate or part thereof	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v
b Exposed wedge plate or part thereof	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v
c Exposed wedges and strands	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v
d Exposed nut and PT bar	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v	n/v
Pourback to anchorhead													
e Missing part or all of pourback	?	?	?	?	?	?	?	?	?	?	?	?	?
f Separation/shrinkage of pourback from substrate	?	?	?	?	?	?	?	?	?	?	?	?	?
g Cracks or spalls in pourbacks	?	?	?	?	?	?	?	?	?	?	?	?	?
h Missing epoxy-coal-tar coating to pourback	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Other visual evidence													
Efflorescence and / or rust stains or water leaks													
i at cracks at / near PT anchors in diaphragms	n/a	n/a	?	?	?	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a
j at cracks in PT anchor blocks / blisters	?	?	n/a	n/a	?	?	?	?	?	?	?	?	?
k at honeycomb at / near PT anchor blocks	?	?	?	?	?	?	?	?	?	?	?	?	?
l from under pourback at anchor	?	?	?	?	?	?	?	?	?	?	?	?	?
Other tributory concerns													
m Cracks in anchor blocks or local anchor zones	?	?	?	?	?	?	?	?	?	?	?	?	?
n Cracks in Diaphragms	n/a	n/a	?	?	?	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Anchor Protection													
Requirements for New Construction													
Strategy requires four "levels" of protection													
Technique that constitutes one "Level" of protection:													
1 Grout - fully filled anchor head and cap	?	?	?	?	?	?	?	?	?	?	?	?	?
2 Permanent non-metallic (plastic) cap	?	?	?	?	?	?	?	?	?	?	?	?	?
3 Concrete cover or epoxy sealed joint													
4 Encapsulating pourback sand-filled epoxy grout	?	?	?	?	?	?	?	?	?	?	?	?	?
5 Elastomeric Seal Coat													
6 Seal with Methyl Methacrylate					?		?						
7 Permanent reinf concrete traffic barrier over top	?	?	?	?		?		?	?	?	?	?	?
8 Surrounding hollow, watertight drained structure													
9 Encapsulating end diaphragm of reinf concrete													
10 Continuous, reinforced deck slab over top													
Accessibility of Anchors for Maintenance Inspection													
The following is a general guide - individual bridges may differ.													
? Would it be necessary to remove pour-back to inspect anchor													
(i) For anchors to pre-2001 methods? **	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
(ii) For anchors to post 2001 methods? **	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
? Even though not recommended, would it be necessary to remove structural concrete to gain access to inspect anchor?	maybe	maybe	maybe	maybe	maybe	maybe	maybe	maybe	yes	yes	maybe	maybe	maybe
? Is anchor normally "Directly Accessible" (yes, not or maybe)	maybe	maybe	not	not	not	not	not	not	not	not	maybe	maybe	maybe
Note - this is only a general guide - individual cases may differ													
** = It is presumed that there is sufficient access space for a person to get to the anchorage in order to inspect it - this may not be possible in all cases													

TABLE 2.6 - ANCHOR PROTECTION - Substructures - Lateral and Vertical Post-Tensioning

SUBSTRUCTURES	Precast and Cast-in-Place Construction						
Tendon Type =	Int'l & Ext'l	Internal and External Non-Aggressive Environment			Internal and External Aggressive Environment		
Anchor Type =	anchor inside hollow* section	anchor in top exposed surface	in exposed side face above ground	in exposed side face below ground	anchor in top exposed surface	in exposed side face above gl & > 12ft wl	in exposed side face below ground
n/v = should not be visible without removal of concrete							
n/a = not applicable							
* = hollow structures must be watertight and well drained							
? = reliable indicator							
o = tributory concern or secondary indicator		Note: only PT bar 1-1/4" dia or larger allowed below 5 feet above ground			Note: no PT below 12 feet above mean high water at water sites		
Visual inspection for evidence of deterioration or loss of anchor protection							
Anchor Components							
a Exposed anchor plate or part thereof	?	n/v	n/v	n/v	n/v	n/v	n/v
b Exposed wedge plate or part thereof	?	n/v	n/v	n/v	n/v	n/v	n/v
c Exposed wedges and strands	?	n/v	n/v	n/v	n/v	n/v	n/v
d Exposed nut and PT bar	?	n/v	n/v	n/v	n/v	n/v	n/v
Pourback to anchorhead							
e Missing part or all of pourback	?	?	?	?	?	?	?
f Separation/shrinkage of pourback from substrate	?	?	?	?	?	?	?
g Cracks or spalls in pourbacks	?	?	?	?	?	?	?
h Missing epoxy-coal-tar coating to pourback	?	n/a	n/a	?	n/a	n/a	?
Other visual evidence							
Efflorescence and / or rust stains or water leaks							
i at cracks at / near PT anchors in diaphragms	n/a	n/a	n/a	n/a	n/a	n/a	n/a
j at cracks in PT anchor blocks / blisters	?	?	?	?	?	?	?
k at honeycomb at / near PT anchor blocks	?	?	?	?	?	?	?
l from under pourback at anchor	?	?	?	?	?	?	?
Other tributory concerns							
m Cracks in anchor blocks or local anchor zones	?	?	?	?	?	?	?
n Cracks in Diaphragms	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Anchor Protection							
Requirements for New Construction							
Strategy requires four "levels" of protection							
Technique that constitutes one "Level" of protection:							
1 Grout - fully filled anchor head and cap	?	?	?	?	?	?	?
2 Permanent non-metallic (plastic) cap	?	?	?	?	?	?	?
3 Concrete cover or epoxy sealed joint							
4 Encapsulating pourback sand-filled epoxy grout		?	?	?	?	?	?
5 Elastomeric Seal Coat	?	?	?	?	?	?	?
6 Seal with Methyl Methacrylate							
7 Permanent reinf concrete traffic barrier over top							
8 Surrounding hollow, watertight drained structure	?						
9 Encapsulating end diaphragm of reinf concrete							
10 Continuous, reinforced deck slab over top							
Accessibility of Anchors for Maintenance Inspection							
The following is a general guide - individual bridges may differ.							
? Would it be necessary to remove pour-back to inspect anchor							
(i) For anchors to pre-2001 methods? **	yes	yes	yes	yes	yes	yes	yes
(ii) For anchors to post 2001 methods? **	yes	yes	yes	yes	yes	yes	yes
? Even though not recommended, would it be necessary to remove structural concrete to gain access to inspect anchor?	maybe	maybe	maybe	maybe	maybe	maybe	maybe
? Is anchor normally "Directly Accessible" (yes, not or maybe)	yes**	not	not	not	not	not	not
Note - this is only a general guide - individual cases may differ							
** = It is presumed that there is sufficient access space for a person to get to the anchorage in order to inspect it - this may not be possible in all cases							

TABLE 2.7 EVIDENCE OF WATER LEAKS - SUPERSTRUCTURES

SUPERSTRUCTURES	Superstructure Types: Precast Segmental Balanced Cantilever	Precast Segmental Span-by-Span: Typical Span	Precast Segmental Span-by-Span: Cantilever or main span unit	Spliced I-Girder with Cast-in-Place Deck Slab	Cast-in-Place Segmental Balanced Cantilever	Cast-in-Place on Falsework: Solid Slab	Cast-in-Place on Falsework: Voided Slab	Cast-in-Place on Falsework: Cellular Box	Superstructures with Transverse PT: PPC Planks	Superstructures with Transverse PT: Double T's
n/a = not applicable or not appropriate ? = more frequent occurrence (especially in pre-2001 structures) o = not common but might occur or infrequent application										
Visual evidence of water leaks										
Efflorescence and / or Rust or Water Stains (in deck) at										
1 match-joints between precast segments (epoxy or dry)	?	?	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2 shrinkage of fill to small holes through slab for lifting, access or formwork	?	?	?	n/a	?	?	?	?	?	?
3 narrow (6" to 12") closure joint poured between precast segments	n/a	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4 shrinkage cracks at edges of pour-back to blockout in narrow closure joint	n/a	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5 shrinkage cracks at edges of pour-back to temp. or perm. PT anchor block-out	?	n/a	?	?	?	?	?	?	?	n/a
6 shrinkage cracks at edges of pour-back to access hole in slab	?	?	?	?	?	?	?	?	n/a	n/a
7 at transverse construction joints containing longitudinal rebar	n/a	n/a	n/a	n/a	?	?	?	?	?	?
8 at transverse cracks in slabs	o	o	o	?	o	o	o	o	?	?
9 shrinkage cracks at longitudinal cip construction joints between precast units	?	?	?	?	?	?	?	?	?	?
10 at longitudinal cracks along INTERNAL PT tendon path	?	?	?	?	?	?	?	?	n/a	n/a
11 at vertical or diagonal web cracks at ducts	?	?	?	?	?	n/a	n/a	?	n/a	n/a
Other evidence - look for										
12 Water leaks indicating cross-grout communication at joints	?	?	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a
At expansion joints, at PT anchor locations, leaks or efflorescence:										
13 at blockout made for PT jack in dapped seat below expansion joint device	?	?	?		n/a	n/a	n/a	?	n/a	n/a
14 seeping around from rear of pour-back to anchor	?	?	?		?	n/a	n/a	?	n/a	n/a
15 Ponding of water at low points at diaphragms, deviators, anchor blocks	?	?	?		?	n/a	n/a	?	n/a	n/a
16 Blocked drains through bottom slab or plastic drain pipes stand proud of slab	?	?	?		?	n/a	n/a	?	n/a	n/a
Local Details - note any leaks, efflorescence or stains* - at EXTERNAL PT duct splices (boots) between plastic and steel pipes at or near INTERNAL PT duct splices at cast-in-place joints at cracks at / near PT anchors in diaphragms at cracks in PT anchor blocks / blisters at honeycomb at / near PT anchor blocks at honeycomb at / near PT ducts (*refer also to evidence for incomplete grout and loss of anchor protection)										

TABLE 2.8 EVIDENCE OF WATER LEAKS - SUBSTRUCTURES

SUBSTRUCTURES	Lateral Post-Tensioning			Lateral and Vertical PT		Vertical Post-Tensioning		
n/a = not applicable or not appropriate ? = more frequent occurrence (especially in pre-2001 structures) o = not common but might occur or infrequent application	Hammerheads of Columns (Solid CIP)	Straddle Beam Simply Supported (Solid CIP)	Confinement of Caps (reactions) (PC or CIP)	Cantilever C-Piers (Solid CIP)	Portal Frame (Monolithic Straddle) (Solid CIP)	Hollow Precast Pier	Precast I-Section Pier	Hollow Reinforced Pier (CIP)
Visual evidence of water leaks								
Effloresence and / or Rust or Water Stains at								
1 match-joints between precast segments	n/a	n/a	n/a	n/a	n/a	?	?	n/a
2 shrinkage of fill to small holes through PRECAST CAP for lifting or formwork	n/a	n/a	n/a	n/a	n/a	?	?	n/a
3 shrinkage cracks at edges of pour-back to temp. or perm. PT anchor block-ou	?	?	?	?	?	?	?	?
4 shrinkage cracks at edges of pour-back to access hole in cap	n/a	n/a	n/a	n/a	n/a	?	n/a	n/a
5 shrinkage cracks at edges of pour-back to access hole in pier column	n/a	n/a	n/a	n/a	n/a	?	n/a	?
6 at longitudinal cracks along INTERNAL PT tendon path	o	o	o	o	o	o	o	o
Other evidence - look for								
7 Water leaks indicating cross-grout communication at precast joints	n/a	n/a	n/a	n/a	n/a	?	?	n/a
8 Water leaks (cross-grout communication) at reinforced construction joints	o	o	n/a	o	o	n/a	n/a	o
9 Ponding of water inside structure	n/a	n/a	n/a	n/a	n/a	?	n/a	?
10 Blocked weepholes from interior of hollow pier	n/a	n/a	n/a	n/a	n/a	?	n/a	?
Local Details - note any leaks, efflorescence or stains* - at EXTERNAL PT duct splices (boots) between plastic and steel pipes at or near INTERNAL PT duct splices at cast-in-place joints at cracks at / near PT anchors or pour-backs in pier caps and columns at cracks in PT anchor blocks / blisters inside columns at honeycomb at / near PT anchor blocks at honeycomb at / near PT ducts (*refer also to evidence for incomplete grout and loss of anchor protection)								

FLOWCHART 2.1 ENHANCED POST-TENSIONING

ENHANCED POST-TENSIONING

BEGIN

RETRIEVE RECORDS
- **Contract Drawings**
- **Shop Drawings**
- **Construction Records**
- **Maintenance Reports**

Refer to
Chapter 1.2 Identification of Bridge Type and Post Tensioning
Table 1.1 Identify Bridge Type - Superstructure
Table 1.4 Identify Bridge Type - Substructure

Identify Bridge Type

Refer to
Chapter 1.3 Procedure to Visually Identify Bridge Type and PT
Table 1.2 Identify Superstructure Post-Tensioning

Identify Type of Post-Tensioning

when was bridge built?

Before 2001 / **After 2001**

Refer to Inspection Procedure
Chapter 2.1 Enhanced Post-Tensioning Systems
see 2.1.1 Tendon Protection

Refer to
Chapter 1.2 Table 1.3 - Diagnostics of Bridge Type

Before 2001: **Identify most probable PT protection system (old standards) and Identify symptoms to look out for**

After 2001: **Identify most probable PT protection system (new standards) and Identify symptoms to look out for**

Examine records and Drawings, identify, plot or mark tendon and anchor locations on structure and perform visual inspection to verify
- **Type of Post-Tensioning**
- **PT protection (3 "levels")**

Refer to Chapter 2.1 "Enhanced Post-Tensioning Systems"

Internal Tendons require 3 levels of protection comprising:
- Grout - a fully grouted tendon - (see also 2.2)
- Duct - a continuous, impervious duct - note: discontinuous or pervious ducts or breached ducts do not comply - (see 2.1)
- Cover - sufficient, sound concrete cover or well sealed joints (cip or precast) note: inadequate cover, honeycombed concrete or leaky joints between precast segments, joints between cip pours or cracks does not comply

External Tendons require 3 levels of protection comprising:
- Grout - a fully grouted tendon - (see also 2.2)
- Duct - a continuous, impervious duct - note: cracked, punctured or damaged duct or duct that does not meet current (post 2001) material quality or thickness requriements does not comply - (see 2.1)
- Cover - a surrouding, water-tight, well drained box structure (see 2.4)

Does PT system comply with the "3 levels" of protection ?

Yes → **STOP**

No

Record details of ways in which PT system falls short of current requirements

DECISION TO BE MADE BY FDOT

Make appropriate repairs based upon available funds and maintenance program

STOP

Possible immediate / cost effective actions*	Repair Procedure**
Internal Tendons	
Seal leaks in joints between precast segments and	4.1 or 4.2
Seal leaks deck pour-back joints, holes or block-outs	4.15
Seal leaks at cip deck slab joints or cracks	4.15
Rehabilitate anchor protection at expansion joints	4.6, 4.10, 4.13
Grout voids in internal tendons	4.5, 4.8,4.9, 4.11, 4.12
Rehab protection for anchors inside box	4.6, 4.7, 4.8, 4.10, 4.13
External Tendons	
Repair external duct by heat welding	4.20
Rehabilitate anchor protection at expansion joints	4.6, 4.10, 4.13
Repair external duct by wrapping	4.3
Repair external duct using half-pipe	4.4
Rehab protection for anchors inside box	4.6, 4.7, 4.8, 4.10, 4.13

* individual projects may differ ** may not necessarily cover all repairs needed for a particular bridge

FLOWCHART 2.2 FULLY GROUTED TENDONS

FULLY GROUTED TENDONS
(AND CORROSION)

Follow
Chapter 1.2 Identification of Bridge Type and Post-Tensioning
Chapter 1.3 Procedure to Visually Identify Bridge Type and PT
and follow Flowchart 1.1 to
"Identify Bridge Type by Superstructure"

Follow
Chapter 1.2 Identification of Bridge Type and Post-Tensioning
Chapter 1.3 Procedure to Visually Identify Bridge Type and PT
and follow Flowchart 1.1 to
"Identify Bridge Type by Superstructure"

Seek for evidence given in
Table 2.1 Evidence of Incomplete Grout Superst Longitudinal PT
Table 2.2 Evidence of Incomplete Grout Superst Transverse PT
Table 2.3 Evidence of Incomplete Grout Substructure

Incomplete Grout
Seek for evidence given in
Table 2.1 Evidence of Incomplete Grout Superst Longitudinal PT
Table 2.2 Evidence of Incomplete Grout Superst Transverse PT
Table 2.3 Evidence of Incomplete Grout Substructure
mainly thus -

Efflorescence and / or rust stains or water leaks:
a at match-cast joints at or near internal PT ducts
b at closure pour joints at or near internal PT ducts
c at construction joints with rebar at or near internal PT ducts
d at cracks in slabs at or near internal PT ducts
e at external PT duct splices or boots
f at internal PT duct splices at cast-in-place joints
g at longitudinal cracks along internal PT tendon path
h at vertical or diagonal web cracks at ducts
i at cracks at or near PT anchors in diaphragms
j at cracks in PT anchor blocks or blisters
k at honeycomb concrete at or near PT anchor blocks
l at honeycomb concrete at or near PT ducts

For examples - see:
Figure 2.1 Efflorescence
Figure 2.2 Efflorescence and Rust Stain

To make inspection ports follow Repair Procedures:
Chapter 4.5 Drill Grout Port or Inspection Port into Internal Duct
Chapter 4.6 Create Grout Port or Inspection Port at Anchor

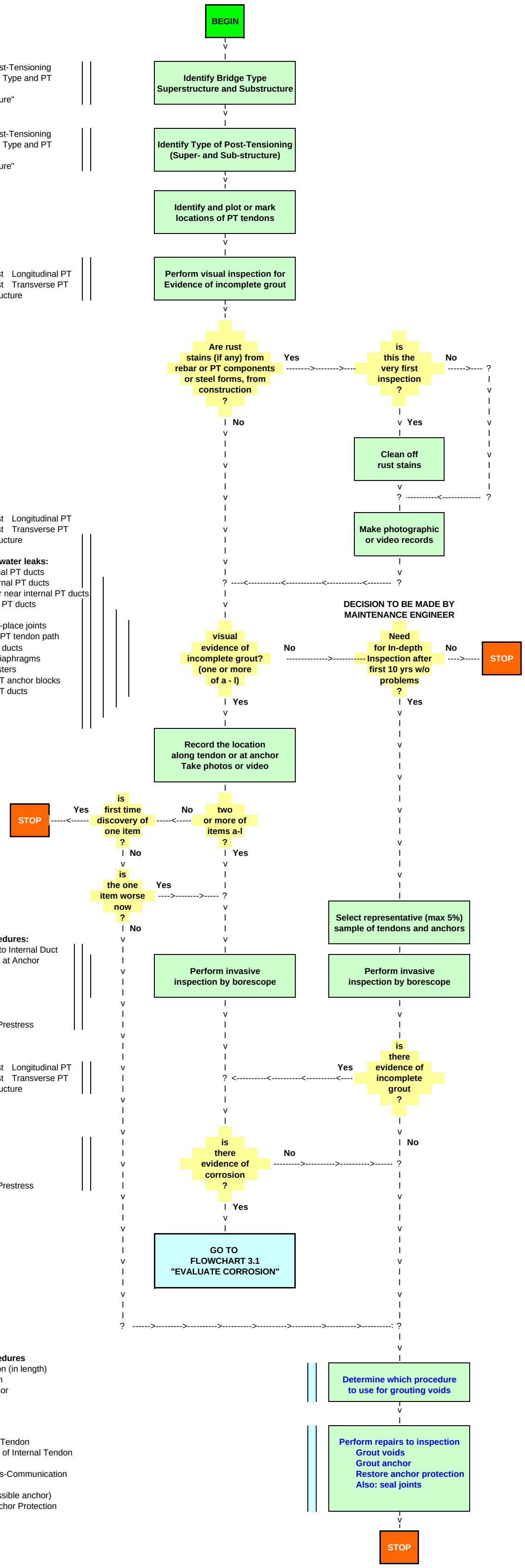
Follow Assessment Procedures:
Chapter 3.1 Assess (Internal) Tendon (in length)
Chapter 3.2 Assess External Tendon
Chapter 3.3 Assess Tendon at Anchor
Chapter 3.4 Assess Overall Integrity of Level of Prestress

Incomplete Grout
Seek evidence (as above) as given in
Table 2.1 Evidence of Incomplete Grout Superst Longitudinal PT
Table 2.2 Evidence of Incomplete Grout Superst Transverse PT
Table 2.3 Evidence of Incomplete Grout Substructure

Follow Assessment Procedures:
Chapter 3.1 Assess (Internal) Tendon (in length)
Chapter 3.2 Assess External Tendon
Chapter 3.3 Assess Tendon at Anchor
Chapter 3.4 Assess Overall Integrity of Level of Prestress

Refer to guidance given in Assessment Procedures
Chapter 3.1 Inspect and Assess (Internal) Tendon (in length)
Chapter 3.2 Inspect and Assess External Tendon
Chapter 3.3 Inspect and Assess Tendon at Anchor

Use Repair Procedures
Chapter 4.8 Inject Grout to Long Void in Internal Tendon
Chapter 4.9 Vacuum Inject Grout into Local Void of Internal Tendon
Chapter 4.10 Vacuum Inject Grout at an Anchor
Chapter 4.11 Grout Multiple Duct Voids with Cross-Communication
Chapter 4.12 Seal Grout Ports and Vents
Chapter 4.13 Restore Anchor Protection (to accessible anchor)
Chapter 4.14 Clean and make Local Repair to Anchor Protection



FLOWCHART 2.3 **ANCHOR PROTECTION**

ANCHOR PROTECTION
(AND CORROSION)

Follow
Chapter 1.2 Identification of Bridge Type and Post-Tensioning
Chapter 1.3 Procedure to Visually Identify Bridge Type and PT
and follow Flowchart 1.1 to
"Identify Bridge Type by Superstructure"

Follow
Chapter 1.2 Identification of Bridge Type and Post-Tensioning
Chapter 1.3 Procedure to Visually Identify Bridge Type and PT
and follow Flowchart 1.1 to
"Identify Bridge Type by Superstructure"

Loss of Anchor Protection
Seek for evidence given in

Table 2.4	Anchor Protection	Superstructure	Longitudinal PT
Table 2.5	Anchor Protection	Superstructure	Transverse PT
Table 2.6	Anchor Protection	Substructure	

Also look out for evidence of incomplete grout:

Table 2.1	Evidence of Incomplete Grout	Superstructure	Longitudinal PT
Table 2.2	Evidence of Incomplete Grout	Superstructure	Transverse PT
Table 2.3	Evidence of Incomplete Grout	Substructure	

Loss of Anchor Protection
Refer to Tables 2.4, 2.5, 2.6 and look for any deterioration of anchor protection
In particular - items a through h - mainly:
Evidence of deterioration or loss of anchor protection
a Exposed anchor plate or part thereof
b Exposed wedge plate or part thereof
c Exposed wedges and strands
d Exposed nut and PT bar
e Missing part or all of pour back
f Separation or shrinkage crack of pour-back from substrate
g Cracks or spalls in pour-back
h Missing coating to pour-back
Indicators of grout void at anchor include:
Efflorescence and / or rust stains or water leaks at
i cracks at or near PT anchors in diaphragms
j cracks in PT anchor blocks
k honeycomb at or near PT anchor blocks
l from under pourback at anchor
Other tributory concerns
m Cracks in anchor blocks or local anchor zones
n Cracks in Diaphragms

For examples - see:
Figure 2.1 Efflorescence
Figure 2.2 Efflorescence and Rust Stain

Incomplete Grout
Seek for evidence given in

Table 2.1	Evidence of Incomplete Grout	Superstructure	Longitudinal PT
Table 2.2	Evidence of Incomplete Grout	Superstructure	Transverse PT
Table 2.3	Evidence of Incomplete Grout	Substructure	

mainly thus -
Efflorescence and / or rust stains or water leaks:
a at match-cast joints at or near internal PT ducts
b at closure pour joints at or near internal PT ducts
c at construction joints with rebar at or near internal PT ducts
d at cracks in slabs at or near internal PT ducts
e at external PT duct splices or boots
f at internal PT duct splices at cast-in-place joints
g at longitudinal cracks along internal PT tendon path
h at vertical or diagonal web cracks at ducts
i at cracks at or near PT anchors in diaphragms
j at cracks in PT anchor blocks or blisters
k at honeycomb concrete at or near PT anchor blocks
l at honeycomb concrete at or near PT ducts

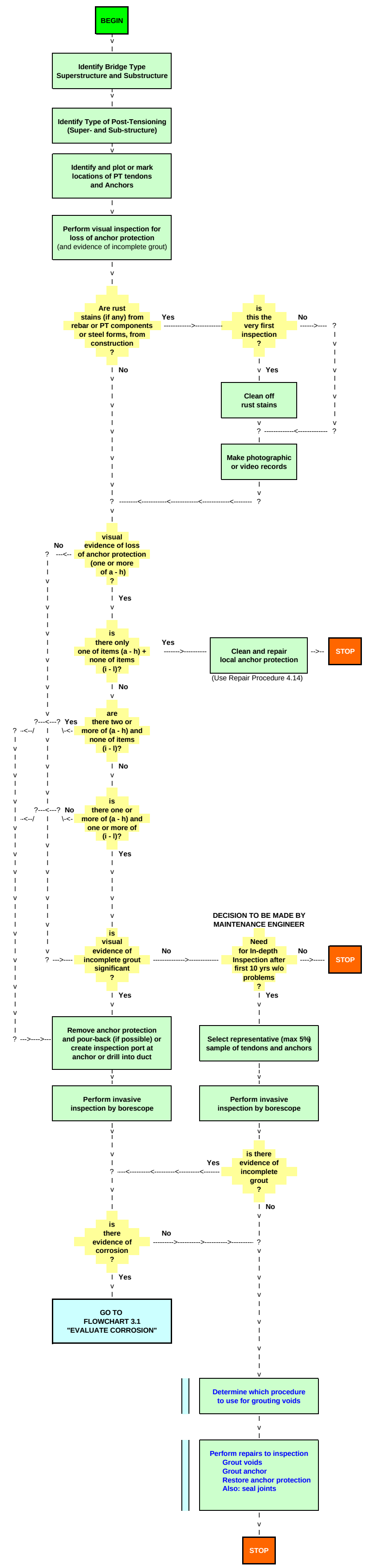
To make inspection ports follow Repair Procedures:
Chapter 4.5 Drill Grout Port or Inspection Port into Internal Duct
Chapter 4.6 Create Grout Port or Inspection Port at Anchor

Follow Assessment Procedures:
Chapter 3.1 Inspect and Assess (Internal) Tendon (in length)
Chapter 3.2 Inspect and Assess External Tendon
Chapter 3.3 Inspect and Assess Tendon at Anchor
Chapter 3.4 Assess Overall Level of Prestress

Seek for evidence given in

Table 2.1	Evidence of Incomplete Grout	Superstructure	Longitudinal PT
Table 2.2	Evidence of Incomplete Grout	Superstructure	Transverse PT
Table 2.3	Evidence of Incomplete Grout	Substructure	

Follow Assessment Procedures:
Chapter 3.1 Inspect and Assess (Internal) Tendon (in length)
Chapter 3.2 Inspect and Assess External Tendon
Chapter 3.3 Inspect and Assess Tendon at Anchor
Chapter 3.4 Assess Overall Level of Prestress



Refer to guidance given in Assessment Procedures
Chapter 3.1 Assess (Internal) Tendon (in length)
Chapter 3.2 Assess External Tendon
Chapter 3.3 Assess Tendon at Anchor

Use Repair Procedures
Chapter 4.8 Inject Grout to Long Void in Internal Tendon
Chapter 4.9 Vacuum Inject Grout into Local Void of Internal Tendon
Chapter 4.10 Vacuum Inject Grout at an Anchor
Chapter 4.11 Grout Multiple Duct Voids with Cross-Communication
Chapter 4.12 Seal Grout Ports and Vents
Chapter 4.13 Restore Anchor Protection (to accessible anchor)
Chapter 4.14 Clean and make Local Repair of Anchor Protection

WATERTIGHT STRUCTURE

CAST-IN-PLACE SEGMENTAL
BALANCED CANTILEVER

? Structural cracks may require addition of PT or rebar

? Non-Strutural cracks may be treated per FDOT Standard Specification

Cast-in-place construction has rebar through joints - but leaks may occur

Efflorescence or rust stain associated with water leak may indicate corrosion of tendon or anchor etc.

Follow Inspection Procedure
2.2 Evidence of Incomplete Grout
Follow Assessment Procedures
3.1 Assess (internal) Tendon
3.2 Assess (external) Tendon
3.3 Assess Tendon at Anchor
3.4 Assess Overall Integrity Level of Prestress
Also see Flow Chart 2.2 "Fully Grouted Tendons"

Use Repair Procedures:
4.1 Seal Joints using Methyl Methacrylate
or 4.2 Seal Joints using Epoxy Injection

Pour-backs and filled holes include
? Permanent PT anchor block-outs
? Temporary PT bar block-outs
? Access holes (personnel or equipment)
? Holes for lifting devices or tie-downs
? Holes to secure personnel platforms etc.

Use Repair Procedure:
4.15 Seal Pour-back Joints or Filled Holes

Interior barriers include:
? Anchor blocks, diaphragms, deviator saddles or ribs etc.
? There must be no ponding at anchors or at deviator pipes and duct connections

Use Repair Procedure:
4.16 Install Drains through Bottom Slab

A leaky expansion joint device can allow water to penetrate below seat and to get into PT anchors in diaphragm

Expansion joint seats may have had block-outs for clearance for PT jacks that were then filled with ordinary concrete that has since shrunk - forming cracks and leaks, or similar

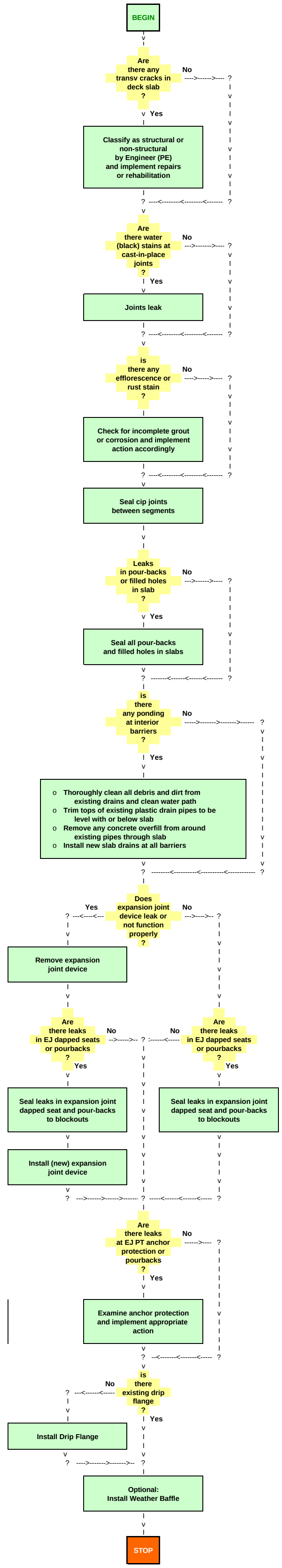
Use Repair Procedure:
4.15 Seal Pour-back Joints or Filled Holes

NOTE - use an expansion joint device that has a self-cleaning gland or drainage trough

Follow Inspection Procedure:
2.3 Inspect Anchor Protection
Follow Assessment Procedure:
3.3 Assess Tendon at Anchor
Also see Flow Chart 2.3 "Anchor Protection"
Use Repair Procedure:
4.13 Restore Anchor Protection (to directly accessible anchors)

Use Repair Procedure:
4.17 Installing Drip Flanges and under Seat of Expansion Joint

Use Repair Procedure:
4.18 Install Weather Baffle at Expansion Joint
Note - a weater baffle is an optional additional protection device intended for very exposed conditions to prevent wind driven spray settling on anchor pour-backs at expansion joints
It is not an alternative to a gland or drain trough beneath the expansion joint device



FLOWCHART 2.5 MULTIPLE TENDON PATHS

Strategy #5 Multiple Tendon Paths
MULTIPLE TENDON PATHS

BEGIN

I
V
I

Retrieve Documents

? Contract Drawings
? Shop Drawings
? Construction Records
? Maintenance Records

I
V
I

Perform Office Review by Engineer (P.E.)

I
V
I

Do tendons satisfy MTP criteria ?

Yes ----------------->---------- **STOP**

I No
V
I

Consult with FDOT

I
V
I

Add PT?

No ----------------->---------- **STOP**

I Yes
V
I

Perform Design and Produce Detailed Contract Drawings and Specifications

I
V
I

Engage CEI let to Construction Implement

I
V
I

STOP

Chapter 3 – Assessment Procedures

3.1 Assess Internal Tendon (at location along the tendon length)

3.1.1 Applicability

It is assumed that the presence of a grout void somewhere along the tendon has already been determined or is strongly suspected from other inspection or evidence and that it has been decided to carry out an inspection and assessment of the condition of the tendon using a bore-scope or similar visual aid device.

It is also assumed that a hole has already been created for inspection – if not, refer to Repair Procedure: **4.5 - *Drill Grout Port or Inspection Port into Internal Duct*** - in order to prepare for inspection and subsequent grout injection.

The following applies to internal tendons comprised of strands.

3.1.2 Assess by Borescope Inspection

(1) When access hole has been created to voided area of tendon then probe to determine length and estimate likely volume of grout void

(2) Insert bore-scope (or other visual aid) and carefully inspect interior of void, the condition of the strand (or PT bar) and as far as possible along the length of the tendon

(3) Note completeness of grout:

Does grout completely coat the strands?
Or are any strands (or PT bar) exposed?

(4) Examination condition of existing strand (or bar):

Are wires of strands (or is PT bar) corroded?
Estimate approximate amount of section loss due to corrosion
Estimate and record the number of broken wires

(5) Record and report findings (Use Table 3.1 “Count of Corroded Wires”).

(Refer to Figures 3.1, 3.2 and 3.3 below for examples of various corrosion conditions).

3.1.3 Assess Condition of Tendon (at location along the tendon length)

Follow Flowchart 2.2 and, if there is evidence of corrosion, then go to Flowchart 3.1

(1) If there is no void then this portion of tendon is considered satisfactory and no action need be taken with the tendon itself. (Fill and seal the inspection port using the Repair Procedure: 4.12 - ***Seal Grout Ports and Vents***)

(2) If there is a grout void then first probe and estimate the length of the void. Then examine and record the condition of the strands:

If the strands (or PT bar) are coated with grout, with no evidence of rust and no broken wires or loss of section to corrosion then the tendon is considered satisfactory and grouting may proceed.

(3) At the location of the inspection port at the void of the strand tendon, first probe and estimate the length of void to be grouted. Then examine and record condition of strands as follows.

(4) The following is intended as a guide in order to facilitate interpretation of the condition in order to apply the test to see if the "Overall Integrity of Level of Prestress" is satisfactory according to 3.4 (Also see 3.4 for reasoning):

Either - if 5% or more of the total number of wires are broken (Using Table 3.1 for "Count of Corroded Wires")

Or - if 25% of the total number of strands (as distinct from individual wires) are corroded and covered in heavy scale such that they have lost significant amount of their outer surface to corrosion

Then the tendon is deemed effectively to have lost at least 5% of the wires at this section

If the tendon has lost less than the above amounts then it is deemed to have lost less than 5% of its wires at this section

(5) Do not immediately grout any internal grout void without first carrying out a similar (bore-scope) inspection and assessment of other tendons in the structure at this section as necessary in order to assess the level of prestress according to the Inspection and Assessment Procedure: ***3.4 - Assess Overall Integrity of Level of Prestress*****.**

Follow Flowchart 3.1 "Evaluate Corrosion" to assess the overall integrity level of the prestress and then proceed as follows:

(1) If the overall integrity of the level of prestress is found to be satisfactory (by the Engineer), then grouting of the voided tendon(s) may proceed using the appropriate procedure as determined below

(2) If the overall level of prestress at the critical sections in the structure is found to be NOT satisfactory (by the Engineer), then remedial action is necessary. This may require the addition of post-tensioning to the structure. (See Repair Procedure: **4.19 -** ***Install Additional Tendons)***

3.1.4 Determine which Procedure to Use for Grouting Void

After probing of length of void:

- If the void is estimated to be of relatively short length, small or of limited volume then fill void by vacuum injection of grout and seal inspection / grout port in all accordance with the Repair Procedure*:* ***4.9 - Vacuum Inject Grout into Local Void of Internal Tendon.***

- If the void is estimated to be many feet long or of relatively large volume then determine optimum location(s) for drilling grout ports and vents. Grout void and seal vents all in accordance with the Repair Procedure*:* ***4.8 - Inject Grout to Fill a Long Void in an Internal Duct.***

- If there is cross grout communication between tendons (as may occur in precast segmental construction with poorly sealed joints between segments) then follow Repair Procedure: ***4.11 - Grout Multiple Duct Voids with Cross Communication.***

- Upon satisfactory completion of grouting of void, seal inspection and grout ports and vents in accordance with the Repair Procedure: **4.12 -** ***Seal Grout Ports and Vents.***

3.2 Assess External Tendon

This procedure is to inspect and assess the integrity of an external tendon. It addresses the tendon protection (i.e. HDPE pipe duct), possible damage to plastic ducts and the integrity of grout and strand in the system. It offers recommendations for the repair, wrapping, or replacement of the post-tensioning.

3.2.1 Applicability

This procedure applies to all bridges with external tendons in both superstructure and substructure.

3.2.2 Procedure

Identify on the structure, the locations of the post-tensioning tendons and their anchors – and for records, make photographic or video record.

Perform visual inspection (at close range) for evidence damage to external HDPE ducts and for any evidence of incomplete grouting. (For the latter, follow Inspection Procedure 2.2 “Fully Grouted Tendons”, Flowchart 2.2 and Tables 2.1, 2.2 and 2.3. Also, follow Inspection Procedure 2.3 “Anchor Protection”, Flowchart 2.3 and Tables 2.4, 2.5, 2.6 to assess the anchor protection and the condition of the tendon at the anchor as necessary)

Examine ducts for splits, nail holes or similar damage. Also, look for loose neoprene sleeves (boots) connecting plastic duct to steel duct at deviators and diaphragms. Check if the band clamps are in place. There should be at least two on each boot, one sealing boot to plastic pipe and one sealing boot to steel duct.

Compare current inspection with records, photographs and video from previous inspections to determine if evidence of damage is static or getting worse.

In making comparisons from one inspection to another, it is important to know what the structure looked like originally, just after completion. If there is doubt, then photograph (in color) the condition of the ducts. Mark and date the extent of any splits or defects on the duct (or on adjacent concrete) at this inspection to be able to look for changes at the next.

If this is the first inspection or if no previous records, photographs or video are available then make appropriate records during this inspection.

3.2.3 Assess Condition of Duct and Decide Repairs

Small Puncture (nail) Holes or Cuts in Plastic Duct

Providing that there is no evidence of grout voids or corrosion of the tendon (neither in the length of the tendon, nor at the boots nor at the anchors) then, remove any nails and repair all small puncture holes or cuts using heat welding of the polyethylene duct. (Follow Repair Procedure: ***4.20 Repair External Tendon Duct by Heat Welding***.)

Split Plastic Duct (any length of split)

Providing that there is no evidence of grout voids or corrosion of the tendon (neither in the length of the tendon, nor at the boots nor at the anchors) then, repair the split by wrapping the full length of the duct (between embedded steel pipes) in which the split occurs. (Follow Repair Procedure: ***4.3 - Repair External Tendon Duct by Wrapping***.)

Alternatively, new “Half-Pipe” ducts may be installed over the whole length. (Follow Repair Procedure*:* ***4.4 - Install New Half-Pipe Duct around External Tendon***).

Holes, Splits and Incomplete Grout

If small (nail) holes or splits are accompanied by evidence of incomplete grout, then examine closely for evidence of corrosion.

In the external portion of the tendon, unclamp the neoprene boots and slide aside to examine the condition of the grout and strands at the connection of the external to internal duct.

At splits, slightly pry open the plastic pipe and examine the condition of the grout and strands.

If there is no evidence of any corrosion of the strands – but only incomplete grout – then repair ducts using new “Half-Pipe” ducts and inject new grout to annulus between old duct and new half-pipes. (Follow Repair Procedure: **4.4 -** ***Install New Half-Pipe Duct around External Tendon***)

Quality of Existing HDPE Pipe

If the existing HDPE pipe has many tears or cracks, then remove small samples for analysis of the material. History indicates that the HDPE pipe in some bridges has not always met requirements.

Evidence of Corrosion

If there is any evidence of corrosion (i.e. efflorescence, rust stains or water leaks) from the ducts at or near (boot) connections or similar evidence at the anchors or pour-backs to the anchors, then asses the anchor protection and condition of the tendon at the anchor. (Follow Inspection Procedure: **2.3 - *Anchor Protection***, Flowchart 2.3 and Tables 2.4 and 2.6) and Assessment Procedure: **3.3 - *Inspect and Assess Tendon at Anchor*** (Internal or external))

And, in the external portion of the tendon, unclamp the neoprene boots and slide aside to examine the condition of the grout and strands at the connection of the external to internal duct.

At any tears or cracks, slightly pry open the plastic pipe and examine the condition of the grout and strands - as follows.

3.2.4 Assess the Condition of External Tendon

(1) If the strands are coated with grout, of if the surface of the strands is only slightly rusty (not pitted anywhere) and there are no broken wires or loss of section to corrosion then this portion of the tendon is considered satisfactory.

(2) If the inspection of other portions of this same tendon is likewise satisfactory it may be possible to restore the duct for this particular tendon – providing that the overall level of prestress is satisfactory (below).

(3) If the strands are rusty or corroded at any location in the length of the external tendon, *then remove the existing plastic pipe* and make a close examination to determine if this particular tendon has effectively lost more than 5% of the wires as follows.

(4) The following is intended as a guide in order to facilitate interpretation of the condition in order to apply the test to see if the "Overall Integrity Level of Prestress" is satisfactory per Chapter 3.4 – (also see 3.4 for reasoning):

Either - if 5% or more of the total number of wires are broken (Using Table 3.1 "Count of Corroded Wires")

Or - if 25% of the total number of strands (as distinct from individual wires) are corroded and covered in heavy scale such that they have lost significant amount of their outer surface to corrosion

Then the tendon is deemed effectively to have lost at least 5% of the wires in this portion (at the sections represented by this tendon)

If the tendon has lost less than the above amounts then it is deemed to have lost less than 5% of its wires (at this sections represented by this tendon)

(5) Do not immediately restore the ducts nor grout without first carrying out a similar assessment of other tendons at this section in the structure and in order to be able to assess the overall integrity of the level of prestress using the Assessment Procedure 3.4 "***Assess Overall Integrity Level of Prestress***"

Follow Flowchart 3.1 “Evaluate Corrosion” to assess the overall integrity level of the prestress and then proceed as follows:

(1) If the overall integrity of the level of prestress is found to be satisfactory (by the Engineer) the duct for this tendon may be restored by using new “Half-Pipe” ducts and injecting new grout to the annulus between old duct and new half-pipes. (Follow Repair Procedure: **4.4 - *Install New Half-Pipe Duct around External Tendon***).

(2) If the overall level of prestress is found NOT to be satisfactory (by the Engineer) then remedial action is necessary either to remove and replace the tendon(s) concerned or to add supplementary post-tensioning to the structure. (See Repair Procedure: **4.19 - *Install Additional Tendons***)

3.3 Assess Tendon at Anchor (Internal or External Tendon)

3.3.1 Applicability

This applies to all anchors – including “face anchors” or others that may be embedded within the body of the concrete and are not directly accessible for inspection without removing pour-backs or structural concrete. Also, this procedure applies in so far as an anchor may be physically accessible to inspection and maintenance personnel. Clearly, an anchor that is covered by structural concrete is not accessible. (A distinction between anchors that are and are not directly accessible is made in Repair Procedure 4.6 “Create Grout Port or Inspection Port at Anchor”)

It is assumed that the presence of a grout void in the anchor zone has already been determined or is strongly suspected from other inspection or evidence and that it has been decided to carry out an inspection and assessment of the condition of the tendon using a bore-scope or similar visual aid device.

It is also assumed that a hole has already been created for inspection. (If not, then refer to Repair Procedure: **4.6 - *Create a Grout Port or Inspection Port at an Anchor*** in order to prepare for inspection and subsequent grout injection.)

The following applies to tendons comprised of strands.

3.3.2 Assess by Borescope Inspection

(1) When access hole has been created to area behind anchor then probe to determine length and estimate likely volume of grout void

(2) Insert bore-scope (or other visual aid) and carefully inspect interior of anchor cone (or duct) behind anchor plate and as far as possible along the length of the tendon

(3) Note completeness of grout: Does grout completely coat the strands? Or are any strands (or PT bar) exposed?

(4) Examination condition of existing strand (or bar): Are wires of strands (or is PT bar) corroded? Estimate approximate amount of section loss due to corrosion. Estimate and

record the number of broken wires

(5) Record and report findings (Use Table 3.1“Count of Corroded Wires”)

(Refer to Figures 3.1, 3.2 and 3.3 below for examples of various corrosion conditions).

3.3.3 Assess Condition of Tendon at Anchor Using Borescope

(1) If there is no void at the rear of the anchor then all is considered satisfactory and no action need be taken with the tendon itself. Fill and seal the inspection port and replace anchor protection. (Follow Repair Procedures: **4.10 - *Vacuum Inject Grout at an Anchor***, **4.12 *- Seal Grout Ports and Vents”*** and **4.13 - *Restore Anchor Protection***)

(2) If there is a grout void at the rear and if the strands (or PT bar) are coated with grout, with no evidence of rust and no broken wires or loss of section to corrosion then the tendon and anchor are considered satisfactory, then fill void by vacuum injection of grout, seal inspection / grout port and replace anchor protection. (Follow Repair Procedures: **4.10 - *Vacuum Inject Grout at an Anchor***, **4.12 *- Seal Grout Ports and Vents”*** and **4.13 - *Restore Anchor Protection***)

(3) If there is a void at (or near) the anchor but the strands (or PT bar) are not fully coated with grout then assess the condition as follows.

(4) The following is intended as a guide in order to facilitate interpretation of the condition in order to apply the test to see if the “Overall Integrity Level of Prestress” is satisfactory according to 3.4:

Either - if 5% or more of the total number of wires are broken (Using Table 3.1 for “Count of Corroded Wires”)

Or - if 25% of the total number of strands (as distinct from individual wires) are corroded and covered in heavy scale such that they have lost significant amount of their outer surface to corrosion

Then the tendon is deemed effectively to have lost at least 5% of the wires at this section

If the tendon has lost less than the above amounts then it is deemed to have lost less than 5% of its wires at this section

(5) Do not immediately grout any internal grout void without first carrying out a similar (bore-scope) inspection and assessment of other tendons in the structure at this section as necessary in order to assess the level of prestress according to Assessment Procedure: ***3.4 - Assess Overall Integrity of Level of Prestress*.**

Follow Flowchart 3.1 “Evaluate Corrosion” to assess the overall integrity level of prestress and then proceed as follows:

(1) If the overall integrity of the level of prestress is found to be satisfactory (by the Engineer), then grouting of the voided tendon(s) may proceed using the appropriate

procedure as determined below

(2) If the overall level of prestress at the critical sections in the structure is found to be NOT satisfactory (by the Engineer), then remedial action is necessary. This may require the addition of post-tensioning to the structure. (See Repair Procedure*:* ***4.19 - Install Additional Tendons****)*

3.3.4 Determine which Procedure to Use for Grouting Void at Anchor

If the void at the anchor connects with a void in the tendon then after probing of length of void:

- If the void is estimated to be of relatively short length, small or of limited volume then fill void by vacuum injection of grout and seal inspection / grout port in all accordance with the Repair Procedure*:* ***4.10 - Vacuum Inject Grout into at Anchor.***

- If the void is estimated to be many feet long or of relatively large volume then determine optimum location(s) for drilling grout ports and vents. Grout void and seal vents all in accordance with the Repair Procedure: **4.8 -** ***Inject Grout to Fill a Long Void in an Internal Duct.***

- If there is cross grout communication between tendons (as may occur in precast segmental construction with poorly sealed joints between segments) then follow Repair Procedure: **4.11 -** ***Grout Multiple Duct Voids with Cross Communication***

- Upon satisfactory completion of grouting of anchor void, restore anchor protection and seal any other grout ports and vents accordance with Repair Procedures: 4.13 - ***Restore Anchor Protection*** *(to directly accessible anchors)"* and **4.12 -** ***Seal Grout Ports and Vents.***

3.4 Assess Overall Integrity of Level of Prestress

3.4.1 Applicability

The following procedure applies to internal (bonded) and external (unbonded) tendons in all types of structures.

It is intended to serve as a means for an initial determination to see if the structure is or is not satisfactory. It is a greatly simplified and relatively conservative procedure for the majority of post-tensioned structures. It may be considered as a "screening test" to identify potentially significant loss of PT. However, it does NOT relieve the Engineer from the responsibility of making a proper structural analysis.

3.4.2 Procedure

For both internal (bonded) and external (unbonded) tendons in all types of structures:

- It is satisfactory if no more than 5% of the wires are lost (or no more than 5% are deemed lost) in any one tendon (at a given section)

- It is satisfactory if no more than 2.5% of all wires in all tendons at any one cross section are lost

- If more than 5% of all wires are lost globally in the structure then it is NOT satisfactory and remedial action is necessary.

The term "globally in the structure" applies as follows:

- For a simple span – it means in the one span – including all tendons in a single box, all tendons in multiple boxes, all tendons in all I-girders or all tendons in a multiple cellular box for that span
- For a continuous structure – it means in the continuous length of structure between expansion joints – including all tendons in a single box, all tendons in multiple boxes, all tendons in all I-girders or all tendons in a multiple cellular box for that length of continuous structure
- For a column – it means in the one column
- For a hammerhead, straddle beam, monolithic frame or C-pier – it means in that entire piece of substructure

As an initial estimate of the percentage of wires lost globally in the structure, sum up all wires lost in all sections and locations examined as a percentage of the sum of all wires at those sections and locations throughout the length of the structure concerned. This is to say - if there are C1 lost to corrosion of N1 total wires at section 1, C2 lost of N2 total wires at section 2 – etc. then the total percentage lost "globally in the structure" is given by:

$$\text{Global loss} = 100^* \, (C_1+C_2+C_3 \; .... \; +C_i ... \; +C_n) \; / \; (N_1+N_2+N_3 \; .... \; +N_i ...+N_n)$$

where n = number of sections considered.

In this context, for an initial estimate, apply the results for each anchor as appropriate to the sections affected by that anchor.

If the global loss exceeds 5% then a qualified Engineer should make a more close examination of the distribution of the lost wires and the effect of those lost at each section – particularly critical sections – such as over interior piers in continuous structures and mid-span regions.

Clearly, there is no way to tell from an inspection if wires corroded at one anchor of an tendon are the same as those corroded at the other anchor – and each may be different to the ones corroded at some intermediate location along the tendon. On the other hand, wires corroded at one anchor with no corrosion elsewhere along the tendon may be an acceptable condition if the tendon is grouted and bonded. Then again, significant loss of an internal tendon at one section may or may not necessarily alter the overall capacity of a continuous structure. Various such considerations based upon experience for different types of structure underlie the above "5%" guide.

When assessing the effectiveness of corroded post-tensioning, the Engineer, may take account of the fact that although an internal tendon may have completely corroded and failed at one section (say at an anchor), once grouted, it may contribute partially or fully to the ultimate level capacity at another - by virtue of the bond developed between the sections – and depending, of course, upon the condition of the tendon in between.

An internal tendon that is not well grouted and has failed at one section may no longer contribute to the effective prestress force at the service level condition at another section. However, after repair grouting, it may be able to contribute to some degree to the ultimate capacity – again, depending upon the condition of the tendon in between the sections.

On the other hand, an external tendon that is fully corroded at one location (albeit at an anchor, deviator or somewhere in between) effectively looses all its force along its length and must be replaced.

3.4.3 Clarification of "5%" Rule

Clarification of the basis for the above 5% rule and the other, percentages in Chapter 3, parts 3.1, 3.2 and 3.3 is as follows.

The above "5% rule" is based upon the fact that once a tendon (strands) loses 5% or more of its wires at one point, the PT force is locally transferred to the other strands at that location placing them in a higher state of stress. For example, if the final stress level after all losses is, say 65% F_{pu}, then a 5% loss of section area places the tendon at a level of approximately 69% F_{pu} locally – which is < 70% and may be considered satisfactory.

If 25% of the strands in one tendon are heavily corroded and fail so that their force is locally transferred to the adjacent strands, then the stress in the remaining (good) strands would increase from 65% (say) after losses to about 86% of ultimate. This is approaching an upper limit above which the strand might begin to yield and fail were it to suffer further section loss - (yield, for typical low relaxation post-tensioning strand, being in the range of 93% to 96% F_{pu}) Or, for another example, if an individual wire loses 10% of its diameter, it loses nearly 20% of its area - the local stress level in such a wire would change from 65% F_{pu} to 79% F_{pu}

3.5 Examples of Tendon Conditions

The following images offer guidance on the type of corrosion or conditions to look for when using a borescope or examining a tendon, whether internal or external.

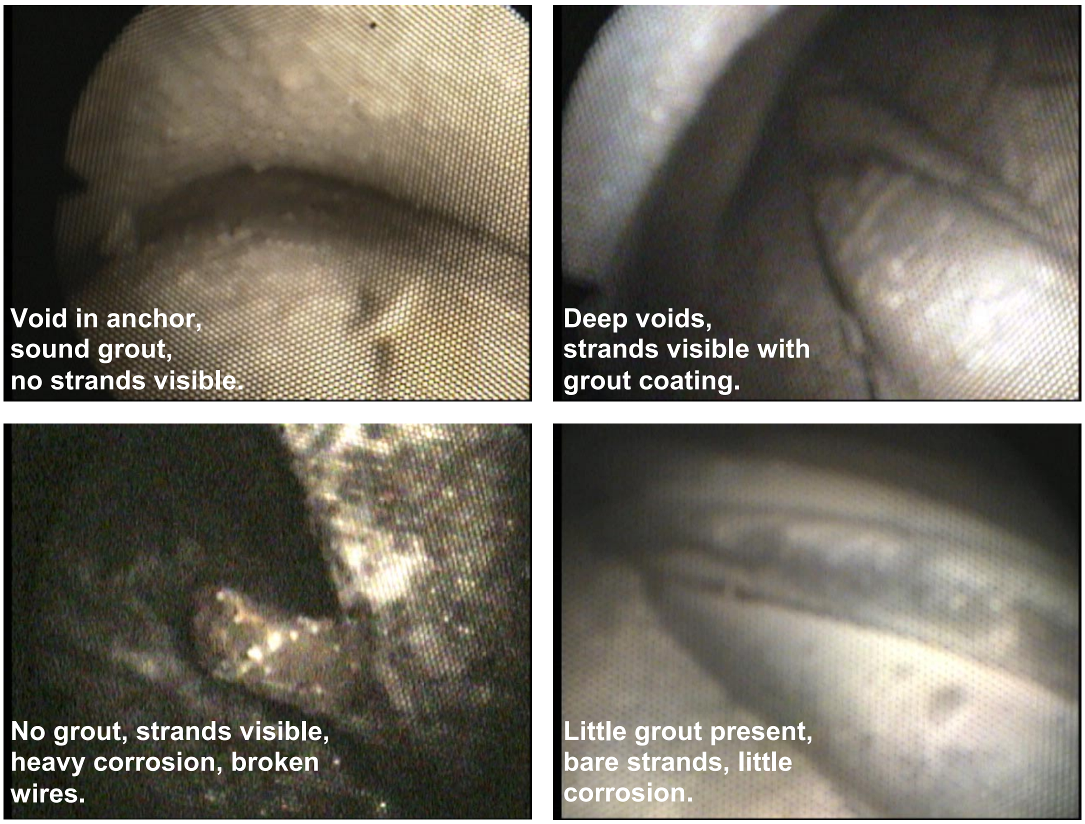


Figure 3.1 – Example of borescope images

Figure 3.1 - Clockwise from top:

(1) At void in anchor, the grout is sound and no strands are visible. This would be reported as no corrosion. However, the void at the anchor must be grouted as soon as possible.

(2) A deep void with visible strands coated with grout – but with no evidence of rust stain. This would be reported as no corrosion. However, the void must be grouted as soon as possible

(3) Although the strands are bare, there is no evidence of corrosion. This would be reported as no corrosion. However, the void must be grouted as soon as possible.

(4) There is heavy corrosion on the strands and some broken wires. The borescope (video) must be used to examine the remainder of visible strands and make an estimate the number of failed wires at this location. If it is more than 5% of the total wires, then it is a significant corrosion condition and further checks must be made of other tendons at the affected section.

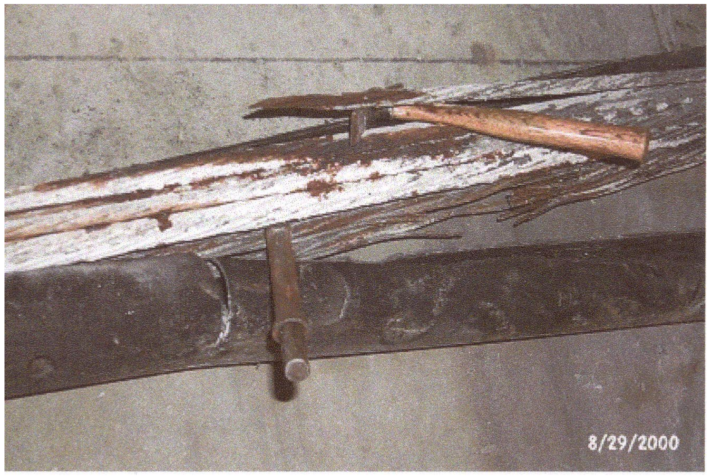


Figure 3.2 – Failure of external tendon due to corrosion (Mid-Bay)

Figures 3.2 and 3.3 illustrate the serious corrosion than might occur where water and salts have access into the tendon due to incomplete grouting. A little grout is visible on some strands, but most grout is missing and the strands are heavily corroded. If a borescope reveals similar corrosion in a tendon that has not yet failed, then it must be immediately reported to the Engineer as significant corrosion and appropriate repairs initiated.

Figure 3.2 – Failure of external tendon due to corrosion (Skyway)

TABLE 3.1 COUNT CORRODED WIRES

	Number	Name / Location		Inspection
Bridge:			Date:	
Span(s):			Inspector:	
Tendon:			Comments:	
Anchor:				

Notes:

? There are seven wires per strand - six around central king wire
? Only the outer six are visible in any one strand - not normally the king wire
? Assume the king wire is in the same condition as surrounding wires
? If strand is exposed count the king wire as exposed too
? Count the evidence in terms of number of wires not number of strands
? Enter information only in yellow highlighted boxes with blue text

		Number counted		Number visible	Number corroded	Number OK
Total number of wires in tendon (7*no. of strands)	N	0				
Wire Conditions: Estimated number of wires in following conditions:						
1 Wires embedded in grout (these are assumed not to be corroded)	n1		not visible			0
2 Wires coated with grout film but with no rust or only a slight yellow tint to grout film	n2		visible	0		0
3 Wires exposed as clean bare steel or with only slight discoloration or light scale	n3		visible	0		0
4 Wires exposed and rusty (wires have rust scale but are not necked down or broken)	n4		visible	0	0	
5 Wires exposed and broken (or very nearly rusted through)	n5		visible	0	0	
6 Wires exposed but not visible to borescope	n6		not visible			

Total number of wires counted = Ntot = 0 Count is OK wires in all strands

Percentage visible (of total number) = $\left[\frac{= Nvis*100}{(Ntot)} \right]$ % = 0 % visible

number visible = Nvis 0

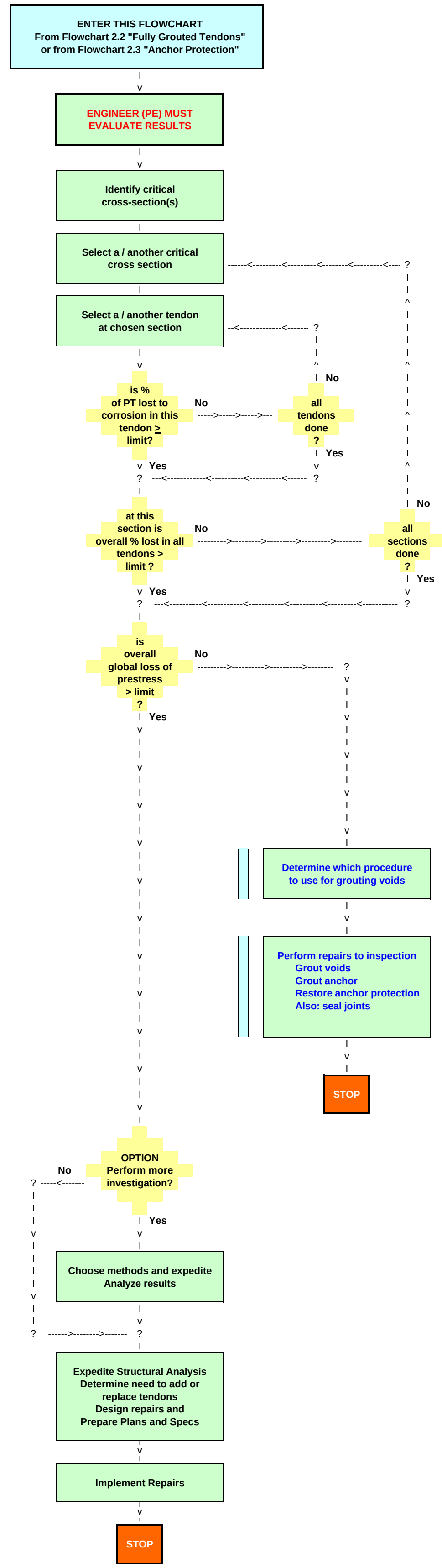
number estimated to be corroded = NG 0

number not corroded = Nok 0

Calculation of percentage lost to corrosion = $\left[\frac{= NG*100}{(Nok+NG)} \right]$ % = = percentage lost to corrosion = 0.0 OK

FLOWCHART 3.1 EVALUATE CORROSION

EVALUATE CORROSION



Follow Inspection and Assessment Procedures:
Chapter 3.4 Assess Overall Integrity of Level of Prestress
Chapter 3.4.2 **Limit is 5% of wires lost in a single tendon**

Follow Inspection and Assessment Procedures:
Chapter 3.4 Assess Overall Integrity of Level of Prestress
Chapter 3.4.2 **Limit is 2.5% of all wires lost in all tendons at chosen (critical) section**

Follow Inspection and Assessment Procedures:
Chapter 3.4 Assess Overall Integrity of Level of Prestress
Chapter 3.4.2 **Limit is 5% of all wires lost "globally in the structure"**

"Globally in the Structure" means
- Simple span - it means in the one span including all tendons in a single box, all tendons in multiple boxes, all tendons in all I-girders or all tendons in a multi-cellular box for that span
- For a continuous structure - it means in the continuous length of the structure between expansion joints - including all tendons in a single box, all tendons in multiple boxes, all tendons in all I-girders or all tendons in a multi-cellular box for that length of continuous structure
- For a column - it means in the one column
- For a hammerhead, straddle beam, monolithic frame or C-pier - it means that entire piece of substructure

To determine which procedure to use refer to Assessment Procedures
Chapter 3.1 Assess (Internal) Tendon (in length)
Chapter 3.2 Assess External Tendon
Chapter 3.3 Assess Tendon at Anchor

Use Repair Procedures
Chapter 4.8 Inject Grout to Long Void in Internal Tendon
Chapter 4.9 Vacuum Inject Grout into Local Void of Internal Tendon
Chapter 4.10 Vacuum Inject Grout at an Anchor
Chapter 4.11 Grout Multiple Duct Voids with Cross-Communication
Chapter 4.12 Seal Grout Ports and Vents
Chapter 4.13 Restore Anchor Protection (to accessible anchor)
Chapter 4.14 Local Repair to Anchor Protection

For overview of available methods refer to
Appendix B Overview of Inspection Methods and Table B.1
Possibilities include:
For Internal Tendons
- Ultrasonic sounding through concrete may confirm voids but cannot directly detect corrosion
- Impact Echo - ditto

External Tendons
- Magnetic Flux Exclusion can detect corrosion in accessible portions (possible up to 85% length) of external tendons
- Vibration of tendon may confirm reduced mass due to voids and can, with interpretation, detect loss of force that may arise from wire failures due to corrosion

For other possibilites, refer to Appendix B.1

Chapter 4 – Repair Procedures

4.1 Seal Joints using Methyl Methacrylate

4.1.1 Applicability

The following is for use in existing superstructures with dry (non-epoxy filled) joints between precast segments where it is necessary to seal leaks through the top slab portions of the joints.

It may also be used for sealing existing superstructures with epoxy joints between precast segments as an alternative to sealing by epoxy injection. Methyl methacrylate bonds with concrete and will, to some degree, bond with the epoxy and as a result fill gaps.

In particular, this procedure applies to:

- Precast Segmental Balanced Cantilever bridges
- Precast Segmental Span-by-Span bridges built with dry joints (before 2001)
- Precast Segmental Span-by-Span bridges built with epoxy joints (after 2001)

This procedure may also be used for sealing the top surface of:

- Joints between cast-in-place closure pours and precast segments
- Transverse construction joints in cast-in-place segmental construction
- Transverse construction joints in slabs, voided slabs or cellular boxes cast-in-place on falsework
- Non-structural transverse cracks in reinforced concrete deck slabs
- Non-structural transverse cracks in slabs, voided slabs or cellular boxes cast-in –place on falsework
- Similar transverse and longitudinal non-structural cracks or separation (shrinkage) cracks between precast concrete components and cast-in-place concrete joints or pour-backs

Methyl methacrylate is a very fluid material and, as such, penetrates very well into narrow gaps or cracks. It is capable of filling cracks up to 1/8” wide – however, at this width, it begins to exhibit shrinkage. In general, gaps between segment faces or cracks within concrete are much narrower. There is no minimum limit to a gap or crack width for the use of methyl methacrylate and it can penetrate over an inch into very fine cracks. Hence it is very useful for sealing most cracks in bridge decks and similar situations. In order to assist penetration, in some cases it helps to pond the material in a small reservoir.

The following procedure is for sealing joints in segmental bridges or similar gaps or cracks in decks of limited extent (e.g. a narrow strip across the deck at each joint). However, this procedure is not for general surface area application and so does not require the addition of any coarse sand finish to restore friction.

4.1.2 Procedure

(1) Take precautions to close lanes to traffic and implement traffic control as necessary. Operation may be done by closing a lane at a time, as appropriate.
(2) Examine top of deck surface and locate transverse joints between segments
(3) Using a concrete saw blade or other suitable tool cut a “V”, “U” or rectangular shaped groove centered on each joint for the width of the joint to be treated. The groove should be at least 3/8” wide by 1/2” deep but no more than 1/2” wide by 5/8” deep. Alternatively, use a suitable material (such as epoxy or silicone) to make a small bead dam approximately ½” wide by ½” high and approximately ½” clear of but parallel to and along each side of joint for width of joint to be treated. Bead dams may be installed after the drying period ((5) below).
(4) Clean along surface of joint. Use gentle water-blasting or sand-blasting and clean away all debris
(5) Allow groove and joint faces to dry for at least 48 hours prior to sealing. The period of drying shall start over again from the end of any wet cleaning operations or wet weather experienced during drying. (However, traffic may be allowed to run on deck as normal during drying period)
(6) Under clean, dry conditions, flood groove or dammed bead over joint with methyl methacrylate and allow it to soak into joint all along until no more can be absorbed
(7) Allow to set, bond, harden and cure per Manufacturer’s specification
(8) Clean up and re-open lane(s) to traffic as appropriate after curing (usually after approximately 1 hour)
(9) Repeat as necessary for other lanes until full width of each joint is sealed

4.2 Seal Joints using Epoxy Injection

4.2.1 Applicability

The following is for use in existing superstructures with epoxy joints between precast segments where it is necessary to seal leaks through the top slab portions of the joints.

It may also be used for sealing the top slab portions of existing superstructures with dry (non-epoxy filled) joints between precast segments as an alternative to sealing with methyl methacrylate.

In particular, this procedure applies to:

- Precast Segmental Balanced Cantilever bridges
- Precast Segmental Span-by-Span bridges built with dry joints (before 2001)
- Precast Segmental Span-by-Span bridges built with epoxy joints (after 2001)

This procedure may also be used for sealing the top surface of:

- Joints between cast-in-place closure pours and precast segments
- Transverse construction joints in cast-in-place segmental construction
- Transverse construction joints in slabs, voided slabs or cellular boxes cast-n –place on falsework

- Non-structural transverse cracks in reinforced concrete deck slabs
- Non-structural transverse cracks in slabs, voided slabs or cellular boxes cast-n –place on falsework
- Similar transverse and longitudinal non-structural cracks or separation (shrinkage) cracks between precast concrete components and cast-in-place concrete joints or pour-backs

4.2.2 Procedure

(1) Take precautions to close lanes to traffic and implement traffic control as necessary. Operation may be done by closing a lane at a time, as appropriate.
(2) Examine top of deck surface and locate transverse joints between segments
(3) Clean both top and bottom surface of joint for a width of at least 1" on each side of the joint. Use gentle water blasting or sandblasting and clean away all debris.
(4) Allow joint surfaces and interior of joint to dry for at least 48 hours prior to sealing by epoxy injection. The period of drying shall start over again from the end of any wet cleaning operations or wet weather experienced during drying. (However, traffic may be allowed to run on deck as normal during drying period)
(5) Under clean, dry conditions, install nipples for epoxy injection along bottom of top slab joint at intervals of approximately 1 foot for the full width of the slab and at least half way down each web on the inside and outside faces
(6) Smear epoxy along bottom of joint and half way down web faces to the extent of the installed injection nipples. Allow to set and bond to concrete.
(7) Commencing with the nipples installed on the webs, inject epoxy into the web joint and until it flows from the next nipple or nipples up the web on inside and outside. Close nipples and allow this epoxy to set before proceeding.
(8) Commencing on the low side of the bridge deck, close the shoulder and, if possible, the adjacent traffic lane.
(9) Inject epoxy into the nipples on the underside of the top slab on the low side of the deck until it flows from the next (underside) nipple or from the top surface.

(10) Allow epoxy to gel sufficiently at top to seal joint and continue injection at each succeeding nipple, closing each in turn and allowing epoxy to exude from top of joint
(11) Work steadily across closed traffic lanes of top slab – including over first web.
(12) After this initial epoxy has set, at a convenient time open the closed lanes to traffic and close the next lane(s) as necessary.
(13) Repeat procedure for other lanes working steadily across slab until full width of joint is sealed
(14) When injected epoxy has set and cured, remove injection nipples and clean off epoxy from all external surfaces.
(15) Clean up and re-open lane(s) to traffic as appropriate after setting
(16) Procedure may be run concurrently at several joints along the bridge as necessary and appropriate for traffic control, equipment, personnel and resources for injecting epoxy.

4.3 Repair External Tendon Duct by Wrapping

4.3.1 Applicability

This procedure applies to the repair of tears or cracks by the installation of a heat activated shrink-wrapping material to encase and seal damaged ducts around external tendons.

Do not use this procedure where existing duct has been removed from the tendon for any reason – whether by damage or deliberate removal to inspect the grout or tendon for corrosion. In such cases, repair the duct by installing new half-pipes in accordance with Repair Procedure 4.4 below. However, wrapping may be used where the existing duct is left in place even after slightly prying apart at a crack to inspect for corrosion as long as the pipe is returned to its original position (Figure 4.1).

Wrapping may be used to restore the integrity of ducts for external tendons used in any of the following bridge types:

- Precast Segmental Balanced Cantilever
- Precast Segmental Span-by-Span
- Cast-in-Place Balanced Cantilever
- Cellular Boxes Cast-in-Place on Falsework

It may also be used to repair ducts on external tendons installed as a repair or rehabilitation in any situation – such, as for example, in bridges of precast I-girders. This may also be used to repair ducts around vertical external tendons in hollow precast segmental piers, or similar applications.

The heat activated shrink-wrapping material consists of a cross-linked polyolefin backing coated with a protective heat sensitive adhesive that effectively bonds to both steel and common pipeline coatings including polyethylene and fusion bonded epoxy – i.e. materials typically used for ducts for external tendons. Sheets of wrap have a factory attached closure strip that facilitates rapid field installation. When heat is applied to the sheets, the adhesive is activated and the sheet shrinks significantly – sealing itself to the pipe. When properly installed, the wrap provides the structural integrity of a seamless tube offering durable corrosion protection.

Figure 4.1 – Wrapping External Duct

4.3.2 Procedure

For existing, external HDPE pipe duct that has tears or cracks - leave duct in place and wrap as follows.

(1) Remove steel band clamps securing neoprene boot to HDPE pipe and steel deviator or diaphragm pipe – but leave in place the neoprene boot
(2) Clean external surface of HDPE pipe, neoprene boot and exposed portions of steel pipes
(3) Lay and wrap sheets of material around pipe (working up-hill) with a weather-lap (shingle) overlap so that water cannot penetrate seams or joints and a minimum overlap per the Manufacturer's specifications
(4) Apply heat to activate the adhesive and shrink material onto pipe according to Manufacturer's requirements
(5) Also, apply sheets over neoprene boots and seal around steel pipes
(6) Grout, if it is necessary, may be introduced by vacuum grouting from the anchor once the duct has been sealed with wrap. (Refer to Section 4.10 for vacuum assisted grouting at an anchor).

4.4 Install New Half-Pipe Duct around External Tendon

4.4.1 Applicability

This procedure applies to the repair of tears or cracks by the installation of new, half-round, longitudinally jointed HDPE pipe ducts around external tendons. The new half-pipe ducts are then grouted to encase the tendons.

This procedure must be used where existing external duct has been removed from the tendon - for instance, either by damage or in order to examine the condition of the strands or grout.

It may be used to restore the integrity of ducts for external tendons used in any of the following bridge types:

- Precast Segmental Balanced Cantilever
- Precast Segmental Span-by-Span
- Cast-in-Place Balanced Cantilever
- Cellular Boxes Cast-in-Place on Falsework

It may also be used to repair ducts on external tendons installed as a repair or rehabilitation in any situation – such, as for example, in bridges of precast I-girders. It may also be used to repair ducts around vertical external tendons in hollow precast segmental piers, or similar applications, providing that sufficient length of half-pipe duct can be inserted into the available access in the pier.

The half-pipe has a special seal in the seams and grout ports can be installed in the field. (Figures 4.2 and 4.3)

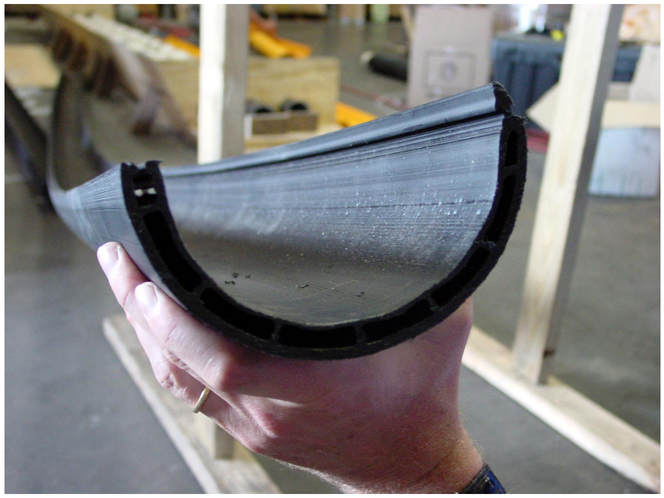


Figure 4.2 – HDPE Half-Pipe Duct with Special Seals to Seams

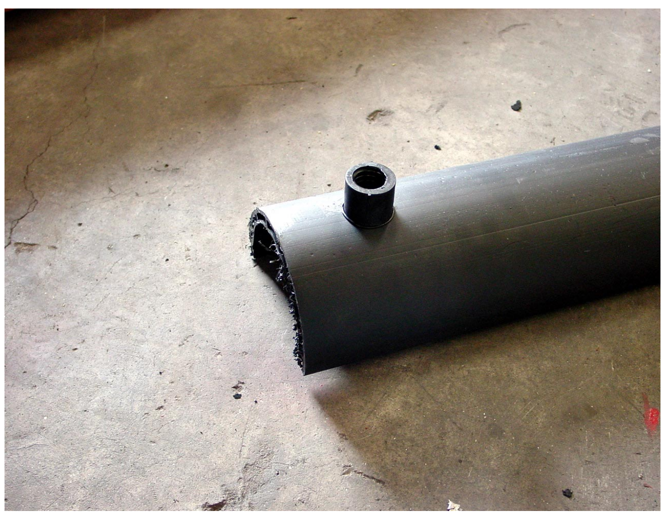


Figure 4.3 – Grout Vent Installed in Half-Pipe Duct

4.4.2 Procedure

(1) Existing torn or cracked HDPE pipe duct may be removed or left in place
(2) Cut portions of half-pipe to pre-measured lengths and install grout ports and vents at each end in accordance with manufacturer's recommendations
(3) Insert half-round pipes into box structure correctly oriented in paired halves
(4) Remove existing circular band clamps from neoprene boots connecting external duct to embedded (steel pipe) duct – but leave boots in place
(5) At known locations of grout voids in existing duct, with EXTREME CARE so as not to

damage the tendon, cut or drill holes (max ¾" dia) to allow grout to enter and fill any existing voids – alternatively, remove portions or all of any split or damaged existing HDPE pipe
(6) Place short pieces (3") of 3/8" self-adhesive foam strip at intervals of approximately 3 feet and at approximately 10 and 2 o'clock positions along top of existing external duct or exposed tendon to create space for grout
(7) Install end seals around neoprene boots
(8) Insert small bead of approved (silicone) sealant along each end 1 foot of new half-pipe joint
(9) Bring together two halves of half-pipe duct in place around existing tendon
(10) Compress together half-pipes until joints are tight all along duct (If necessary, use a suitable power tool, such as an air-powered packaging banding clamp and squeeze duct tight at intervals of approximately 1 foot working along duct)
(11) Inject grout as follows

4.4.3 Grout

Perform grouting all in accordance with FDOT Specifications.

(1) Use only FDOT approved grout, mix grout and perform material on-site fluidity tests in accordance with Specifications
(2) Inject grout (at lowest port) into annulus between existing duct (tendon) and installed half-pipe duct. Inject grout at steady rate of not less than 8 and not more than 12 gallons per minute
(3) Allow air, excess water and grout to flow freely from highest vent until consistency is satisfactory per specifications
(4) Lock-off the grout injection at a pressure of 75 psi - hold this pressure for two minutes and check for leaks. If leaks are indicated by reduced pressure then fix or seal leaks.
(5) Release the pumping pressure and check each vent is completely full of grout
(6) When the system has been filled, open the highest vent to release any accumulated air or bleed water. If necessary, pump grout in again until full. Close the highest vent and release pressure
(7) Pump up pressure and lock off at 30 psi
(8) Allow grout to take set
(9) Twenty four hours after grouting, probe grout vents to determine if the duct is now completely full of grout
(10) If voids are found then fill them using Vacuum Injection as follows (steps 11 through 23) if not, then go to step 24
(11) Attach a T-connector to grout pipe at void
(12) Attach valve to each open end of T-connector (valves (a) and (b))
(13) Attach grout pump to one valve (a)
(14) Attach vacuum pump to other valve (b)
(15) Close both valves (a and b)
(16) Use only FDOT approved grout, mix grout and perform material on-site fluidity tests in accordance with Specifications
(17) Open valve (b) and draw a vacuum to evacuate air. A vacuum is considered a reduction in pressure by 96% to 4% of atmospheric (equivalent to 822mm Hg or 980 mbar vacuum). If vacuum cannot be successfully drawn, cannot be sustained for a period of at least two minutes or the leakage rate exceeds 100mbar per minute, then check system

for leaks and seal them.

(18) Close valve (b)
(19) Open valve (a) and pump grout into anchor and duct under pressure up to 75 psi
(20) When grout fills void, release the pumping pressure to 30 psi and close valve (a)
(21) Allow the grout to set
(22) Twenty-four hours after grouting, open grout pipe valve (a) and probe for void
(23) If void is found, repeat vacuum assisted injection
(24) After completion of grouting, trim grout pipe, cap and seal vents with approved non-metallic caps secured and sealed in place with screw thread and an approved sealant installed according to the manufacturer's instructions

4.4.4 Features of a Currently Available Half-Pipe System

- The half-round, pipe has a longitudinal, male-female, press-fit joint with a longitudinal mechanical seal (Figure 4.2).
- The pipe is made from an approved high density, durable, non-degradable, non-metallic (plastic) material
- It is makes a neat, straight smooth pipe when assembled
- The half-pipe is easy to cut to length and assemble in place around an existing tendon
- An air-powered steel banding clamp is needed (but is efficient) to press-fit tight the joints
- Assembled pipes have performed well – by withstanding over 100psi pressure during test grouting with no sign of leaks
- End seals are placed between the half-pipe and neoprene boot around the steel pipe duct entering the deviation saddle, diaphragm or anchor block.
- It is not necessary to apply any heat shrink-wrap around the ends to supplement end seals
- A bead of sealant may be needed for a length of about 1 foot at each end along the half-pipe joint
- The finished assembly, joints and end seals are easy to inspect
- On-site, fabrication, cutting, installation, assembly, end-seals, installing grout vents and grouting can be performed by a trained work team to ensure consistent quality
- When field installing half-pipes, it is important to remember to orient the half-pipes in pairs, before passing them inside a box section – as there is usually insufficient space to turn pieces end for end once inside!
- Oversight inspection of installation (CEI) should be simple and straightforward
- Having a smooth, uniform finished surface, the pipe would facilitate any future use of inspection devices (such as magnetic flux) that must roll along the pipe at an even distance from the strands.
- The half-pipe system involves no heating or dealing with toxic or noxious fumes in confined spaces inside box girder sections.
- The half-pipe system provides a means of completely encapsulating an existing external duct or of replacing it.
- The HDPE half-pipe system provides duct with a continuous seal, making it as if it is a pipe of monolithic section.
- It offers a practical method of restoring or replacing a damaged external duct.

4.5 Drill Grout Port or Inspection Port into an Internal Duct

4.5.1 Applicability

The following applies to any internal tendon duct found or suspected after visual inspection to contain a grout void. The void may be isolated to a portion of the duct somewhere along the length of the tendon, or it might extend from an anchor for several feet along the tendon.

4.5.2 Procedure

The procedure involves drilling into the duct through the concrete cover, as far as possible avoiding local reinforcement and not damaging the tendon.

(1) From previous inspection reports, Plans, Shop Drawings and field observations:

- For a longitudinal tendon in the top or bottom slab of a box section, locate the lateral position of the tendon in the slab over the length concerned.
- For a longitudinal tendon draped in a web locate the vertical position of the tendon in the web over the length concerned

(2) Also locate other internal post-tensioning if present (e.g. transverse tendons in a top slab of a box girder) and local mild steel reinforcement. Refer to records, Plans and Shop Drawings and use magnetic detection device (cover meter or similar) to determine field position of rebar and post-tensioning.

(3) Determine the optimum location for inspection port to be drilled into the duct.

(4) Also locate inspection port to be drilled with regard to the following:
   (a) Use EXTREME CARE – DO NOT drill into or through post-tensioning tendons – relocate hole as necessary
   (b) As far as possible, avoid drilling through mild steel reinforcement. If rebar is encountered, relocate hole to be drilled
   (c) However, if drilling through mild steel reinforcement cannot be avoided then proceed with caution and drill only through the least possible reinforcement within the following guidelines:
      - In precast segmental bridges (of either balanced cantilever or span-by-span construction) only - it is permissible to drill through longitudinal reinforcement in the top and bottom of the bottom slab providing that the reinforcement to be severed is only of #4 bar size or less. Do not drill through larger diameter longitudinal or transverse reinforcing bars. However, it is permissible to drill through small diameter (#3 bar or D4 wire) running longitudinally or transversely in the bottom slab of these bridges
      - In all precast and cast-in-place segmental bridges, and cast-in-place cellular boxes, do not drill through reinforcement that is part of an anchor blister or deviation saddle
      - For all other structures, do not drill through rebar
      - In case of doubt, seek the advice of a knowledgeable engineer.

(5) At the selected location(s), if it is expected that the void will have to be grouted then first

use a core cutter, saw or other suitable tool to cut a recess into the concrete surface not less than 2” or more than 3-1/2” outside diameter (or square). This recess is for sealing the finished grout vent. Make depth of recess as follows:

- For existing top roadway surface – 2” to 2-1/2” deep
- For top surface of a bottom slab, underside of soffit or side face (of web, substructure cap or similar vertical face) – 1-1/2” to 2” deep
- In all cases, do not exceed the depth of cover

Cut a separate recess for each anticipated grout pipe. If performing operation on two or more adjacent tendons - do not merge recesses into a larger one – keep each recess separate from any adjacent recess by at least 6” (edge to edge) - so that, in future, if a recess or grout pipe is breached only the one tendon will be at risk from leaks and corrosion - not several.

After cutting recess, roughen sides to ensure a good mechanical bond (in addition to chemical or adhesive bond with subsequent epoxy or other approved filler.)

(6) Drill through the center of each recess and into duct using a maximum diameter of 1” (preferably less). Drill with EXTREME CARE so as not to damage post-tensioning strands (or PT bars)

(7) Perform inspection of duct – refer to Inspection and Assessment Procedure:

- ***3.1 Inspect and Assess Internal Tendon***

(8) After completion of inspection, grout any voids and seal – refer to Repair Procedures:

- ***4.8 Inject Grout to Fill a Long Void in an Internal Duct***
- ***4.9 Vacuum Inject Grout into Local Void of Internal Tendon***
- ***4.12 Seal Grout Ports and Vents***

4.6 Create Grout Port or Inspection Port at an Anchor

4.6.1 Applicability

It is assumed that the presence of a grout void in the anchor zone has already been determined or is strongly suspected from previous inspection and that further investigation possibly using a bore-scope is necessary and/or that a pipe for grout injection must be installed.

The anchor must be accessible to directly drill an inspection port into an existing grout vent or it must be accessible for drilling a new inspection port through the existing wedge plate or anchor plate. If not, then it will be necessary to drill into the side of the anchor cone or duct, just behind the anchor plate, from the side, top or bottom of the local anchor block in the concrete member.

Some anchors are more directly accessible than others depending upon the type of structure and the anchor protection or embedment.

The most directly accessible anchors are those in diaphragms or end blocks at expansion joints where there is sufficient clearance for access by maintenance personnel and equipment - and also those in diaphragms, ribs or blisters on the interior of a hollow section accessible to maintenance personnel and equipment. This requires the removal (and replacement) of anchor protection and possibly pour-backs – but does not require the removal of structural concrete. In particular this applies to anchors for longitudinal internal and external tendons in bridges of:

- Precast Segmental Balanced Cantilever (not including face anchors)
- Precast Segmental Span-by-Span
- Cast-in-Place Segmental Balanced Cantilever (not including face anchors)
- Cellular Boxes Cast-in-Place on Falsework

In the above cases, it is a relatively simple matter to remove the anchor protection to access the components. In addition, the following are also directly accessible even though the effort to gain access may be relatively more difficult:

- Anchors (for vertical tendons) located on the accessible inside of hollow section substructure column (usually precast but could be cast-in-place construction)
- Anchors in the ends of substructure hammerhead caps, straddle-beams, monolithic straddle-bents and C-piers

For the purpose of these inspection and repair procedures, anchors in all the above situations are considered and referred to as **"directly accessible anchors".**

Anchors that are not directly accessible are those embedded in a structural concrete member, under a deck slab, in the ends of solid or voided slabs or in similar situations that would require removal not only of a protective pour-back, but also structural concrete – which would be unacceptable. In general, this applies to anchors in bridges and structures of:

- Precast segmental cantilever with face-anchored tendons
- Precast I-girders
- Cast-in-place segmental cantilever with face-anchored tendons
- Solid and Voided Slabs, Cast-in-Place on Falsework
- Substructure column caps (bearing reaction confinement PT)
- Vertical PT anchors in tops of substructure columns
- Transverse PT in deck slabs of precast and cast-in-place segmental bridges
- Transverse PT through precast pre-stressed concrete planks or double-T's
- Vertical PT embedded in superstructure diaphragms or webs box structures

For the purpose of this procedure, these anchors are considered and referred to as **"anchors - not directly accessible".**

The preparation work for gaining access to the anchor for inspection by bore-scope or to install a grout pipe is different depending upon whether the anchor is "directly" or "not directly" accessible – as follows:

4.6.3 Preparation for Directly Accessible Anchors

For anchors that are directly accessible (i.e. at expansion joints or for those in diaphragms, ribs or blisters directly accessible from the inside of a hollow box) then clean and prepare anchor as follows:

(1) Remove existing anchor protection (seal coating), pour-back material and existing grout cap (if any) to expose wedge plate and anchor plate of strand tendon (or anchor nut and plate of PT bar tendon).

(2) Clean existing grout or other material from external surfaces of wedge plate, anchor plate and wedges (or from anchor nut and plate of PT bar).

(3) For strand tendons, examine existing wedge plate and anchor plate for an existing grout vent. Some types of wedge plates may have an existing grout vent at the center, others do not. In anchor plates, an existing grout vent should be outside the perimeter of the wedge plate, and be between 3/8” to ¾” diameter.

Clean out grout vent – if necessary by drilling – to provide access to interior of anchor cone behind anchor plate for inspection by bore-scope or to install pipe for grout injection. Note – drill with EXTREME CARE to avoid damage to tendon.

Caution: If it is not possible to clean out an existing grout vent, it might be possible to drill a hole for inspection or grout injection. A new hole may be drilled through the wedge plate close to the center of the plate. The maximum size of the hole should not exceed 3/8” diameter. However, do not through drill wedge plate if the hole will interfere with or intersect existing wedges or strands. A second possibility is to drill through face of the anchor plate. In this case, center the hole at least 1” from perimeter of wedge plate. Use a maximum diameter of 3/8” and drill at an angle up to approximately 30 degrees from perpendicular in order to enter the anchor trumpet behind the rear of wedge plate. In either case, the manufacturer of the anchorage should be contacted for advice prior to drilling and EXTREME CARE should be taken to avoid damaging the strands or affecting the capacity of the anchorage.

(4) For PT bar tendons, anchor plates generally do not have a grout vent. If the bar tendon has a rectangular, flat (not bell-type) anchor plate then a hole may be drilled through the plate (not the nut). Center the hole at least 1” clear of nut - use maximum size of 1/2” diameter and drill at an angle up to approximately 30 degrees from perpendicular in order to enter voided area of duct at rear of anchor plate. Drill with EXTREME CARE so as not to damage the PT bar. (If PT anchor is a “bell type” then access may be gained by drilling through the side of the anchor block using the procedure for “***Preparation for Anchors Not Directly Accessible***” - below)

(5) For strand (or PT bar tendons), if it is not possible to drill through wedge plates or anchor plates, then the alternative is to drill through side of the anchor zone concrete into the anchor cone of a strand tendon (or into the duct of a bar tendon) – to intersect the cone (or duct) approximately 2” to 4” behind the anchor plate. This may require drilling through several inches of concrete, local anchor zone reinforcement and the steel of an anchor cone (trumpet). The operation then becomes the same as for an anchor that is

embedded and “not directly accessible”. In which case, follow the procedure for “***Preparation for Anchors Not Directly Accessible***” - below.

4.6.4 Preparation for Anchors Not Directly Accessible

For anchors in the ends of post-tensioned I-girders, or embedded in the ends of solid slabs, voided slabs or similar situations where the anchor is not directly accessible without the (unacceptable) removal of structural concrete, then access to the anchor may be gained by drilling through the side of the anchor block concrete - into the anchor cone of a strand tendon (or into the duct of a bar tendon) – to intersect the cone (or duct) approximately 2” to 6” behind the anchor plate. This may require drilling through several inches of concrete, anchor zone reinforcement and the steel of an anchor cone (trumpet).

(1) From previous inspection reports, Plans, Shop Drawings and field observations locate the position of the tendon and anchor on the side, top or bottom, of the anchor block

(2) Locate local mild steel reinforcement. Refer to records, Plans and Shop Drawings and use magnetic detection device (cover meter or similar) to determine field position of rebar

(3) Select a suitable location to drill hole into anchor (or duct), so as to avoid local reinforcement

(4) Drill small diameter (maximum 3/8” diameter) pilot hole. If drill encounters reinforcement, carefully relocate hole

(5) When pilot drill does not encounter reinforcement enlarge hole to size sufficient to accommodate bore-scope or grout pipe (no larger than 1” dia.) and drill to penetrate anchor cone (or duct). Drill with EXTREME CARE so as not to damage strand (or PT bar)

(6) Where grout pipe is to be installed, first carefully cut a recess to facilitate sealing of the finished grout port. Use a core cutter, saw or other suitable tool to cut a recess into the concrete surface not less than 2” or more than 3-1/2” outside diameter (or square). Make depth of recess as follows:

- For existing top roadway surface – 2” to 2-1/2” deep
- For top surface of a bottom slab, underside of a soffit or side face (of web, anchor block, substructure cap or similar vertical face) – 1-1/2” to 2” deep
- In all cases, do not exceed the depth of cover

If performing operation on two or more adjacent tendons or anchors cut a separate recess for each grout pipe - do not merge recesses into a larger one – keep each recess separate from any adjacent recess by at least 6” (edge to edge) - so that, in future, if a recess or grout pipe is breached only the one tendon will be at risk from leaks and corrosion - not several.

After cutting recess, roughen sides to ensure a good mechanical bond (in addition to chemical or adhesive bond with subsequent epoxy or other approved filler.)

(7) Thoroughly clean fill and seal un-used pilot holes. Use an approved (epoxy) filler material and seal surface with an approved sealant. Use only materials from FDOT QPL.

Perform inspection of tendon at anchor (using bore-scope). Follow Inspection and Assessment Procedure: **3.3 -** ***Inspect and Assess Tendon at Anchor.***

Upon completion of inspection and assessment of tendon, if it is determined that the tendon may be left in place (i.e. not removed because of corrosion or other damage) then fill any void by injecting new grout. Follow Repair Procedure to: **4.10 -** ***Vacuum Inject Grout at an Anchor.***

Upon completion of inspection and grouting, for "***directly accessible anchors***" restore anchor protection. Follow Repair Procedure to: **4.11 -** ***Restore Anchor Protection.***

4.7 Determine Volume of Grout Void

4.7.1 Applicability

The following are two possible procedures for determining void size. They are appropriate for internal or external tendons in any structure type. It is anticipated that they would be used in conjunction with repair procedures that subsequently fill voids with grout – by vacuum grouting. Any openings into tendons must be properly sealed afterwards.

4.7.2 Procedure – Air Pressure Method

(1) Drill inspection port into an anchor or a tendon at the location of the suspected void and fit with a suitable (grout) pipe with an airtight connection. (Use EXTREME CARE when drilling to avoid damage to PT strands or bars). It is assumed that at this time the void is at atmospheric pressure (P_a).

(2) Connect a container of known volume (V_c) to the grout pipe. The container should be fitted with a pressure gauge and valve to control the flow of air from the container to the void. The container should be filled with air and pressurized to a known pressure (P_1). This pressure should be at least greater than two atmospheres.

(3) Open valve connecting the container to the void and measure reduced pressure (P_2)

(4) Compute void volume (V_v) using Boyle's Law:

$$(P_1 * V_c) + (P_a * V_v) = P_2 * (V_c + V_v)$$

$$\text{Therefore: } V_v = V_c * (P_1 - P_2) / (P_2 - P_a)$$

It may be necessary to try the test a few times at different initial pressures (P1) until pressure (P2) is held at a pressure greater than atmospheric for a sustained period. If it is not possible to perform test and sustain a pressure (P2) when connected to the void then either the grout void is extensive or it has a leak to the atmosphere. If the pressure (P2) gradually reduces then there is a very likely a tiny leak

4.7.3 Alternative Procedure – "Volumetric Method"

Some types of commercially available equipment for vacuum grouting have a device for automatically measuring the volume of a void. The device functions by measuring the flow of air returning to the void through a flow meter after the pressure has first been reduced to a predetermined pressure level (i.e. one-half atmosphere) in the equipment and the void. This technique is sometimes referred to as the "Volumetric Method". It is very convenient when performing vacuum grouting operations.

When the volume of the void has been determined, the amount of grout needed is directly estimated. For grouting installation, the pressure (vacuum) is reduced by 96% to 4% of atmospheric and grout is introduced under a positive pressure of 75 psi via a separate manifold valve connected in the vacuum line to grout port. This is a very effective way of determining volumes of voids and then filling them with grout.

4.8 Inject Grout to Fill a Long Void in an Internal Duct

4.8.1 Applicability

The following applies to an internal tendon duct found to contain a grout void over a length of many feet as determined after inspection by bore-scope, by probes, sounding or other methods or where attempts to vacuum grout have proven unsuccessful because a vacuum could not be sustained or the leakage rate of air exceeded 100mbar per minute after first attaining a vacuum of 96% of one atmosphere (equivalent to 822mm Hg vacuum).

The void itself may be isolated to a portion of the duct somewhere along the length of the tendon, or it might extend from an anchor along the tendon. The procedure applies to longitudinal internal tendons in all types of bridges and may also be used for internal vertical tendons.

4.8.2 Procedure

The procedure involves drilling into the duct through the concrete cover, as far as possible avoiding local reinforcement and not damaging the tendon.

(1) From previous inspection reports, Plans, Shop Drawings and field observations;
- For a longitudinal tendon in the top or bottom slab of a box section, locate the lateral position of the tendon in the slab over the length concerned.
- For a longitudinal tendon draped in a web locate the vertical position of the tendon in the web over the length concerned

(2) Using results of inspection by bore-scope or other method, locate the longitudinal extent of the known or suspected void along the tendon duct

(3) Also locate other internal post-tensioning if present (e.g. transverse tendons in a top slab of a box girder) and local mild steel reinforcement. Refer to records, Plans and Shop Drawings and use magnetic detection device (cover meter or similar) to determine field position of rebar and post-tensioning.

(4) Determine the location for each grout vent to be drilled into the duct. Locate a vent as near as possible to each end of detected void and at intermediate intervals, if necessary, but no closer than 10 feet. If the grout void is over the crest of a tendon then make sure that one vent is drilled at the high point of the crest profile.

(5) Also locate grout vents to be drilled with regard to the following:
   (a) Use EXTREME CARE when drilling so as not to drill through or damage post-tensioning tendons – relocate the hole as necessary
   (b) As far as possible, avoid drilling through mild steel reinforcement. If rebar is encountered, relocate hole to be drilled
   (c) However, if drilling through mild steel reinforcement cannot be avoided then proceed with caution and drill only through the least possible reinforcement within the following guidelines:
      - In precast segmental bridges (of either balanced cantilever or span-by-span construction) only - it is permissible to drill through longitudinal reinforcement in the top and bottom of the bottom slab providing that the reinforcement to be severed is only of #4 bar size or less. Do not drill through larger diameter longitudinal or transverse reinforcing bars. However, it is permissible to drill through small diameter (#3 bar or D4 wire) running longitudinally or transversely in the bottom slab of these bridges
      - In all precast and cast-in-place segmental bridges, and cast-in-place cellular boxes, do not drill through reinforcement that is part of an anchor blister or deviation saddle
      - For all other structures, do not drill through rebar
      - In case of doubt, seek the advice of a knowledgeable engineer.

(6) At the selected locations, first use a core cutter, saw or other suitable tool to cut a recess into the concrete surface not less than 2” or more than 3-1/2” outside diameter (or square). (This recess is for sealing the finished grout vent). Make depth of recess as follows:

- For existing top roadway surface – 2” to 2-1/2” deep
- For top surface of a bottom slab, underside of soffit or side face (of web, substructure cap or similar vertical face) – 1-1/2” to 2” deep
- In all cases, do not exceed the depth of cover

Cut a separate recess for each grout pipe. If performing operation on two or more adjacent tendons - do not merge recesses into a larger one – keep each recess separate from any adjacent recess by at least 6” (edge to edge) - so that, in future, if a recess or grout pipe is breached only the one tendon will be at risk from leaks and corrosion - not several.

After cutting recess, roughen sides to ensure a good mechanical bond (in addition to chemical or adhesive bond with subsequent epoxy or other approved filler.)

(7) Drill through the center of each recess and into duct using a maximum diameter of 1” (preferably less). Drill with EXTREME CARE so as not to damage post-tensioning strands (or PT bars)

(8) Clean edges and sides of drilled holes and recesses of all debris taking care not to allow debris to enter duct void. Dry concrete sides and edges of holes and recesses

(9) Use non-metallic (plastic), ribbed, grout pipe of tight fitting outside diameter. Insert grout pipes into each drilled hole to depth of nearest edge of PT duct (no deeper) and seal with epoxy. Apply sufficient epoxy to seal pipe but take care not to allow too much excess to drip into duct and locally block the void

(10) When grout pipes are sealed and secure, attach a valve to each one

(11) Open all valves and blow clean, dry, oil-free, air through voided duct to remove any and as much loose debris or water from within

(12) Use only FDOT approved grout, mix grout and perform material on-site fluidity tests in accordance with Specifications

(13) Select the grout pipe at the lowest point of the voided length of duct for the injection port and connect to grout pump and pressure gage

(14) Inject grout at selected port. Inject grout at steady rate of not less than 8 and not more than 12 gallons per minute

(15) Allow air, excess water and grout to flow freely from next intermediate vent until consistency is satisfactory per specifications. Then close this vent and continue pumping at steady rate

(16) Allow air, excess water and grout to flow freely from next vent at a satisfactory consistency per specifications. Then close vent and continue pumping at steady rate

(17) Allow air, water and grout to flow from each intermediate vent in turn until it flows from the final vent until consistency is satisfactory per specifications. Then close final vent

(18) Lock-off the grout injection at a pressure of 75 psi - hold this pressure for two minutes and check for leaks. If leaks are indicated by reducing pressure then repair or seal leaks

(19) Release the pressure and check outlet vent for full grout

(20) If necessary, pump in more grout until completely full and all bleed water and air has been expelled from the outlet vent. Close outlet vent

(21) Pump up pressure lock off at 30 psi

(22) Twenty four hours after grouting, drill with EXTREME CARE and probe all grout pipes to determine if the void is now completely full of grout

(23) If voids are still present, then completely fill them by vacuum assisted grouting (Follow Repair Procedure: **4.9 -** ***Vacuum Inject Grout into Local Void of Internal Tendon.***

(24) After completion of grouting, trim each grout pipe, cap and seal recesses. (Follow Repair Procedure: **4.12 -** ***Seal Grout Ports and Vents.***

4.9 Vacuum Inject Grout into Local Void of Internal Tendon

4.9.1 Applicability

This procedure is for injecting grout into a partially grouted duct at a void of limited extent - but not at an anchor – and where it is not necessary (or practical) to use or to drill more than one grout vent into the duct. This procedure applies to longitudinal internal tendons in all types of bridges and may be used for individual, internal vertical tendons.

4.9.2 Procedure

The procedure involves drilling into the duct through the concrete cover, as far as possible avoiding local reinforcement and not damaging the tendon.

(1) From previous inspection reports, Plans, Shop Drawings and field observations;
- For a longitudinal tendon in the top or bottom slab of a box section, locate the lateral position of the tendon in the slab over the length concerned.
- For a longitudinal tendon draped in a web locate the vertical position of the tendon in the web over the length concerned

(2) Using results of inspection by bore-scope or other method, locate the longitudinal extent of the known or suspected void along the tendon duct

(3) Also locate other internal post-tensioning if present (e.g. transverse tendons in a top slab of a box girder) and local mild steel reinforcement. Refer to records, Plans and Shop Drawings and use magnetic detection device (cover meter or similar) to determine field position of rebar and post-tensioning.

(4) Determine the location of grout vent to be drilled into the duct. Locate vent as near as possible to center of void.

(5) Also locate grout vents to be drilled with regard to the following:
  (a) Use EXTREME CARE when drilling so as not to drill through or damage post-tensioning tendons – relocate hole as necessary
  (b) As far as possible, avoid drilling through mild steel reinforcement. If rebar is encountered, relocate hole to be drilled
  (c) However, if drilling through mild steel reinforcement cannot be avoided then proceed with caution and drill only through the least possible reinforcement within the following guidelines:
    - In precast segmental bridges (of either balanced cantilever or span-by-span construction) only - it is permissible to drill through longitudinal reinforcement in the top and bottom of the bottom slab providing that the reinforcement to be severed is only of #4 bar size or less. Do not drill through larger diameter longitudinal or transverse reinforcing bars. However, it is permissible to drill through small diameter (#3 bar or D4 wire) running longitudinally or transversely in the bottom slab of these bridges
    - In all precast and cast-in-place segmental bridges, and cast-in-place cellular

boxes, do not drill through reinforcement that is part of an anchor blister or deviation saddle

- For all other structures, do not drill through rebar
- In case of doubt, seek the advice of a knowledgeable engineer.

(6) At selected location, first use a core cutter, saw or other suitable tool to cut a recess into the concrete surface not less than 2” or more than 3-1/2” outside diameter (or square). (This recess is for sealing the finished grout vent). Make depth of recess as follows:

- For existing top roadway surface – 2” to 2-1/2” deep
- For top surface of a bottom slab, underside of soffit or side face (of web, substructure cap or similar vertical face) – 1-1/2” to 2” deep
- In all cases, do not exceed the depth of cover

(7) Cut a separate recess for each grout pipe. If performing operation on two or more adjacent tendons - do not merge recesses into a larger one – keep each recess separate from any adjacent recess by at least 6” (edge to edge) - so that, in future, if a recess or grout pipe is breached only the one tendon will be at risk from leaks and corrosion - not several.

(8) After cutting recess, roughen sides to ensure a good mechanical bond (in addition to chemical or adhesive bond with subsequent epoxy or other approved filler.)

(9) Drill through the center of the recess and into duct using a maximum diameter of 1” (preferably less). Drill with EXTREME CARE so as not to damage post-tensioning strands (or PT bars)

(10) Clean edges and sides of drilled hole and recess of all debris taking care not to allow debris to enter duct void. Dry concrete sides and edges of holes and recesses

(11) Use non-metallic (plastic), ribbed, grout pipe of tight fitting outside diameter. Insert grout pipes into each drilled hole to depth of nearest edge of PT duct (no deeper) and seal with epoxy. Apply sufficient epoxy to seal pipe but take care not to allow too much excess to drip into duct and locally block the void

(12) When each grout pipe is sealed and secure, attach a T-connector so that cross piece of T aligns with grout pipe

(13) Attach valve each other open end of T-connector (valves (a) and (b))

(14) Attach grout pump to one valve (a)

(15) Attach vacuum pump to other valve (b)

(16) Close both valves (a and b)

(17) Use only FDOT approved grout, mix grout and perform material on-site fluidity tests in accordance with Specifications

(18) Open valve (b) and draw a vacuum to evacuate air. A vacuum is considered a reduction

in pressure by 96% to 4% of atmospheric (equivalent to 822mm Hg or 980 mbar vacuum). If vacuum cannot be successfully drawn, cannot be sustained for a period of at least two minutes or the leakage rate exceeds 100mbar per minute, then check system for leaks and seal them *.

(19) Close valve (b)

(20) Open valve (a) and pump grout into anchor and duct under pressure up to 75 psi

(21) When grout fills void, release the pumping pressure to 30 psi and close valve (a)

(22) Allow the grout to set

(23) Twenty-four hours after grouting, open grout pipe valve (a) and probe for void

(24) If void is found, repeat vacuum assisted injection

(25) When completely grouted, trim each grout pipe, cap and seal recess. (Follow Repair Procedure: **4.12 - *Seal Grout Port and Vents.***

*Sealing of a leak depends upon the nature of the leak. It is possible that the leak might be along the tendon path and may therefore be larger than estimated by probe or bore-scope examination ***at the local void***. In which case, it may be necessary to locate another grout injection port at another position some distance from the anchor. This would change the nature of the operation to that of installing grout in a portion (length) of un-grouted or partially grouted tendon (*See Repair Procedure:* ***4.8 - Inject Grout to Fill a Long Void in an Internal Duct).*** If the leak is around the injection pipe, then it may be possible to seal it with further epoxy and, if not, then it may be necessary to remove the pipe, clean the hole, re-insert the pipe, seal again with epoxy and then repeat the operation.

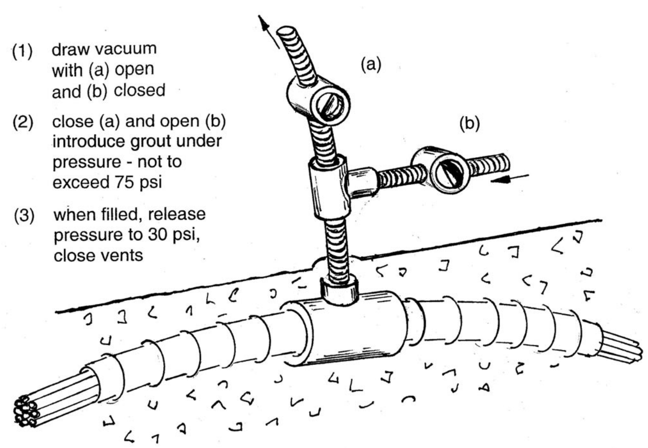


Figure 4.4 – Vacuum injection along the length of a tendon.

4.10 Vacuum Inject Grout at Anchor

4.10.1 Applicability

This procedure applies to all tendons in all bridge types.

It is assumed that the presence of a grout void in the anchor zone has already been determined and that it has also been determined that the tendon in the void behind the anchor is in satisfactory condition to be left in place and re-grouted rather than to be removed and replaced.

If this is not the case, then first carry out inspection and assessment of condition of tendon. (Refer to Inspection and Assessment Procedure: **3.3 - *Inspect and Assess Tendon at Anchor***).

Also refer to Repair Procedure: **4.6 - *Create a Grout Port or Inspection at an Anchor*** in order to prepare for inspection and grout injection.

4.10.2 Procedure

(1) Attach grout pipe to grout vent, port or to hole drilled for the purpose (e.g. Figure 4.5)
(2) Make an airtight connection (seal connection with silicone or epoxy)
(3) Attach T-connector to grout pipe so that cross piece of T aligns with grout pipe
(4) Attach valve to each other end of T-connector (valves (a) and (b))
(5) Attach grout pump to one valve (a)
(6) Attach vacuum pump to other valve (b)
(7) Close both valves (a and b)
(8) Use only FDOT approved grout, mix grout and perform material on-site fluidity tests in accordance with Specifications.
(9) Open valve (b) and draw a vacuum to evacuate air. A vacuum is considered a reduction in pressure by 96% to 4% of atmospheric (equivalent to 822mm Hg or 980 mbar vacuum). If vacuum cannot be successfully drawn, cannot be sustained for a period of at least two minutes or the leakage rate exceeds 100mbar per minute, then check system for leaks and seal them *.
(10) Close valve (b)
(11) Open valve (a) and pump grout into anchor and duct under pressure up to 75 psi
(12) When grout fills void, release the pumping pressure to 30 psi and close valve (a)
(13) Allow the grout to set
(14) Twenty-four hours after grouting, open grout pipe valve (a) and probe for voids
(15) If voids are found, repeat vacuum injection
(16) When grouting has been completed, then:

Either remove grout pipe and restore anchor protection (follow Repair Procedure: **4.13 - *Restore Anchor Protection***), or where it has been necessary to drill into the side of the anchor block to install the grout pipe - trim grout pipe, cap and seal recess (follow Repair Procedure: **4.12 - *Seal Grout Ports and Vents***)

*Sealing of a leak depends upon the nature of the leak. It is possible that the leak might be along the tendon path and may therefore be larger than estimated by probe or bore-scope examination ***at the anchor area***. In which case, it may be necessary to locate another grout injection port at another position some distance from the anchor. This would change the nature of the operation to that of installing grout in a portion (length) of un-grouted or partially grouted tendon (*see Repair Procedure:* **4.8 - *Inject Grout to Fill a Long Void in an internal Duct".***) If the leak is around the injection pipe, then it may be possible to seal it with further silicone or epoxy and, if not, it may be necessary to remove the pipe, clean the hole, re-insert the pipe, seal again with silicone or epoxy and then repeat the operation.

Figure 4.5 – Vacuum injection at anchorages

4.11 Grout Multiple Duct Voids with Cross Communication

4.11.1 Applicability

This procedure applies to precast segmental bridges with internal longitudinal post-tensioning tendons and poorly sealed joints between segments. The bridge may be of precast segmental balanced cantilever or span-by-span construction.

The tendons may be in the top or bottom slab – either cantilever tendons in the top slab – or continuity tendons in both the top and bottom slabs.

(There is a possibility that this or a similar procedure could, if necessary, also apply to vertical tendons internal to the concrete in the walls of a hollow or I-section, precast segmental pier column with poorly sealed joints between segments or at the connection between segments and footings or segments and caps.)

4.11.2 Procedure

For longitudinal internal tendons in deck slabs or bottom slabs of precast segmental boxes

Develop Grouting Plan

(1) Refer to Plans, Shop Drawings and previous inspection reports
(2) Locate tendons in top and bottom slabs, along length of structure
(3) Locate poorly sealed joints between precast segments
(4) From inspection reports (e.g. visual inspection and evidence of water leaks, stains or efflorescence or similar) map likely locations of cross-connections between duct voids.
(5) If necessary, perform (limited) on-site testing by gently using water to lightly pond the surface and watch for leaks or inject water into suspected void in one tendon and note locations where water flows from joints or voids at other tendons – or use air pressure to detect leaks etc. Record results and plot findings on suitable plan of duct layout.
(6) Map tendons affected and likely cross-communication
(7) Develop sequence for grout injection to multiple tendon voids – including suitable locations to drill grout ports and vents into ducts (or anchors)
(8) Drill grout ports and vents and install grout pipes with shut-off valves. Follow Repair Procedure: **4.5 - *Drill Grout Post or Inspection Port into Internal Duct.***
(9) At locations of noticeable (worst) joint leaks, before grouting, locally seal joint using either methyl methacrylate or epoxy injection. Follow Repair Procedure: **4.1 - *Seal Match-Cast Joints using Methyl Methacrylate*** or **4.2 - *Seal Match-Cast Joints using Epoxy Injection.***

Mix and Inject Grout

(1) Before grouting, open all valves and blow clean, dry, oil-free, air through voided ducts to remove as much loose debris and water from within as possible. Sustain this operation until there is no more evidence of water discharge and duct voids appear to be dry at each port.
(2) Using only FDOT approved grout, mix grout and perform material on-site fluidity tests in accordance with Specifications
(3) In accordance with the determined grout injection sequence, select grout pipe at the lowest point of the length of cross-connected duct voids for the injection port and connect to grout pump and pressure gage
(4) Open all other grout vents
(5) Inject grout at injection port. Inject grout at steady rate of not less than 8 and not more than 12 gallons per minute
(6) Allow air, excess water and grout to flow freely from next grout vent until consistency is satisfactory per specifications. Then close this vent and continue pumping at steady rate.
(7) Allow air, excess water and grout to flow freely from next vent at a satisfactory consistency per specifications. Then close vent and continue pumping at steady rate.
(8) Allow air, water and grout to flow from each intermediate vent in turn until it flows from the final vent until consistency is satisfactory per specifications. Then close final vent.
(9) If at any time in the above operation water and grout leaks at joints between segments, then continue pumping until no more water or watery grout is ejected at join leak. Pump until leaking grout is of similar consistency to that being injected. (Note – it is very

unlikely to be practical to attempt to collect and perform flow-test for consistency (as may be done at a normal grout vent). Hence it is acceptable to use good judgment in this case.)

(10) Lock-off the grout injection at a pressure of 75 psi - hold this pressure for two minutes and check for leaks. If leaks are found, then repair or seal leaks.

(11) Release the pressure to 5 psi and wait fifteen minutes for any entrapped air or water to flow to high point(s).

(12) Restore the pressure (75 psi) and bleed each outlet vent starting with the highest point away from the injection port and finishing at the injection port until all outlet vents have been bled.

(13) Reduce the pressure and lock in 30 psi pressure in the voided duct

(14) Twenty four hours after grouting, with EXTREME CARE drill and probe all grout pipes to determine if the void is now completely full of grout

(15) If voids are still present, then completely fill them using the Repair Procedure: **4.9 - *Vacuum Inject Grout into Local Void of Internal Tendon.***

(16) After completion of grouting, trim each grout pipe, cap and seal recesses. Follow Repair Procedure: **4.12 - *Seal Grout Ports and Vents.***

4.12 Seal Grout Ports and Vents

4.12.1 Applicability

The following applies in general to all situations where a grout pipe for an injection port or exit vent has been drilled into a duct (or an anchor) through the surrounding structural concrete and the grout pipe has been installed**.**

4.12.2 Procedure

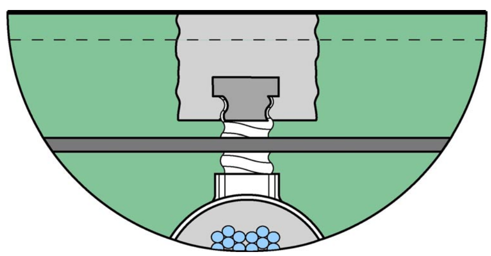
If there is no recess around the grout pipe, then before removing the grout pipe itself, first carefully cut a recess. Use a core cutter, saw or other suitable tool to cut a recess into the concrete surface not less than 2” or more than 3-1/2” outside diameter (or square). This recess is for sealing the finished grout vent – see Figure 4.6. Make depth of recess as follows:

- For existing top roadway surface – 2” to 2-1/2” deep
- For top surface of a bottom slab, underside of soffit or side face (of web, substructure cap or similar vertical face) – 1-1/2” to 2” deep
- In all cases, do not exceed the depth of cover

If performing operation on two or more adjacent tendons (or anchors in anchor block) cut a separate recess for each grout pipe - do not merge recesses into a larger one – keep each recess separate from any adjacent recess by at least 6” (edge to edge) - so that, in future, if a recess or grout pipe is breached only the one tendon will be at risk from leaks and corrosion - not several. (The only exception is for the situation where two very close grout pipes connect with the same tendon – where one pipe connects with the anchor trumpet and the other with the grout cap on the same anchor – in this case, the two pipes can be sealed in the same recess.)

After cutting recess, roughen sides to ensure a good mechanical bond (in addition to chemical or adhesive bond with subsequent epoxy or other approved filler.) Then proceed as follows:

(1) After grout has hardened, trim grout pipes to 1" above bottom of recess
(2) Seal trimmed grout pipe with permanent plastic cap (or plug) screwed or glued to pipe
(3) Thoroughly clean sides and bottom of each recess to sound, dry concrete surface
(4) Fill and seal each recess with a (sand-filled epoxy grout) material approved by FDOT all in accordance with manufacturer's instructions and finish surface level with surrounding concrete.
(5) For top surface recesses, use epoxy grout with good flow properties. For side face and soffit recesses, use a stiffer epoxy grout. In the latter case, take care to ensure that the recess is completely filled and use a form, with a surface that does not adhere to epoxy (i.e. wax paper or similar) to temporarily hold grout until set.
(6) Clean surfaces afterwards – and apply surface coat finish (as necessary).



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

Figure 4.6 – Sealing recess in deck slab

4.13 Restore Anchor Protection (to Directly Accessible Anchor)

4.13.1 Applicability

This procedure applies to the restoration of anchor protection for "Directly Accessible Anchors" after inspection of tendon (using bore-scope) and grout injection of anchor have been completed.

For new construction and repairs to existing construction where the existing pour-back is completely removed, the required four levels of anchor protection for directly accessible anchors on the interior of a hollow box (superstructure or substructure) comprise (1) grout, (2) permanent cap, (3) seal-coat and (4) a surrounding watertight (emphasis on watertight) structure. (Note – in order to make a structure watertight, all joints and cracks must first be sealed using methyl methacrylate or epoxy injection and the structure must be well drained in accordance with other repair procedures herein – e.g. repair procedures 4.1, 4.2 and 4.15 through 4.18). In other cases, for new construction and repairs to existing construction, the required four levels comprise (1) grout, (2) permanent cap, (3) epoxy-grout pour-back and (4) seal coat.

Where there is sufficient access for maintenance personnel and equipment, "Directly Accessible Anchors" are those where, although it may be necessary to remove any existing pour-back material (concrete or epoxy-concrete), it is not necessary to remove structural concrete to gain access to the anchor itself (refer also to Tables 2.4, 2.5 and 2.6.) In particular, this applies to anchors for longitudinal internal and external tendons anchored in diaphragms or end blocks at expansion joints or in diaphragms, ribs or blisters inside the hollow core of bridges of:

- Precast Segmental Balanced Cantilever (not including face anchors)
- Precast Segmental Span-by-Span
- Cast-in-Place Segmental Balanced Cantilever (not including face anchors)
- Cellular Boxes Cast-in-Place on Falsework

In the above cases, it is a relatively simple matter to remove the anchor protection to access the components (Figure 4.7).

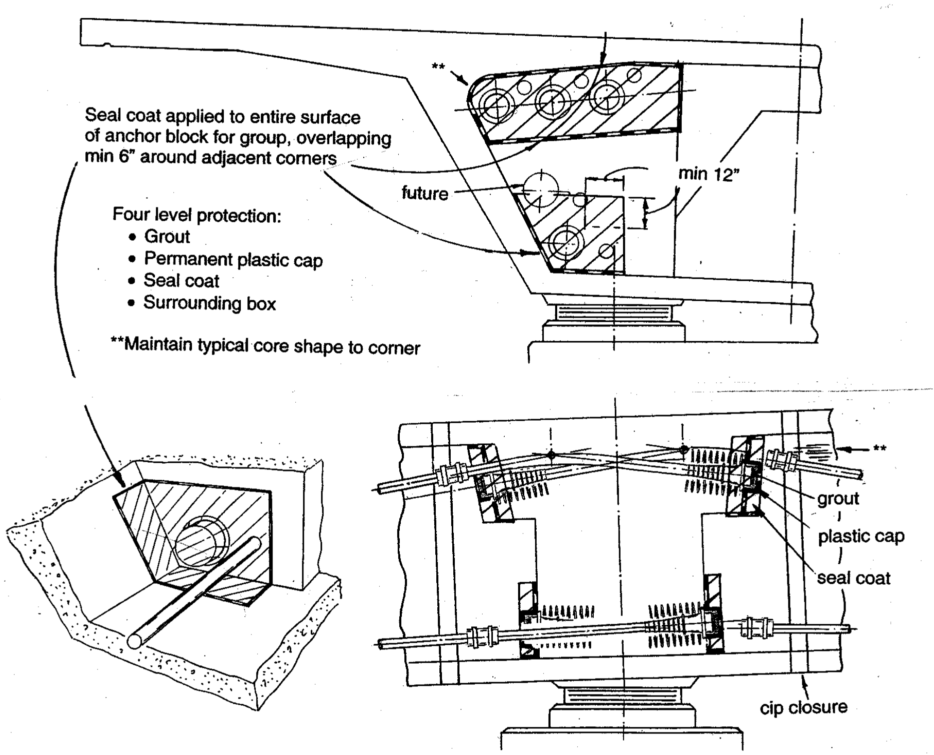


Figure 4.7 – Protection at accessible anchors inside a hollow box

In addition, the following are also "Directly Accessible" even though the effort to gain access may be relatively more difficult:

- Anchors (for vertical tendons) located on the accessible inside of hollow section substructure column (usually precast but could be cast-in-place construction)

- Anchors in the ends of substructure hammerhead caps, straddle-beams, monolithic straddle-bents and C-piers

For the purpose of these inspection and repair procedures, anchors in all the above situations are considered and referred to as **"Directly Accessible Anchors".**

Anchors that are "not directly accessible" are those where it would be necessary to remove structural concrete (or traffic barrier concrete) in addition to any pour-back material, in order to gain access to the anchor itself. This includes, for example, anchors for:

- Longitudinal tendons anchored in end block or under deck slab of I-girder decks
- Anchors in the ends of solid or voided slabs
- Most, if not all anchors for transverse superstructure tendons
- Most, if not all, vertical tendons in webs and diaphragms
- Most vertical tendons in columns that anchor in the pier top under a bridge bearing
- Any existing (pre 2001) vertical strand or bar tendons that anchor in foundations
- Any new (post 2001) vertical bar tendons that anchor in foundations and similar situations.

(Refer also to Tables 2.4, 2.5, 2.6)

4.13.2 Procedure

(1) Clean anchor plate surface outside perimeter of wedge plate

(2) Attach permanent non-metallic (plastic) grout cap to anchor plate to enclose wedge plate. Permanent cap must have a suitable "o-ring" type seal between the cap and the smooth, clean surface of the anchor plate. Secure cap to anchor plate with bolts or studs and nuts fastened into holes drilled and tapped into anchor plate. Permanent cap, o-ring and fastening shall be to FDOT QPL.

(3) Completely fill permanent grout cap with grout (This may be done when vacuum injecting grout to rear of anchor or it may be done afterwards. If done in conjunction with vacuum grouting of anchor then there must be a grout vent connecting through wedge plate to void at rear of anchor – and a sealable vent in the top of the grout cap – to allow grout to be evacuated and to check that cap is full. If done afterwards, then there should be no passage for grout from rear of the anchor to the cap. Either the cap may have two vents, one at bottom for injection and one at top for evacuation of grout or else grout may be poured into the cap by inserting a small grout tube into the cap vent – which must be oriented to the top – and by carefully watching for the cap to be completely filled.)

(4) Clean surface of cap and anchor plate

(5) Directly accessible anchors on the interior of a hollow box (superstructure or substructure) that is made watertight (emphasis on watertight) do not require the installation of a new (epoxy grout) pour-back. Hence, if (and only if) the anchor is on the interior of a watertight structure skip steps 6, 7 and 8 and go to step 11. In all other cases, provide a new, sand-filled epoxy grout pour-back - proceeding from step 6.

(6) Clean and roughen surface of surrounding concrete to amplitude of approximately 1/8 inch to improve bond of pour-back material

(7) For individual anchors and where two or three closely spaced anchors (i.e. less than 16” center to center) are encased by a single pour-back, reinforcement is not required. Skip step 8 and go to step 9.

(8) For multiple anchors encompassed by a single pour-back or for pour-backs containing two or more anchors separated by more than 16” center to center and encompassed by a single pour-back, provide reinforcement as follows:

- Install into structural concrete surrounding each anchor plate, short dowels of “3 rebar and secure with an approved epoxy material
- Embed rebar at least 2” but not more than 3” into concrete and allow to project from surface by length of cap
- Provide at least 4 pieces of #3 rebar per anchor. Locate dowels close to anchor plates so as to provide a minimum of 1” cover to side of anchor block or at least 1” clearance to adjacent concrete (web) or other surface
- Attach #D4 wire to perimeter of rebar studs around each anchor
- Attach #D4 wire around perimeter of dowels at each anchor and at least one strand of #D4 wire around perimeter encompassing all anchors

(9) Attach form for pour-back material so as to provide a minimum of 1-1/2” cover beyond the end of the cap in the longitudinal direction of the tendon and to enclose the edges of the anchor plate with a minimum overlap onto the surrounding concrete of at least 2” beyond the edge of the plate.

(10) Completely fill* form with an approved sand-filled epoxy grout. Epoxy grout shall be of flow-able grade, high strength, high-bond, material all according to FDOT QPL. Mix, place, consolidate and cure material in accordance with manufacturer’s recommendations. If the pour-back is to extend to the underside of a top slab, then provide a slot or “bird-mouth” opening in the top of form in order to facilitate filling and carefully place material, consolidate, top-up and check until form is completely full. When pour-back has properly cured, remove formwork – if necessary, remove excess material formed by bird-mouth to a neat and clean surface.

(11) Clean and prepare all surfaces to receive seal coat material. For visibly exposed surfaces (e.g. ends of hammerhead pier caps, straddle beams and similar situations) use a seal coat to match the required color and finish of the structure.

(12) Apply seal coat material over entire surface of pour-back extending at least 12” onto the surrounding structural concrete of the diaphragm or anchor block containing the anchor(s) beyond the perimeter of the pour-back. Use a seal-coat material from FDOT QPL and apply in accordance with manufacturer’s recommendations. (Seal coat to have waterborne epoxy based primer, followed by base and top coats of polyurethane based material with good adhesion and long life properties compatible with the substrate).

4.14 Locally Repair Anchor Protection (to Directly Accessible Anchor)

4.14.1 Applicability

This procedure applies to the local repair of anchor protection for "Directly Accessible Anchors*" providing that inspection shows that the tendon is satisfactory and that the existing pour-back may remain in place but is not fully complete. However, if more than 25% of existing pour-back is missing then remove and replace pour-back according to 4.13 above.

This repair procedure is for use only on directly accessible anchors on the interior of a hollow box (either superstructure or substructure). It must not be used to for repairs to anchors at expansion joints or to repair directly accessible anchors in the ends of substructure hammerhead caps, straddle-beams, monolithic straddle-bents and C-piers. For such cases, completely remove any pour-back and restore in accordance with Repair Procedure 4.13 above.

In cases where an existing pour-back (say of ordinary concrete) is to remain in place at a directly accessible anchor on the interior of a hollow box (superstructure or substructure) then the four levels of protection are provided by (1) grout, (2) permanent cap, (3) seal coat (4) surrounding water-tight structure - where the seal coat is applied to the existing pour-back and any repair to that pour-back made according to the procedure below. (Note - being a repair, the pour-back itself is not counted as a level of protection.)

Also, if there is any evidence of a water leak, efflorescence or rust-stain associated with the anchor – or if there is a local leak into the structure in the vicinity of the anchor (at a leaky match-cast joint for example) then completely remove the anchor protection and pour-back and perform an inspection of the anchor – in particular, follow:

2.3 ***Anchor Protection***
3.2 ***Inspect and Assess Tendon at Anchor***
3.4 ***Assess Overall Integrity Level of Prestress***

Seal any leaks in the vicinity using the appropriate repair procedure and restore the anchor protection in accordance with Repair Procedure 4.13 above.

(*Refer to Repair Procedure 4.13 (also Tables 2.4, 2.5 and 2.6) for a description of anchors that are "Directly Accessible".)

4.14.2 Procedure

Only if there is no evidence of a water leak, efflorescence or rust stain associated with the anchor and if there are no leaks into the structure in the vicinity of the anchor whatsoever, then local repairs may be made to the anchor pour-back and protection as follows:

(1) Clean surfaces of all previous coating material (e.g. epoxy coal tar)

(2) Cut and trim missing portions of pour-back to neat square faces and edges

(3) Roughen trimmed surfaces to an amplitude of approximately 1/8"

(4) Form missing surfaces – provide opening into form as necessary for filling

(5) Completely fill* form with an approved sand-filled epoxy grout. Epoxy grout shall be of flow-able grade, high strength, high-bond, material all according to FDOT QPL. Mix, place, consolidate and cure material in accordance with manufacturer's recommendations.

(*Note: If the pour-back is to extend to the underside of a top slab, then provide a slot or "bird-mouth" opening in the top of form in order to facilitate filling. Carefully place material, consolidate, top-up and check until form is completely full.)

(6) When cured, remove formwork, clean and prepare surfaces to receive seal coat material. (If necessary, remove excess material formed by "bird-mouth" to clean neat surface).

(7) Apply seal coat material over entire surface of pour-back extending at least 12" onto the surrounding structural concrete of the diaphragm or anchor block containing the anchor(s) beyond the perimeter of the pour-back. Use an elastomeric seal-coat material from FDOT QPL and apply in accordance with manufacturer's recommendations. (Seal coat to have waterborne epoxy based primer, followed by base and top coats of polyurethane based material with good adhesion and long life properties compatible with the substrate).

4.15 Seal Pour-Back Joints or Filled Holes using Methyl Methacrylate

4.15.1 Applicability

This procedure applies to top deck slabs of structures where there is a separation (shrinkage) crack around any pour-back to a block-out formed in the surface. In general, this applies to the following bridge types and details:

Precast Segmental Cantilever Bridges:

- Anchor pockets and recesses for cantilever and continuity tendons in top slabs
- Access holes for personnel or equipment
- Small diameter holes through slabs used for lifting, securing erection equipment or closure devices

Precast Span-by-Span Bridges

- Block-outs or shrinkage cracks in cast-in-place joints at each end of span
- Block-outs or access holes for personnel or equipment
- Small diameter holes through slabs used for lifting or securing erection equipment

I-Girder Bridges

- Block-outs in deck slab for anchors in pockets in top of girders

Cast-in-place Segmental Cantilever Bridges

- Anchor pockets and recesses for cantilever or continuity tendons in top slabs

- Access holes for personnel or equipment
- Small diameter holes through slabs used for securing form travelers or other erection equipment

Bridges Cast-in-Place on Falsework
- Anchor pockets or recesses for PT tendons
- Access holes in cellular boxes for personnel or equipment
- Small diameter holes through slabs used for securing formwork or other construction equipment

Transversely Post-Tensioned Superstructures
- Separation (shrinkage) cracks between longitudinal cast-in-place concrete joints and precast pre-stressed concrete planks or double-T's
- Longitudinal separation (shrinkage) cracks between longitudinal cast-in-place closure-joints between deck slab wings of precast or cast-in-place boxes – (whether only transversely reinforced or post-tensioned)
- Separation (shrinkage) cracks between pour-back concrete and anchor pockets for transverse tendons in edges of deck slabs of precast and cast-in-place segmental bridges

This procedure may also be used for some substructure applications, such as:
- Separation (shrinkage) cracks around concrete pour-backs to anchor pockets in top surface of pier caps for vertical or lateral (confinement) tendons

4.15.2 Procedure

(1) Take precautions to close lanes to traffic and implement traffic control as necessary. Operation may be done by closing a lane at a time, as appropriate.

(2) Carefully examine top surface of concrete and locate pour-backs to anchor pockets, block-outs, access holes or filled, small diameter holes used for lifting or temporary construction purposes.

(3) Clean surface of pour-back and all edges of pour-back joint using gentle water-blasting or sandblasting. Clean away all debris. The concrete and joints to be sealed must be dry for at least 48 hours prior to sealing. The period of drying shall start over again from the end of any wet cleaning operations or wet weather experienced during drying. (However, traffic may be allowed to run on deck as normal during drying period)

(4) Either - using a concrete saw blade or other suitable tool, cut a "V", "U" or rectangular shaped groove along and centered on the joint between the pour-back and surrounding concrete or on the separation (shrinkage) crack. Groove to be at least 3/8" wide by 1/2" deep but no more than 1/2" wide by 5/8" deep. Clean away debris.

Or – using a suitable material (such as epoxy or silicone) form a small bead dam approximately ½" wide by ½" high approximately ½" outside and around the perimeter of the pour-back joint or filled hole to be sealed. Bead dams may be installed after the 48 hour required drying period.

(5) Under clean, dry conditions, flood groove or bead dam area with methyl methacrylate and allow it to soak into pour-back joint or filled hole until no more can be absorbed

(6) Allow to set, bond, harden and cure according to Manufacturer's specifications

(7) Clean up and re-open lane(s) to traffic as soon as material has set

(8) Repeat for other traffic lanes as necessary until all such pour-back joints or filled holes are sealed

4.16 Install Small Drains through Bottom Slabs of Hollow Sections

4.16.1 Applicability

This procedure involves drilling a hole through the bottom slab of a box section where water may pond against a barrier such as a deviation saddle, anchor block or diaphragm. It is applicable to bridges with a hollow cross section including:

- Precast Segmental Balanced Cantilever
- Precast Segmental Span-by-Span
- Cast-in-Place Segmental Cantilever
- Cellular Boxes Cast-in-Place on Falsework

In particular, this procedure does not apply to:

- Voided Slabs Cast-in-Place on Falsework
- Hollow Substructure Columns

4.16.2 Other Preparation – Existing Drains

Clean all existing drains of debris and blockages of any kind. Trim any projecting pipes and overfilled concrete or spilled grout material etc., until level with the concrete surface. If necessary, create a small dish to the pipe - maximum of ½" deep and dished out over approximately a 6" radius. Also clean and seal (with an approved sealer) water-paths inside box so that any future water has unobstructed flow path.

Install new drains as follows.

4.16.3 Procedure – New Drains

(1) At each internal barrier at which water may pond, i.e. at deviator saddles, diaphragms, ribs or anchor blisters, install 2" diameter drain through bottom slab as follows:

(2) From previous inspection reports, Plans, Shop Drawings and field observations:

- Locate the lateral positions of longitudinal internal tendons (if present) in the bottom slab
- Locate longitudinal position of any internal transverse tendon (if present) in the

bottom slab

(3) Use magnetic detection device (cover meter or similar) to determine or verify field position of internal post-tensioning and mild steel reinforcement on both top (and bottom surface, if accessible) of slab.

(4) Also locate drain holes to be drilled with regard to the following:
   (a) Use EXTREME CARE AND so as not to drill through or damage post-tensioning tendons – relocate hole as necessary
   (b) As far as possible, avoid drilling through mild steel reinforcement. If rebar is encountered, relocate hole to be drilled
   (c) However, if drilling through mild steel reinforcement cannot be avoided then proceed with caution and drill only through the least possible reinforcement within the following guidelines:
      - In precast segmental bridges (of either balanced cantilever or span-by-span construction) only - it is permissible to drill through longitudinal reinforcement in the top and bottom of the bottom slab providing that the reinforcement to be severed is only of #4 bar size or less. Do not drill through larger diameter longitudinal or transverse reinforcing bars. However, it is permissible to drill through small diameter (#3 bar or D4 wire) running longitudinally or transversely in the bottom slab of these bridges
      - In all precast and cast-in-place segmental bridges, and cast-in-place cellular boxes, do not drill through reinforcement that is part of an anchor blister or deviation saddle
      - For all other structures, do not drill through rebar
      - In case of doubt, seek the advice of a knowledgeable engineer.

(5) Drill 2" diameter hole through bottom slab

(6) An area of up to 6" in radius around the top of the hole may be cut and dished up to 1/2" deep, if necessary, to intersect water path

(7) Thoroughly clean area around hole and along existing or potential water path of all dirt and debris

(9) Seal area for a minimum of 12" radius around hole and along existing or potential water path with an approved elastomeric seal coat taken from the FDOT QPL

4.17 Install Drip Flange under Seat of Expansion Joint

4.17.1 Applicability

Expansion joints are essential for long continuous span units of long bridges. However unfortunately but inevitably, water leaks through expansion joint devices. Expansion joint devices are usually set in a recess and are supported by a transverse rib (sometimes referred to as a dapped seat) below the soffit of the top slab extending from one side of the bridge deck to the other. This rib passes over the top of the end diaphragm face at the expansion joint in which longitudinal tendons are anchored. Water can leak under the expansion joint device and then seep into the back of the anchorages, under their protective pour-backs and into any grout voids in the tendons at the anchor head. The purpose of this procedure is to install a drip flange to prevent seepage into the anchor heads (Figure 4.8).

In new construction and when repairing an existing structure, expansion joints should, wherever possible, be fitted with a self-cleaning drainage trough. Nevertheless, a drip flange should be installed even though a trough may be fitted.

This detail applies to bridges with a hollow cross section where it is possible to access the area under the expansion joint. Generally, this applies to bridges of:

- Precast Segmental Balanced Cantilever
- Precast Segmental Span-by-Span
- Cast-in-Place Segmental Cantilever
- Cellular Boxes Cast-in-Place on Falsework

A similar expansion joint recess detail is often provided in long, continuous units of spliced I-girder bridges - formed in the top of the end of the deck slab above the transverse diaphragm at the expansion joint. It is possible that water might seep into any poorly protected anchors in the ends of such decks. However, because of the very narrow gap between diaphragms at the expansion joint, these anchors are inaccessible. Consequently this procedure does not apply to I-girder decks.

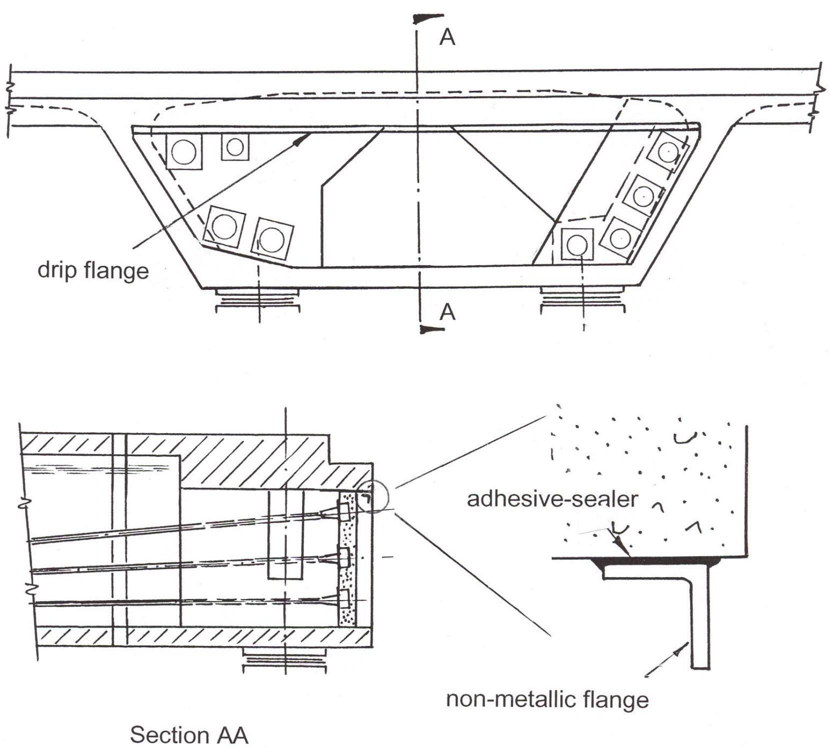


Figure 4.8 – Drip Flange (concept)

4.17.2 Procedure

The procedure involves installing a small flange of angle (or similar suitable section) on the underside of the top slab expansion joint device support rib (dapped beam seat) to create a drip flange so that water drips clear of the end anchors and their protective pour-backs.

(1) Provide drip flange of minimum size 1-1/2” x 1-1/2” x ¼” angle or other similar section of suitable, durable, non-metallic (glass reinforced plastic) or similar, approved, material to FDOT QPL.
(2) Drip flange may be supplied in pieces but must be installed to make a continuous strip from one side to the other with no gaps
(3) Shape drip flange to fit snug to profile of underside of rib between webs
(4) Orient and install drip flange angle with leg of angle extending from surface placed closest to center of expansion joint.
(5) Thoroughly clean concrete surface to receive flange and adhesive-sealer.
(6) Secure drip-flange to underside of expansion joint support rib (dapped beam seat) across full width between webs using an approved adhesive-sealer material selected from FDOT QPL that is compatible with and will bond to both the material of the drip flange and the concrete
(7) Apply generous amount of adhesive-sealant material to secure drip flange to concrete and securely clamp in place until adhesive has cured and bonded to concrete and flange in accordance with the Manufacturer’s specifications

4.18 Install Weather Baffle at Expansion Joint

4.18.1 Applicability

Expansion joints are essential for long continuous span units of long bridges. However unfortunately but inevitably, water leaks through expansion joint devices. Expansion joint devices are usually set in a recess and are supported by a rib (sometimes referred to as a dapped beam seat) below the soffit of the top slab extending from one side of the bridge deck to the other. This rib passes over the top of the end diaphragm face at the expansion joint in which longitudinal tendons are anchored. Water can leak under the expansion joint device and then seep into the back of the anchorages, under their protective pour-backs and into any grout voids in the tendons at the anchor head.

In addition, in exposed locations, wind may drive rain or salt-laden spray into the gaps at the expansion joints and directly onto the anchors or their protective pour-backs. This procedure addresses the installation of a weather baffle board to prevent wind driven rain or salt spray directly settling on the anchors and their protective pour-backs in extremely exposed and aggressive situations.

The installation of a weather baffle is an optional addition to the “four levels of anchor protection” as provided at expansion joints but it is not intended to replace any one of them. Neither is it intended to replace any policy, decision or need for a watertight drainage trough to be installed under new or existing expansion joints.

The detail may be applied to bridges with a hollow cross section where it is possible to access the area under the expansion joint. Generally, this applies to bridges of:

- Precast Segmental Balanced Cantilever
- Precast Segmental Span-by-Span
- Cast-in-Place Segmental Cantilever
- Cellular Boxes Cast-in-Place on Falsework

A similar expansion joint recess detail is often provided in long, continuous units of spliced I-girder bridges - formed in the top of the end of the deck slab above the transverse diaphragm at the expansion joint. It is possible that water might seep into any poorly protected anchors in the ends of such decks. However, because of the very narrow gap between diaphragms at the expansion joint, these anchors are inaccessible. Consequently this procedure does not apply to I-girder decks. In such situations, it would be appropriate to consider installing a water-tight drainage trough to the joint.

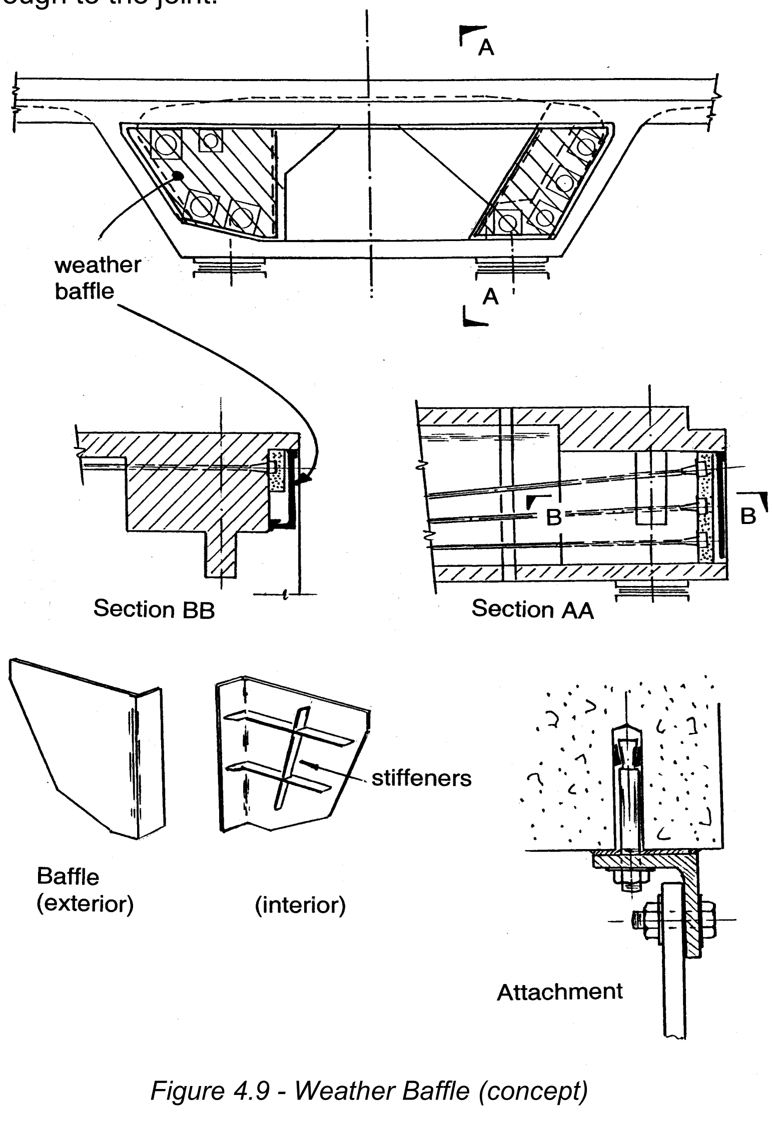


Figure 4.9 - Weather Baffle (concept)

4.18.2 Procedure

The procedure involves installing a small flange of angle section (or similar suitable section) around the interior perimeter of the underside of the top slab expansion joint device support rib (dapped beam seat) and webs to which is attached a weather baffle board to prevent direct wind driven rain or salt spray settling on the end anchors and their protective pour-backs. Weather baffle must be light-weight, easily secured and removable to facilitate maintenance inspection of anchorages.

(1) Provide flange of stainless steel angle of minimum 1-1/2" x 1-1/2" x 1/8" or of a minimum size of 1-1/2" x 1-1/2" x ¼" angle of other suitable, durable, non-metallic (glass fiber reinforced plastic), or other approved, material to FDOT QPL.

(2) Flange may be supplied in pieces but must be installed to make a continuous strip around the interior perimeter of the section with no gaps

(3) Shape flange to fit snug to profile of underside of rib between webs, around corner between underside of rib and top of webs and down webs to 1-1/2" above top of bottom slab (to provide 1" to 1-1/2" gap under baffle at bottom for drainage).

(4) Orient and install flange with extended leg closest to center of expansion joint.

(5) Secure flange to underside of expansion joint support rib (dapped beam seat) across full width between webs around top corners and down webs using stainless steel, self-anchoring (expanding) studs (or bolts) spaced at 9" center to center. (Anchors must be from FDOT QPL)

(6) Secure another piece of flange down the end face of each side of the diaphragm access hole but inboard of any and all anchorages and pour-backs using the same studs and spacing.

(7) Locate studs (or bolts) at a minimum of 2" inboard from end face of concrete

(8) Minimum diameter of studs (or bolts) to be ¼" and minimum embedment into concrete to be 2"

(9) Thoroughly clean and prepare surface of concrete prior to drilling and installing anchor studs (or bolts) for securing flange

(10) Apply generous amount of silicone (or other approved) sealant material between flange and concrete and securely tighten anchor studs or bolts to seal

(11) Provide weather baffle board of light-weight, non-corrosive, material to approved FDOT QPL (e.g. stainless steel sheet, high density plastic or glass fiber reinforced plastic (GFRP)). Shape weather baffle board to fit contour of interior profile of underside of rib, top corner and webs for each side of the section covering the end anchors and their protective pour-backs but leave 1" to 1-1/2" gap above bottom slab. Provide a return flange on weather baffle boards to extend to and connect with the flange attached to the side of the access hole. Make exposed face of baffle boards smooth but provide stiffening ribs on rear as necessary.

(12) Secure weather baffle boards to inboard sides of flanges using minimum diameter ¼” stainless steel bolts, with washers and nuts at intervals of 9” around perimeter. Apply generous amount of silicone (or other approved) sealant material between baffle and flanges and securely tighten bolts to seal.

(Note – The above does not necessarily facilitate “easy” removal and replacement for anchor inspection – hence a possible alternative would be to slide baffle board into place resting it on bottom slab and secure with just a few lock-nuts in locations convenient for maintenance personnel – but do not provide silicone sealant – provide intermittent gaps at bottom of baffle for drainage)

4.19 Install Additional Tendons

4.19.1 Assess Condition of PT

For any structure, the tendon condition and the overall integrity level of prestress should be assessed by following the appropriate Assessment Procedures:

3.1 ***Assess Internal Tendon (at location along the length)***
3.2 ***Assess External Tendon***
3.3 ***Assess Tendon at Anchor (Internal or External Tendon)***
3.4 ***Assess Overall Integrity Level of Prestress***

As a result, if the assessment of the overall level of prestress is less than acceptable, then it may be necessary to add supplementary post-tensioning. This requires structural analysis and design by a qualified Engineer.

4.19.2 State of Stress and Analyzing for Loss or Addition of Tendons

It is important to understand the state of stress within a bridge. Clearly, it is not possible to know the exact state of stress as a consequence of suspected or unknown corrosion damage – especially with internal tendons. Hence it is necessary to perform some parametric analyses to test the sensitivity of the structure to conditions with and without suspect tendons or to the addition of new tendons in order to be satisfied that the overall conditions are within reasonable stress ranges and limits. Strengthening with PT tendons may or may not bring the state of stress back to idealized limits - such as 0 psi tension or 100 psi compression - but the addition of the PT may add significantly to the overall ductility.

Depending upon the bridge type and circumstances, the Engineer responsible for a retrofit may wish to consider the use of unbonded bars rather than strands if there is a concern for a possible lack of ductility – say, for example, in a cantilever with internal top, grouted and bonded tendons that may be suffering corrosion. Installing external PT bars through corbels (blisters) originally used for erection purposes, may suffice to improve the stress conditions in the negative moment region at an interior pier. Furthermore, being at a low eccentricity, such bars may also offer ductile warning of potential failure by allowing cracks or joints to open if further corrosion occurred in the top internal cantilever tendons.

When analyzing or retrofitting an existing bridge, the Engineer should give consideration to the actual state of stress, given that the original post-tensioning forces have reduced and internal forces, moments and secondary effects have been redistributed over time due to long term losses, shrinkage and creep. As a consequence, it may not be necessary to install new tendons of the same size and force level as original ones – it may suffice to install a limited number of smaller tendons or bars to attain the desired overall state of stress.

Post-tensioned bridges of various kinds have been strengthened in a variety of ways by the addition of both internal, though more frequently, external tendons. Tendons may comprise bars or strands and may be straight or deviated to an appropriate longitudinal profile. In a few cases bars or strands may be retroactively added to vertically post-tension webs. Retrofit tendons may be anchored in existing diaphragms, ribs or corbels (blisters) built during construction or added as a subsequent repair or rehabilitation.

Examples include:

- At the Eau Gallie Bridge, straight longitudinal PT bars were added within the top deck slab and to the top of the bottom, mid-span flange of one of the bulb-T girders to compensate for strands that could not be fully installed due to blocked and damaged ducts discovered only after erection.
- For the same reasons, a similar repair was made to a post-tensioned AASHTO I-girder bridge near West Palm Beach.
- Additional longitudinal external tendons were installed in the first few spans of Long Key Bridge when greater than expected friction losses were initially experienced.
- Vertical and longitudinal bars and strands were added externally to strengthen cracked webs at a few dapped-hinge expansion joints in three segmental box girder bridges at the I-595 / I-75 interchange in Fort Lauderdale. The external strands were then coated with a corrosion protection compound and covered with spray applied concrete for cover and finish.
- Additional longitudinal tendons were added to strengthen cast-in-place balanced cantilever bridges on I-70 at Vail Pass Bridges in Colorado

Such cases and similar situations elsewhere, led directly to the requirements in the AASHTO Guide Specification for Segmental Bridges, to make provision in new designs for extra PT to allow for unforeseen conditions during construction and for additional post-tensioning to be installed at a future time, if necessary.

In summary, when preparing a retrofit, the Engineer should consider various available post-tensioning systems (bars or strands), possible tendon profiles, anchor locations and methods of installation to best optimize the range and state of stress under the known or estimated corrosion conditions.

4.19.3 Application

In each bridge, the extent of corrosion damage and type of solution is individual. There is no way to provide a simple "across-the-board" solution for all situations. The following offer some general ideas for the following bridge types:

- Precast Segmental Balanced Cantilever

- Precast Segmental Span-by-Span
- Spliced I-Girder
- Cast-in-Place Segmental Cantilever
- Cellular Box, Cast-in-Place on Falsework

Additional tendons are not likely to be installed in other superstructure types or in substructures.

Precast Segmental Cantilever

Possible solutions include:

- Add PT bars using the temporary PT bar blisters or holes in diaphragms from construction
- Add longitudinal PT (strand) tendons in a straight or draped profile. It should be possible to add internal anchor blisters, ribs or deviators as necessary.
- Also, it should be possible to core holes through existing diaphragms providing they do not interfere with any transverse post-tensioning or substantial reinforcement.

Precast Segmental Span-by-Span

Possible solutions include:

- Add PT bars using any temporary PT bar blisters or holes in diaphragms from construction
- Add longitudinal PT (strand) tendons in a straight or draped profile. It should be possible to add internal anchor blisters, ribs or deviators as necessary.
- Also, it should be possible to core holes through existing diaphragms providing they do not interfere with any transverse post-tensioning or substantial reinforcement.

Spliced I-Girder

Possible solutions include:

- Add permanent PT bars through new reinforced concrete buttresses (blisters) secured by dowels to flanges of I-girders and through holes in diaphragms.
- Add longitudinal PT (strand) tendons in a straight or draped profile – facilitated by adding external tendon anchor blisters, ribs, deviators or diaphragms as appropriate.
- Also, it should be possible to core holes through existing diaphragms providing they do not interfere with any transverse post-tensioning or substantial reinforcement.

Cast-in-Place Segmental Cantilever

Possible solutions include:

- Add permanent PT bars or strand tendons through new reinforced concrete buttresses (blisters) secured by dowels to interior top and bottom slab or web-slab corners and through holes in diaphragms.
- Add longitudinal PT (strand) tendons in a straight or draped profile. It should be possible to add internal anchor blisters, ribs or deviators as necessary.
- Also, it should be possible to core holes through existing diaphragms providing they do not interfere with any transverse post-tensioning or substantial reinforcement)

Cellular Box, Cast-in-Place on Falsework

Possible solutions include:

- Add permanent PT bars or strand tendons through new reinforced concrete buttresses (blisters) secured by dowels to interior top and bottom slab or web-slab corners and through holes in diaphragms.
- Add longitudinal PT (strand) tendons in a straight or draped profile. It should be possible to add internal anchor blisters, ribs or deviators as necessary.
- Also, it should be possible to core holes through existing diaphragms providing they do not interfere with any transverse post-tensioning or substantial reinforcement)

4.20 Repair External Tendon Duct by Heat Welding

4.20.1 Applicability

This procedure applies to the repair of minor puncture holes or small cuts by heat welding of existing HDPE pipe. It is only applicable for repair of existing, external HDPE pipe duct that has only small puncture holes or small accidental or deliberate cuts. It should not be used where a duct has suffered tears or cracks. These may have been caused by other factors – such as inherently defective or substandard material – and there is no certainty that such defects would not return after repair by heat welding. Such defects should be repaired using wrapping per 4.3 or by installing half-pipes and grout per 4.4

Heat welding may be used to restore the integrity of ducts for external tendons used in any of the following bridge types:

- Precast Segmental Balanced Cantilever
- Precast Segmental Span-by-Span
- Cast-in-Place Balanced Cantilever
- Cellular Boxes Cast-in-Place on Falsework

It may also be used to repair HDPE pipe ducts on external tendons installed as a repair or rehabilitation in any situation – such, as for example, in bridges of precast I-girders.

This may also be used to repair HDPE ducts for vertical external tendons in hollow precast segmental piers, or similar applications.

Heat welding is a commercially available (patented) process that creates a strong weld by injecting molten weld below the surface of the plastic. It is available for routine bonding of thermoplastics (including polyethylene). The material of the weld rod and substrate are mixed by the welding process to create a stress free weld.

4.20.2 Procedure

Heat welding is a proprietary technique. Perform heat welding repairs in accordance with recommendations of the Manufacturer of heat welding equipment and weld material in manner that adds material to the hole or cut in the process.

Appendix A – Cracking in Post-tensioned Concrete Bridges

A.1 Cracks

A.1.1 Effect of Cracks on Corrosion Protection of Post-Tensioning

Intact and adequate concrete cover is one of the three primary means of protecting a post-tensioning tendon (i.e. cover / impervious duct / grout)

Cracks breach the integrity of the concrete cover and allow water and chlorides to attack the ducts and post-tensioning tendons. Cracks must be investigated and properly repaired not only to restore the integrity of the structure but also to restore the integrity of the corrosion protection for the post-tensioning.

Cracks arise from a variety of causes and although the origin of a crack may be traced back to an inadvertent design omission, an improper detail or inadequate construction (poor quality work / material) or a combination thereof – there is rarely a single cause.

A.1.2 Structural and Non-Structural Cracks

Cracks may be classified as “structural” or “non-structural”. In general, structural cracks are those initiated by a stress usually induced by a load that is greater than anticipated for the resistance of the section at the crack. Structural cracks are important and have implications for the safe operation and longevity of the structure unless properly investigated and appropriate repairs made. However, occasionally, a structural crack initiated by overstress or restraint in a continuous structure may not necessarily have serious implications because it is possible for an internal redistribution of forces to occur – i.e. as part of the structure relieves itself of load at a crack other parts pick up a greater share of the load. Therefore it is important to understand the behavior of the structure and to recognize different types of cracks.

In general, non-structural cracks are caused by effects such as shrinkage, differential shrinkage or temperature. Non-structural cracks tend to be random and relatively small, but may be influenced by abrupt changes in section at discontinuities such as diaphragms or anchor blocks.

A.1.3 Cracks Types and Origins

Different types of cracks are recognized depending upon their location and predominant initiating action. These are:

- Flexure
- Shear (and flexural-shear)
- Anchor zone cracks
- Local effects
- Discontinuity effects
- Material or environment effects – i.e. thermal-shrinkage-curing

A.2 Types of Cracks, Significance, Inspection and Action

The following is a summary of 31 different cracks divided into the above types.

A.2.1 Flexural Cracks

(1) Longitudinal flexure crack across soffit of box girder (mid-span region)

If they were to occur, longitudinal flexure cracks would appear transversely across part or all the width of the bottom flange in the mid-span (positive moment) region.

They may be of any width. Such cracks are transient – that is, they are likely only to occur under conditions of extreme over-load and, once the load has past, they would close. Under conditions of dead load and prestress any such cracks would remain closed. Only if there is a very substantial loss (i.e. over 30 to 40%) of longitudinal prestress would such cracks appear under dead load only conditions.

In precast segmental structures with epoxy joints, (e.g. balanced cantilever or span-by-span (post 2001)) these cracks would most likely be discrete (i.e. only one or two) and would appear at or close to an epoxy joint near mid-span

In span-by-span (pre 2001) structures with dry-joints (no-epoxy) such cracks would probably appear as a slight opening of a discrete (single) joint near mid-span

In cast-in-place segmental cantilever, cellular boxes and solid or voided slabs cast-in-place on falsework where there is continuous mild steel reinforcing through construction joints any such flexural cracks would be narrow and likely be distributed at intervals in the mid-span region as a consequence of the distributive influence of the reinforcing.

Being transient, such cracks are not a concern for the integrity of the post-tensioning (i.e. it is not a permanent breach of cover). However, bring any such cracks that appear to be permanent to the attention of the Engineer.

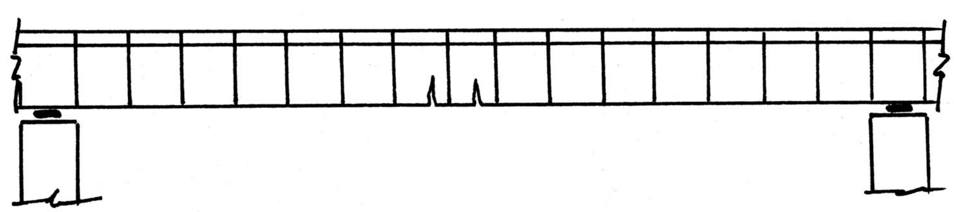


Figure A.1 - Longitudinal flexure crack across soffit of box girder (mid-span region)

(2) Longitudinal flexural crack across top of box girder (over or near piers)

If they were to occur, longitudinal flexural cracks would appear transversely across part or all the width of the top flange in the negative moment region at or near an interior pier.

They may be of any width. Such cracks are transient – that is, they are likely only to occur under conditions of extreme over-load combined with rare conditions of reverse (negative) thermal gradient that can induce tension over an interior pier. Once the conditions have past, such cracks should close. Under conditions of dead-load and pre-stress any such cracks would remain closed. Only if there is a very substantial loss (i.e. over about 40%) of longitudinal prestress would such cracks appear under dead load only conditions

In all types of structures, such cracks would be discrete (i.e. only one or two) and would be above or close to an interior span pier

In a precast segmental balanced cantilever with epoxy joints, such a crack might appear at or close to an epoxy joint.

In cast-in-place segmental cantilever, cellular box and solid or voided slab cast-in-place on falsework with continuous mild steel reinforcing passing through construction joints such a crack may would either be in the structural concrete or at a construction joint close to the pier

In each of the above cases, such a flexure crack might, temporarily, extend down to the internal post-tensioning tendons that are in the top of the section over interior piers. However, the transient nature of such a crack is not a concern for a the integrity of the post-tensioning (i.e. it is not a permanent breach of cover)

In precast segmental span-by-span structures (with dry - non-epoxy joints (pre 2001) or epoxy joints (post 2001)) such cracks would probably appear as a separation at a cast-in-place closure joint next to the pier. However, because (in Florida) all span-by-span bridges have external tendons, any such cracks could not affect the tendons in any way. The only possibility might be at the interior pier (channel pier) of a main three-span continuous unit that contains internal cantilever tendons (i.e. Mid-Bay or Garcon Point Bridges). Here again though, the conditions would be rare and transient and would not permanently breach any cover.

Being transient, such cracks are not a concern for the integrity of the post-tensioning (i.e. it is not a permanent breach of cover). However, bring any such cracks that appear to be permanent to the attention of the Engineer.

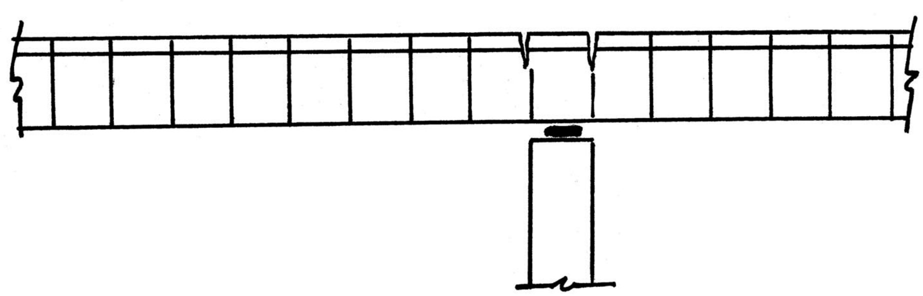


Figure A.2 - Longitudinal flexural crack across top of box girder (over or near piers)

(3) Longitudinal flexural cracks across soffit of I-girder (near mid-span)

If they were to occur, longitudinal flexural cracks appear transversely across the full width of the bottom flange, be of any width, - but usually narrow and would be distributed at intervals along the mid-span region as a consequence of the influence of the continuous pre-tensioning strands in the bottom of the I-girder. Such a flexural crack in the bottom of an I-girder may extend vertically up the bottom flange, and in a severe case, into the web.

Such cracks are transient – that is, they are likely only to occur under conditions of extreme over-load and, once the load has past, they would close. Under conditions of dead-load and pre-stress any such cracks would remain closed. Only if there is a very substantial loss (i.e. over 30 to 40%) of longitudinal prestress would such cracks appear under dead load only conditions

In flanges containing internal tendons, a flexural crack might breach the tendon path.

The transient nature of such a crack is not a concern for the integrity of the post-tensioning (i.e. it is not a permanent breach of cover). However, bring any such cracks that appear to be permanent to the attention of the Engineer.

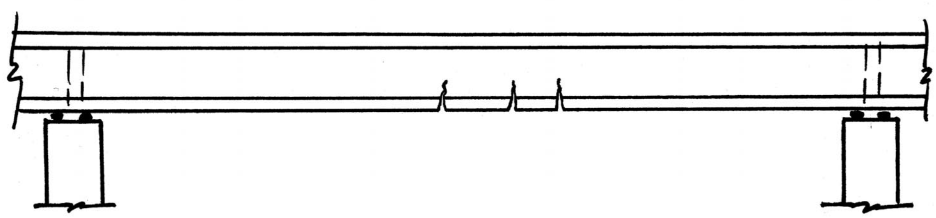


Figure A.3 - Longitudinal flexural cracks across soffit of I-girder (near mid-span)

(4) Longitudinal flexure crack across top of I-girder deck slab over interior piers

This is usually a single, transverse crack across the deck slab, close to or over an interior pier in a superstructure unit of two or more continuous spans. If and when it occurs, it usually coincides with a transverse construction joint in the deck slab at or near the pier.

In some cases, a deliberate transverse crack is induced by an under-reinforced (“poor-boy”) joint over the top of the pier.

The crack may be of any width – however, when coincident with deliberately made construction joints – the crack may be quite wide and noticeable

Such a crack is induced by combination of dead loads, the pouring sequence of the deck slab and shrinkage of the deck-slab concrete. The crack is a permanent feature and does not close under any conditions. Under severe live-load and rare cases of thermal gradients, such a crack would, temporarily, be made wider.

If a crack extends down to top of girder (or into top of girders) it may breach the post-tensioning ducts and allow water or salts to attack the tendon – especially in some early bridges designs using continuously post-tensioned spliced girders where the tendon profile rises into the deck slab and is spliced in a cast-in-place joint over the pier.

This type of crack can be significant to corrosion protection in such bridges.
Seal the deck slab and cracks.

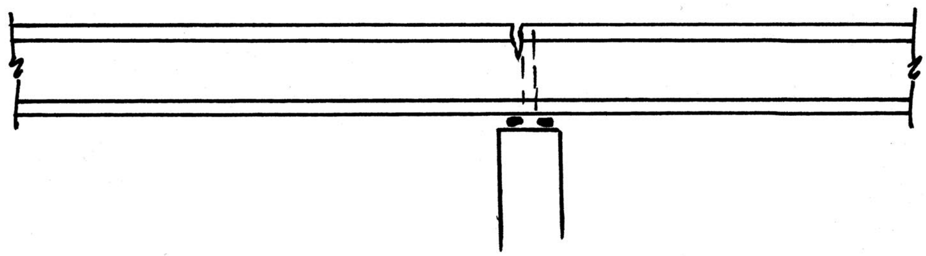


Figure A.4 - Longitudinal flexure crack across top of I-girder deck slab over interior piers

(5) Transverse flexural crack in box along inside top of web near or at top slab

These cracks may run longitudinally inside a box section close to or at the top of the web at the intersection with the underside of the top slab.

They may result from transverse flexural effects. They may also be a consequence of the casting and curing process and may sometimes be initiated by a discontinuity - such as a diaphragm or anchor blister

Generally, such cracks do not penetrate deep into the web or top slab (i.e. deeper than cover) and present little risk to the integrity of any internal post-tensioning either in the web or slab

Seal the cracks

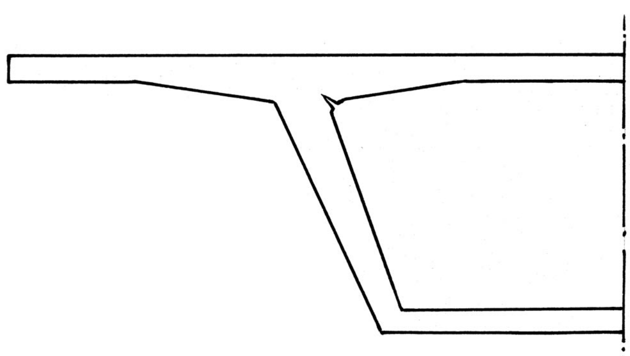


Figure A.5 - Transverse flexural crack in box along inside top of web near or at top slab

(6) Transverse flexural crack in box along outside top of web at root of top slab

These cracks may run longitudinally on the outside of a box section close to or at the intersection (root) of the top slab and web

Such a crack may result from the top transverse post-tensioning inducing tension in the soffit corner that is greater than the compression from the self weight of the wing

Such cracks may also be an artifact of the casting and curing process (binding of forms or shrinkage / thermal effects – particularly in precast construction)

Generally, they do not penetrate deep into the web or top slab (i.e. are less deep than cover) and present no risk to the integrity of any internal post-tensioning either in the web or slab

Seal the cracks

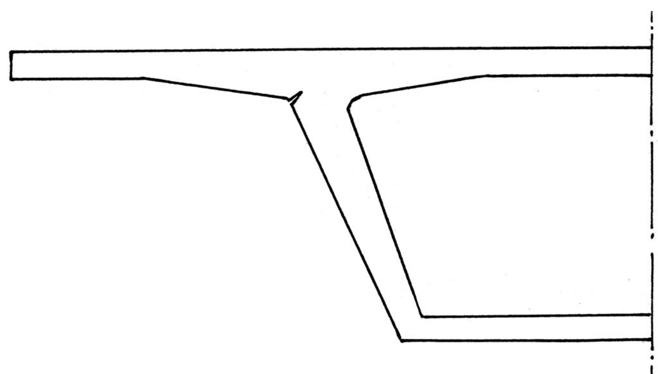


Figure A.6 - Transverse flexural crack in box along outside top of web at root of top slab

(7) Transverse flexure crack in box along inside bottom of web / slab corner

These cracks may run longitudinally at the inside intersection of the bottom slab and web

They are probably caused by local transverse flexure of the bottom slab from its' own self weight and local concentrated utility loads or similar effects

Providing that they do not penetrate more than the surface cover, they present little risk to the integrity of any internal post-tensioning in the bottom slab

Seal the cracks to prevent any water seeping into the rebar or concrete

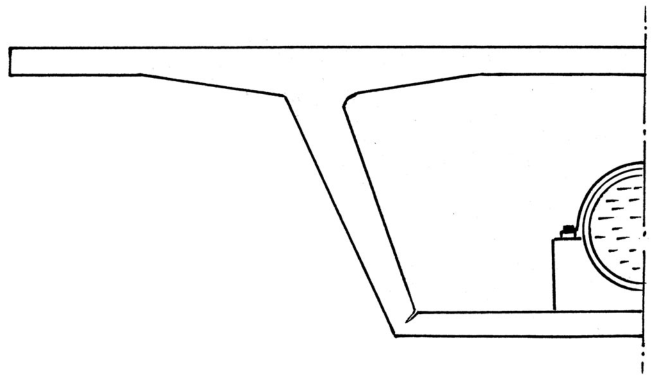


Figure A.7 - Transverse flexure crack in box along inside bottom of web / slab corner

(8) Transverse flexure crack in top slab along top at or near the web

In a transversely prestressed deck slab, such a crack would only occur under very severe transverse live-load conditions. However, being transient, the crack should close once conditions return to normal.

The transient nature of such a single crack over the web is not a concern for the integrity of the post-tensioning (i.e. it is not a permanent breach of cover)

However, if any such (permanent) cracks are found then bring them to the attention of the Engineer for further investigation.

(Information: When the top slab of a box-section is reinforced transversely only by rebar, a crack or series of parallel cracks may occur under the transverse flexure effects of dead and live load. This can be aggravated by excessive cover to rebar or the lack of intimate bond between epoxy coated rebar and the concrete (e.g. Seven Mile Bridge). However, when the same slab is prestressed (either by pre- or post-tensioning), such cracks do not occur (see (26) below))

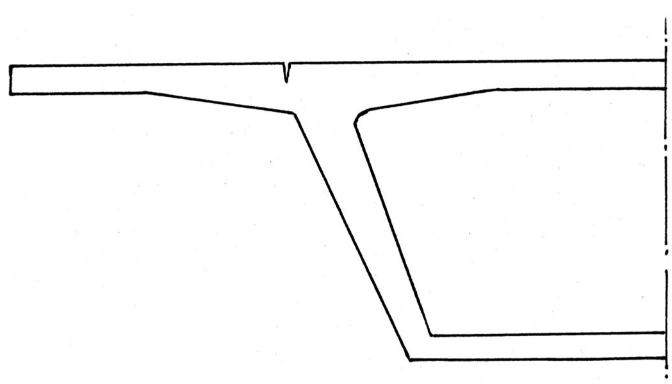


Figure A.8 - Transverse flexure crack in top slab along top at or near the web

A.2.2 Shear Cracks

(9) Shear cracks in web

Shear cracks generally occur near the ends of a span in regions near the supports (usually less than one-quarter of the span of a member).

Shear cracks are inclined - in prestressed (pre- and post-tensioned members) with no vertical post-tensioning - the inclination is typically less than 45 degrees to the horizontal and rising toward mid-span. If there is vertical prestress (e.g. PT bars) in the webs, cracks may incline steeper than 45 degrees

Shear cracks may be isolated or may occur at intervals along the web. They may be of any width and are generally at their widest in the mid to upper half of a web in a box-section or I-girder – i.e. near the neutral axis of the section. Shear cracks generally pass through a web and appear on both sides (check both sides).

In general, once a shear crack occurs in a web, it does not close under any conditions. Consequently, if there is draped post-tensioning in the web, this type of crack can be significant to corrosion protection since it permanently breaches the tendon path.

Furthermore, shear cracks are structural - bring such cracks to the attention of the Engineer. Before making repairs, first check any affected tendons for grout voids or corrosion. Make structural repairs only at the direction of the Engineer. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

If structural repairs are not needed, then seal all cracks to prevent corrosion of the reinforcing.

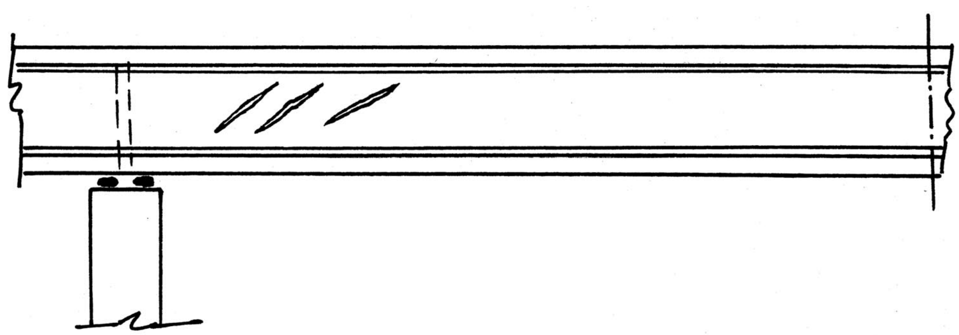


Figure A.9 - Shear cracks in web

(10) Flexural-Shear Cracks

In some cases, a shear crack may be initiated by or connect with a flexural crack. Such “flexural-shear” cracks usually occur approximately in the one-third point region of the span -

beginning with a vertical crack in the bottom flange that extends into the web and inclines over, running at a shallow angle toward mid-span.

Flexural-shear cracks may be isolated or there maybe several at intervals. They generally pass through a web and appear on both sides (check both sides).

In general, as for shear cracks, once flexural-shear crack occurs in a web, it does not completely close. Consequently, if there is draped post-tensioning internal to the web, this type of crack can be significant to corrosion protection since it permanently breaches the tendon path.

Furthermore, flexural shear cracks are structural - bring such cracks to the attention of the Engineer. Before making repairs, first check any affected tendons for grout voids or corrosion. Make structural repairs only at the direction of the Engineer. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

If structural repairs are not needed, then seal all cracks to prevent corrosion of the reinforcing.

Figure A.10 - Flexural-Shear Cracks

A.2.3 Anchor Zones (bursting effects - also bearing reaction confinement)

(11) Cracks in Anchor Blocks, Blisters or Diaphragms

Localized cracks in an anchor block are caused by concentrated forces from the tendon anchor bearing on the concrete

Anchor block cracks may be of any width, but are generally narrow and of limited length (several inches to a foot or so)

Cracks may extend a short distance from the end of the anchor block along the center of the tendon path (i.e. a splitting crack - similar to driving a wedge lengthwise into a log)

Cracks may propagate from the corners of the anchor bearing plate, flaring at an angle to the tendon path when viewed from the side, from above or from below

Cracks may also propagate from the center or corners of an anchor plate laterally across the width of the anchor block when viewed from the end (i.e. looking along the tendon)

Cracks from one anchor may propagate and join with those from an adjacent anchor when there is a group of anchors together (e.g. in a diaphragm at an expansion joint or pier segment of a box girder)

Cracks in an end anchor block of an I-girder may not be visible if the end is embedded in a diaphragm or pour-back

In all cases, cracks in anchor blocks should be arrested and contained by local reinforcing within the anchor block, blister or diaphragm containing the anchor(s)

However, anchor block cracks are structural - bring such cracks to the attention of the Engineer. Before making repairs, first check any affected tendons for grout voids or corrosion. Make structural repairs only at the direction of the Engineer. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

If structural repairs are not needed, then seal all cracks to prevent corrosion of the reinforcing.

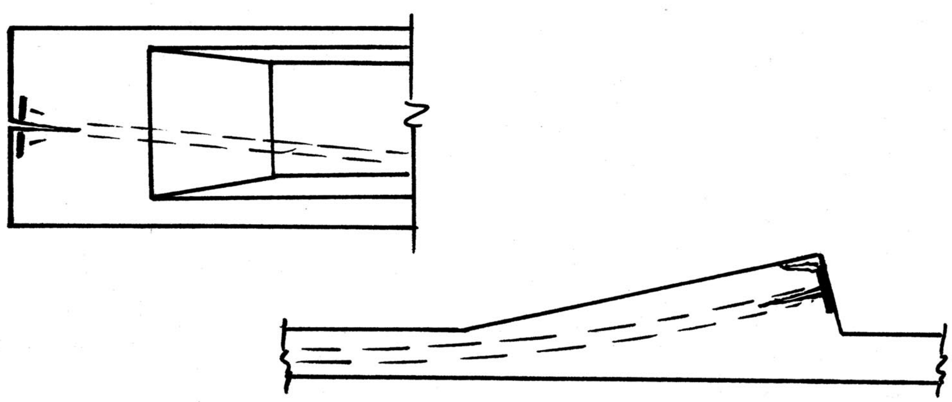


Figure A.11 - Cracks in Anchor Blocks, Blisters or Diaphragms

(12) Cracks in expansion joint segment diaphragms

Cracking may occur on the end (anchor face) of a diaphragm local to the anchors or at the intersection of the diaphragm and web or slab. If there are any cracks approximately at mid-height of the diaphragm on the opposite face – then the cracks would have been induced by local tendon forces at the time of construction. Such cracking can occur in relatively thin diaphragms (i.e. that may be only 4 feet thick in the longitudinal direction when the depth of the box is more than about 8 feet.) Cracks in the anchor face may also be exacerbated by local anchor bursting effects in some cases.

These cracks are structural in that they were originally induced by loads. However, those loads (i.e. anchor forces) gradually reduce with long term losses so the condition should never become more serious than at the time of construction.

Bring such cracks and to the attention of the Engineer. Repairs might require the addition of local strengthening. So, make repairs only at the direction of the Engineer.

Before making repairs, first check any affected tendons and anchors for grout voids or corrosion. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

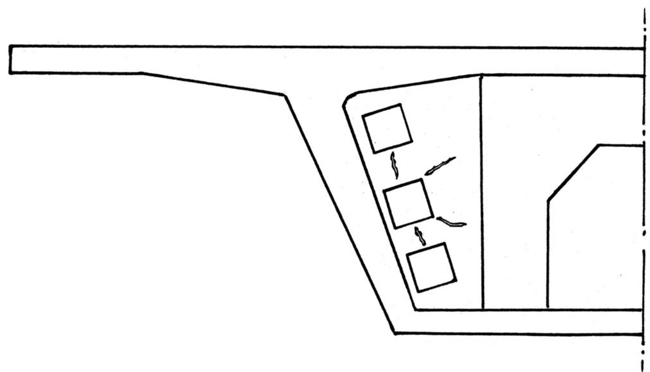


Figure A.12 - Cracks in expansion joint segment diaphragms

(13) Spalls at anchors in edges of slabs

Anchors for transverse tendons cast into the edges of cantilever wings of deck slabs of box girders and similar, are prone to splitting or spalling effects from the concentrated force of the anchor bearing on the relatively thin edge of the slab. Anchor splitting occurs locally along the center of the tendon or from a corner of the bearing plate and propagates through to the top or bottom and appears as a spall.

(In the past, this situation was made worse when anchor pockets were cast using separate (plastic) pocket formers. The formers distorted under the pressure of wet concrete and left a surface that did not perfectly match the anchor bearing plate and made a high-spot that initiated a crack. For this reason, anchor pocket formers are no longer used.)

Anchor splitting (or bursting) reinforcement must be placed close to the bearing plate and must completely cut and encompass any potential crack or spall path. Suitably designed and details reinforcement is essential. This may comprise links or bars bent with multiple reverse U-bends to facilitate installation.

Such cracks or spalls affect the anchor area and can provide an avenue for water or salts to the anchor plates and possibly into the transverse tendon. It is paramount that they are properly repaired.

Such cracks should no longer occur. However, for any that are found - bring cracks or spalls that to the attention of the Engineer. Repair and seal cracks and spalls.

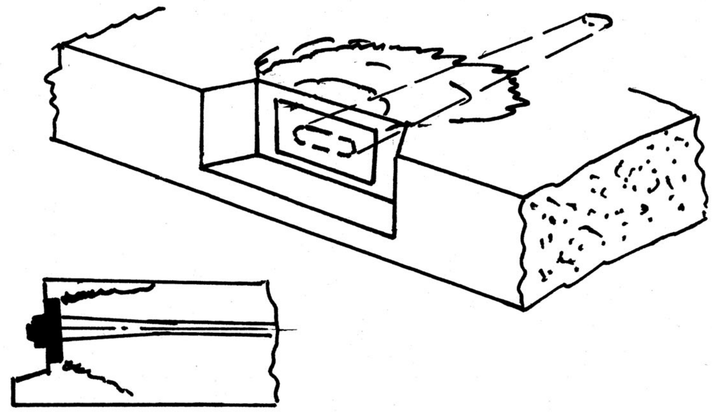


Figure A.13 - Spalls at anchors in edges of slabs

(14) Local cracking in bottom flange of I-girder at bearing

Such a crack may occur in the bottom flange of a girder due to incomplete development of longitudinal pre- or post-tensioning force right at the end, local to the bridge bearing, so that local bearing stresses may not be well confined. Such cracks are usually small and narrow.

A short narrow crack of this type does not threaten the protection of any internal post-tensioning.

Measure and record crack location, length and maximum width
Make photographic or video record

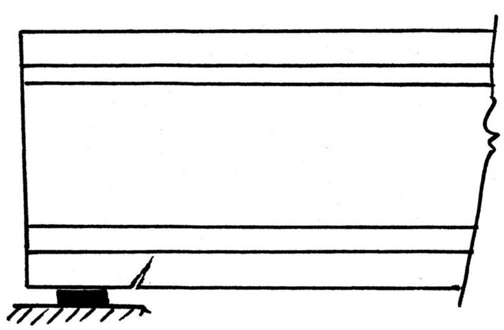


Figure A.14 - Local cracking in bottom flange of I-girder at bearing

A.2.4 Concentrated or Local Effects

(15) Cracks in tops of deviators

Cracks in deviator saddles can arise from the high lateral, radial force of the tendon as it bears against the deviator pipe. The force is concentrated over a relatively short length of deviator pipe. If the pipe itself is slightly misaligned or is bent by the tendon bearing against it after it emerges from the deviator, then local deformation of the pipe can occur and can lead to a crack or small spall in the end cover concrete of the deviator.

Lateral forces from the tendons must be restrained by the local reinforcing in the deviator itself. The reinforcing must be accurately placed for maximum efficiency.

Tendons are usually contained in galvanized steel pipes through deviators, so locally, they are protected. Any cracks in the deviator itself do not pose a concern for the corrosion protection of the tendon. However, such cracks may open pathways for water to attack the reinforcing.

Consequently, bring cracks in deviators to the attention of the Engineer. A crack in the end cover only may not necessarily be significant. A crack all the way across the deviator may be structural (the reinforcing might be overstressed) and the deviator should be checked by the Engineer.

Before making repairs, first check any affected tendons for grout voids or corrosion. Make structural repairs only at the direction of the Engineer. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

If structural repairs are not needed, then seal all cracks to prevent corrosion of the reinforcing.

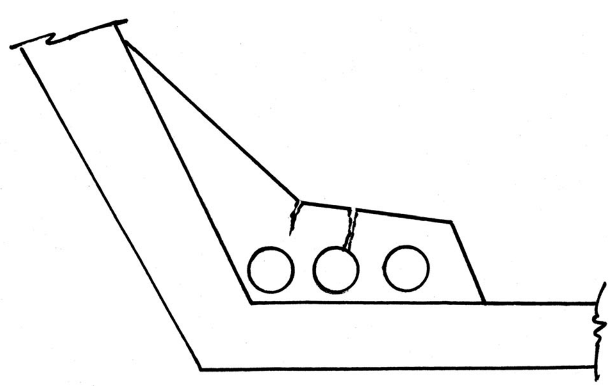


Figure A.15 - Cracks in tops of deviators

(16) Radial force from tendon (in anchor blister inside box girder)

The radial force from a tendon that curves into an anchor blister at the corner of a box (top or bottom) exerts a high lateral load that must be restrained by suitable reinforcing.
If not, it can lead to cracking or a significant spall – usually at the thinnest end of the anchor blister where it meets the slab.

Such cracks or spalls locally weaken the slab and are, therefore, a structural concern. Repair may require the addition of strengthening. Such cracks also breach the concrete cover to the tendon and open pathways for water to attack the reinforcing.

Consequently, bring cracks or spalls from radial tendon effects in anchor blisters or slabs to the attention of the Engineer.

Before making repairs, first check any affected tendons for grout voids or corrosion. Make structural repairs only at the direction of the Engineer. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

If structural repairs are not needed, then seal all cracks to prevent corrosion of the reinforcing.

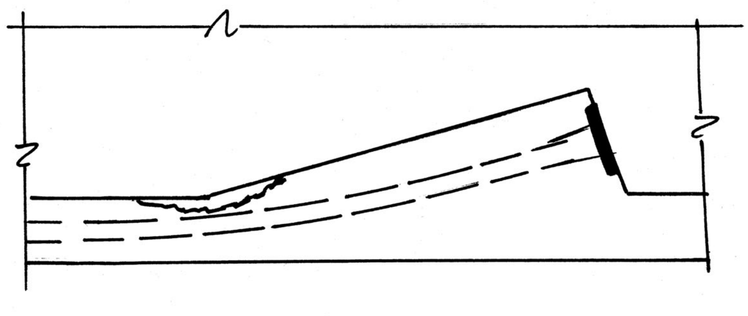


Figure A.16 - Radial force from tendon (in anchor blister inside box girder)

(17) Spall in top surface over a diaphragm containing opposing PT anchors

When external tendons from adjacent spans overlap and anchor in a diaphragm so that the anchors oppose each other, it is possible to induce high lateral tensile effects at right angles to the tendon path – i.e. in the vertical direction. The effect mainly arises from the lateral behavior of concrete under compressive load (Poisson-ratio effect) that tends to split the concrete parallel to the compression. If not confined by reinforcement, this can lead to a local spall. In pier segments this may appear as a circular crack or spall over the top of the diaphragm (e.g. early Keys Bridges). The effect is magnified, if the tendons curve over the diaphragm and the opposing anchors are angled upwards. However, it is possible to confine the effect with suitable diaphragm reinforcing.

Any such spalls that occur in the top deck surface may create an avenue for water to reach the reinforcing, if not the tendons themselves over the pier depending upon the depth of the spall. Since most diaphragms are massive and well reinforced, a spall of this nature may not be structurally significant.

Nevertheless, bring any such new spalls to the attention of the Engineer.

Before making repairs, first check any affected tendons for grout voids or corrosion. Make structural repairs only at the direction of the Engineer. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

If structural repairs are not needed, then seal all cracks to prevent corrosion of the reinforcing or PT.

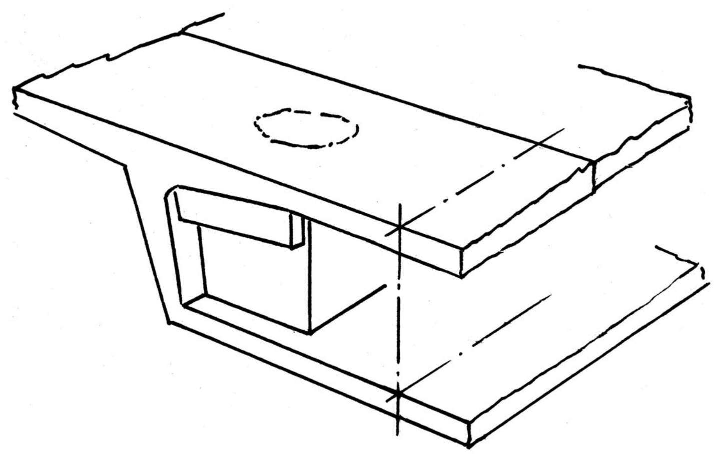


Figure A.17 - Spall in top surface over a diaphragm containing opposing PT anchors

(18) Longitudinal crack along path of internal tendon in a web

A crack along the path of an internal tendon, draped in a web, may occur at any location, be of any length and of any width – sometimes as wide as .03 inches (1/32") or more

It is usually initiated by a design or construction defect – such as a badly installed duct with too much wobble, a duct crushed locally by too tight reinforcing, lack of web width or a local weakness in the web itself (low strength material, void, honeycomb) etc.

Occasionally, a longitudinal crack along the path of a tendon in a web may have an associated delamination (spall) – investigate the spall carefully:

- Sound the web surface locally by lightly tapping with a hammer – if it has a hollow sound then there is probably a delamination (spall) with the crack
- Identify the surface extent of the spall (if possible), measure, record approximate extent in notebook
- Take photograph(s) or video and record in notebook

A spall might significantly weaken a web, locally. Bring all such cracks or spalls to the attention of the Engineer. Although such cracks and spalls may not necessarily be structurally significant, they breach the concrete cover, opening the corrosion protection of the tendon to water or salts.

Before making repairs to spalls and cracks, first check any affected tendons for grout voids or corrosion. Make structural repairs only at the direction of the Engineer. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

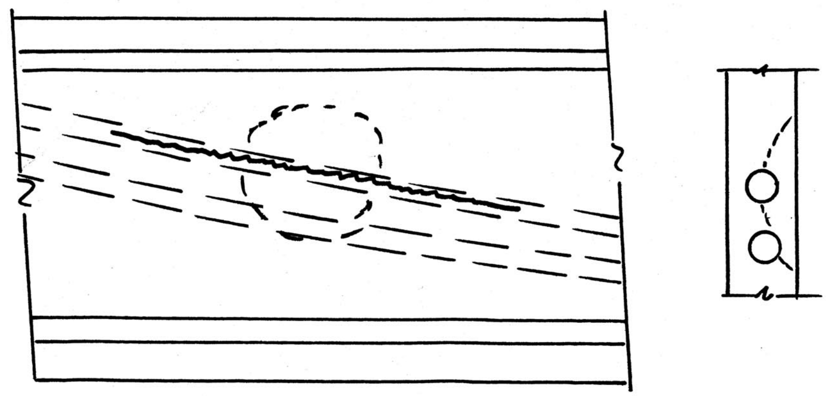


Figure A.18 - Longitudinal crack along path of internal tendon in a web

(19) Lateral effect of internal tendon in curved web (plan curve)

If an internal tendon is inside a web of a box section aligned to a horizontal curve, it exerts a lateral force on the reinforcement and cover concrete on the inside of the curve. This lateral force must be restrained by suitable lateral reinforcement at regular intervals to tie the tendon into the web (e.g. by horizontal ties around both web bars)

If it is not suitably tied, the tendon may break out of the web as it attempts to straighten itself to the chord of the curve.

Should the web not completely fail, it is possible that delamination cracking would occur possibly appearing as one or more local spalls with a circular crack pattern centered on the points of maximum lateral force as the tendon bears locally and internally against the web concrete or reinforcing.

Such cracks not only breach the concrete protection of the tendon and offer an avenue for water or salts but also weaken the web – they are structural cracks.

Bring such defects to the attention of the Engineer. Repairs may require the addition of local strengthening. Make repairs only at the direction of the Engineer.

Before making repairs to spalls and cracks, first check any affected tendons for grout voids or corrosion. Include any necessary tendon repairs with structural repairs as appropriate.

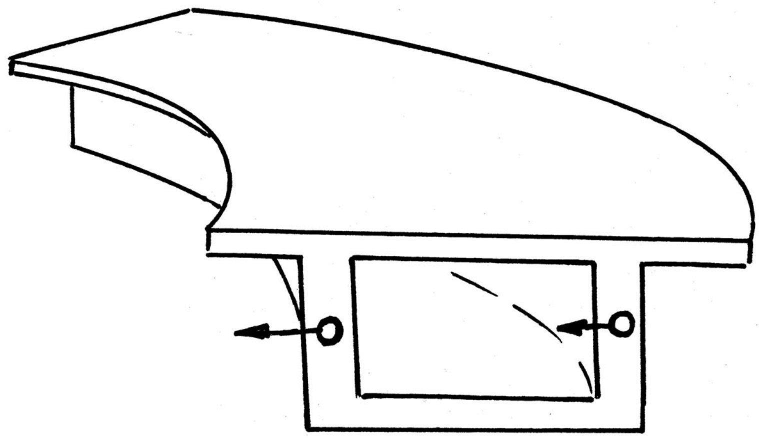


Figure A.19 - Lateral effect of internal tendon in curved web (plan curve)

(20) Delamination crack in thin slab with multiple closely spaced tendons

A group of internal tendons, closely spaced, in a relatively thin slab (of a thickness of say, twice the duct diameter) may - because of imperfections in duct alignments (wobble) in both lateral and vertical directions – initiate a lateral crack between the ducts – approximately at the mid-depth of the slab. This crack will propagate between ducts and then turn to the soffit or top of the slab where it emerges as a longitudinal crack in the surface. The crack may create a large spall to the depth of the ducts.

Sound the concrete to check for a possible delamination (spall) by lightly tapping with a hammer. Examine the edge of the crack at the surface, - if it emerges at an angle of 30 to 50 degrees (i.e. not perpendicular), cuts back to the ducts and sounds hollow, then it is most probably a delamination crack (spall) – if the crack emerges more perpendicular to the surface, is a single crack and there is no hollow sound - then it may not be a spall and it may have a different cause.

Spalls that result from such delamination cracks locally reduce the effective area of the slab. This has structural implications and must be brought to the attention of the Engineer.

Such delamination also breaches the cover to the tendons and affects the corrosion protection. Depending upon the location of the crack or spall, it may allow water or salts to reach the tendons.

Repairs may require the addition of local strengthening. Make repairs only at the direction of the Engineer. Before making repairs to spalls and cracks, first check any affected tendons for grout voids or corrosion. Include any necessary tendon repairs with structural repairs as appropriate.

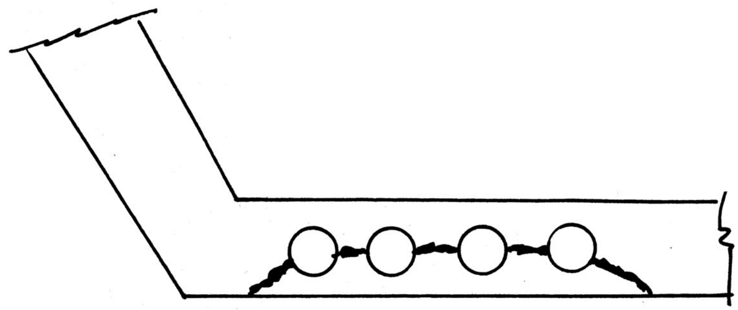


Figure A.20 - Delamination crack in thin slab with multiple closely spaced tendons

A.2.5 Discontinuity Cracks (abrupt changes in section)

(21) Crack at intersection of diaphragm to top or bottom slab corners

Generally, this type of crack is local to the diaphragm and is usually a consequence of the thermal-shrinkage effects from curing. Such cracks should be sealed so as not to compromise the corrosion protection of the post-tensioning afforded by the diaphragm.

However, if such cracks are accompanied by other cracks – on the opposite face of an end diaphragm face – then they may be structural – induced by local tendon force effects - see (12) above.

If the cracks are not structural, then seal them. However, before making repairs, first check any affected tendons or anchors for grout voids or corrosion. Include any necessary tendon repairs (e.g. grouting) with sealing of cracks as appropriate.

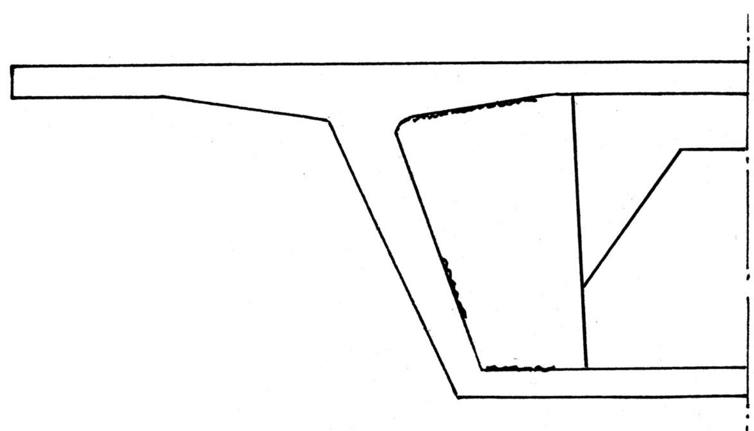


Figure A.21 - Crack at intersection of diaphragm to top or bottom slab corners

(22) Cracks in dapped hinge zones

Cracks in dapped hinges usually follow a 45 degree path from the corner of the hinge. The crack path may be steeper if there is any effective longitudinal prestress in the hinge zone. Cracks in dapped hinges can occur in any type of structure – i.e. box sections or I-girders.

In some structures, (e.g. boxes) the crack pattern may be more widespread and complex – particularly if the bearings in the hinge zone are offset transversely to the line of the webs without adequate transverse stiffening.

The key to preventing cracks in such hinges is to provide the right amount and disposition of effective post-tensioning to compress the concrete - supplemented with reinforcement to contain the PT and local bearing effects.

Bring such structural cracks to the attention of the Engineer. Repairs might require the addition of local strengthening. Make repairs only at the direction of the Engineer.

Before making repairs, first check any affected tendons or anchors for grout voids or corrosion. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

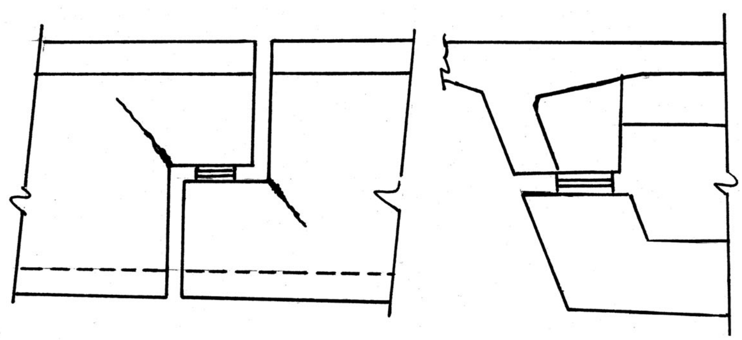


Figure A.22 - Cracks in dapped hinge zones

(23) Opening of wing tip joints or cracks at end of wide deck slab (shear lag)

Local tensile effects can be induced in the edges of the wing tips of a wide deck slab of a box section due to the effect of shear lag from the action of tendons compressing the section in the center of the box. Shear lag is the effect created by the dispersal of concentrated local forces – approximately at 30 degrees to the line of force. The longitudinal compression from the anchors does not reach the edge of the deck, and, in fact can be shown to induce local tension in the edge.

The design solution is to provide a longitudinal PT tendon (perhaps bars or strands) in the wing tip edges of a wide box that anchors in the expansion joint face.

Without such local longitudinal PT, after the bridge is built, the effect might reveal itself as a slight crack in the concrete or opening of a transverse joint in a segmental box at the wing edge. This may be significant only if the crack is noticeable or wide enough to admit water into the concrete that might then find its way into the expansion device or any tendons or anchors in the concrete in this region.

Seal the cracks. If the cracks are wide, then additional PT bars could be installed longitudinally, perhaps by making use of the edge barriers rather than disrupting the slab itself. Refer to Engineer.

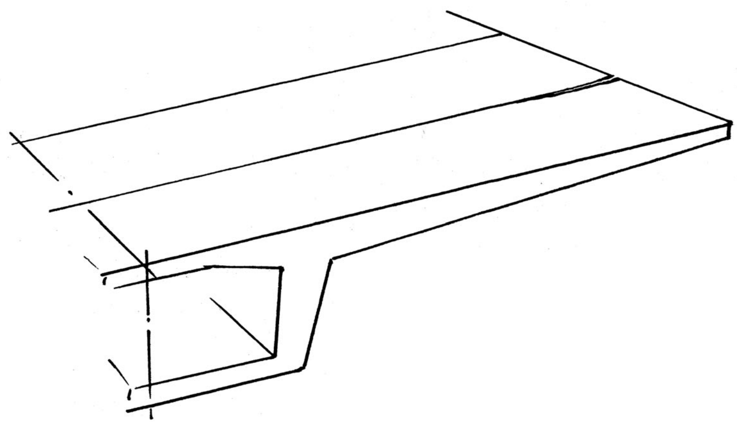


Figure A.23 - Opening of wing tip joints or cracks at end of wide deck slab (shear lag)

(24) Local crack across slab or web at anchor end of blister

This local crack can occur at or near to the anchorage end of a blister inside a box section at the corner of the web or slab. It is induced by tensile effects from the anchor forces, transmitted by shear lag to the slab or web. Such cracks might occur with single anchor blister even if the slab is appropriately reinforced. If there is more than one anchor – say two or more in a group in such a blister, then the effect is much more likely.

These cracks might open avenues for water to get into any tendons contained in a bottom slab. Similar cracks on the underside of a top slab would not necessarily present a risk.

The cracks are usually permanent. Since they are induced by load effects, they are structural. However, the effects that cause them (anchor forces) tend to reduce with time due to losses. Consequently, such cracks, if small and narrow, may not be a significant structural concern.

However, bring any such cracks to the attention of the Engineer. Repairs might require the addition of local strengthening. Make repairs only at the direction of the Engineer.

Before making repairs, first check any affected tendons or anchors for grout voids or corrosion. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

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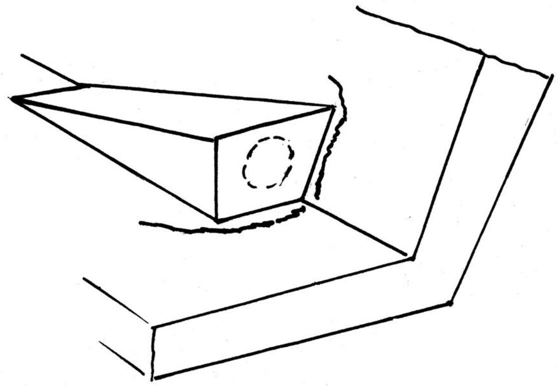

Figure A.24 - Local crack across slab or web at anchor end of blister

(25) Local crack in slab at corners of temporary PT bar blister

Local cracks may sometimes occur in a slab surface at the corners of a blister for temporary post-tensioning bars used for erection purposes. Such cracks might occur even if the blister and slab are properly reinforced – but they should be small and narrow.

These cracks might open avenues for water to get into any tendons contained in a bottom slab. Similar cracks on the underside of a top slab would not necessarily present a risk.

Bring any such cracks to the attention of the Engineer. If the temporary blisters are needed for any future PT purposes, then repairs might require the addition of local strengthening. Make repairs only at the direction of the Engineer.

Before making repairs, first check any affected tendons or anchors for grout voids or corrosion. Include any necessary tendon repairs (e.g. grouting) with structural repairs as appropriate.

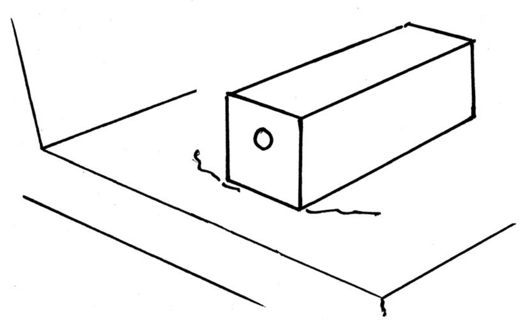

Figure A.25 - Local crack in slab at corners of temporary PT bar blister

A.2.6 Material and Environmental Cracks

The last category of cracks is those induced by material characteristics and environmental conditions – generally concrete curing, shrinkage, thermal rise and fall or thermal gradient.

(26) Regularly spaced longitudinal cracks in top slab of box girder (7-Mile)

These may arise with box girder sections that are relatively wide and reinforced transversely only with rebar – i.e. no transverse prestress. The phenomenon arises from a combination of conditions that include shrinkage, transverse flexure, excess cover and ineffective bond between rebar and concrete (i.e. epoxy coating). Nowadays, all such boxes must be transversely prestressed (by either pre- or post-tensioning) – there has been no recurrence.

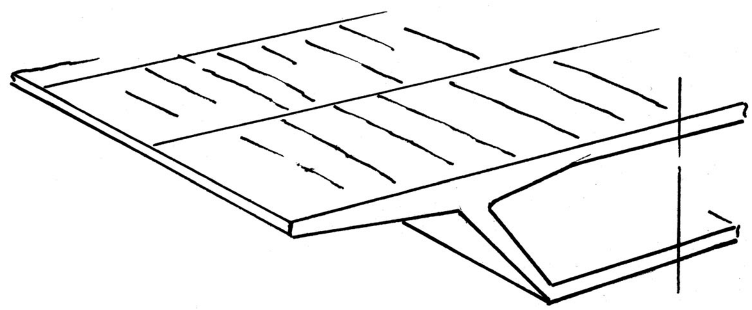

Figure A.26 - Regularly spaced longitudinal cracks in top slab of box girder (7-Mile)

(27) Regular transverse cracks across I-girder deck slab

Transverse cracks at regular intervals of a few feet may occur along entire span but may be more frequent near piers (negative moment region /deck pour sequence)

These cracks usually extend through deck slab and are visible on soffit because of efflorescence (white powder) that leaches from the concrete cracks when it rains.

They are primarily the result of differential shrinkage between the (younger at time of casting) deck slab concrete and the (older precast) girder concrete

Such cracks may be induced or made worse by effects from dead-loads – especially the deck slab pouring sequence

If such a crack extends down to top of girder (or into top of girders) it may breach the post-tensioning ducts and allow water or salts to attack the tendon. Examine soffit of deck slab in regions close to interior piers for any evidence of leaks, efflorescence or rust stains that might come from tendons in top of girder or deck slab over pier.

In early designs using continuously post-tensioned spliced girders, the tendon profile may rise into deck slab over pier – so this type of crack might affect corrosion protection of tendons at duct splices in the cast-in-place closure over the pier

Seal cracks and deck slab

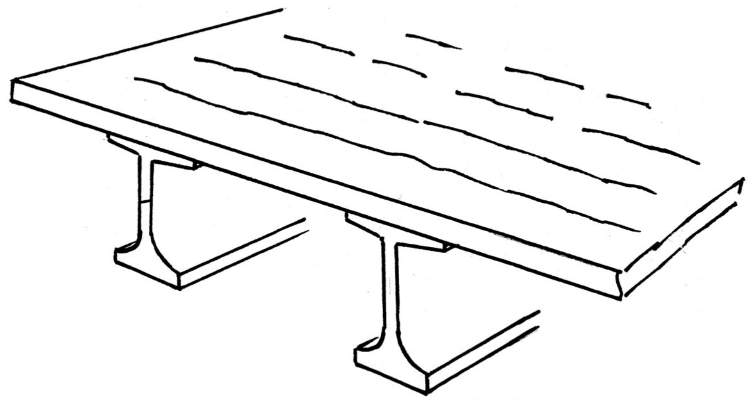

Figure A.27 - Regular transverse cracks across I-girder deck slab

(28) Shrinkage separation cracks at cast-in-place pour-backs to blockouts or holes

Ordinary structural concrete shrinks significantly relative to older similar concrete. Consequently, such concrete used for pour-backs to block-outs for anchors, access holes or small diameter holes through slabs for lifting or construction purposes lead to shrinkage and open up avenues for water to enter the structure, and perhaps get into anchors and tendons.

Similar cracks can occur in any type of cast-in-place structure where there is an opening for access or construction purposes. Also, similar shrinkage cracks can occur at anchor block-outs in the edges of transversely post-tensioned deck slabs and precast prestressed concrete planks. However, in the latter cases, these are mostly covered by traffic barriers.

Seal all shrinkage cracks. If there is any evidence of rust associated with cracks, check the anchor or tendon for possible corrosion and repair as necessary prior to sealing.

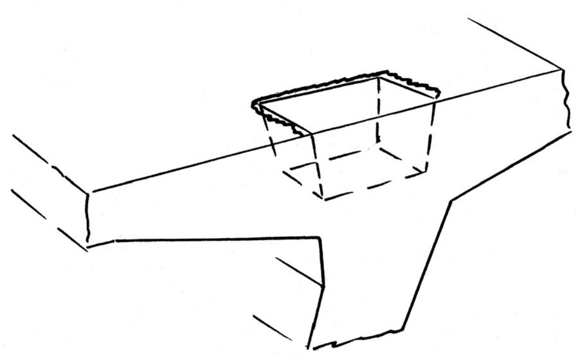

Figure A.28 - Shrinkage separation cracks at cast-in-place pour-backs to blockouts or holes

(29) Transverse crack at construction joint in deck slab of I-girder

This type of crack usually occurs at a construction joint near or over the top of a pier in a continuous bridge deck slab cast on I-girders. The crack can be noticeable and quite wide in some cases.

It is caused by a combination of shrinkage of the deck slab concrete relative to the older, mature concrete of the girders and the deck-slab pouring sequence. The latter can induce a tensile stress in the deck slab at this point under certain pouring sequences. It is preferable to pour the portions over the piers last to minimize this effect. If there is no longitudinal post-tensioning through the spans, (i.e. in decks with poor-boy joints) on going long term creep and shrinkage of the I-girders tends also to induce further tension at this point.

If there is longitudinal post-tensioning in the girders that rises to the deck slab and the ducts are spliced over the pier, it is susceptible to corrosion because such a crack breaches the primary protection afforded by concrete cover.

Seal such cracks. If there is any evidence of rust associated with cracks, check the splice joint and tendon for possible corrosion and repair as necessary prior to sealing.

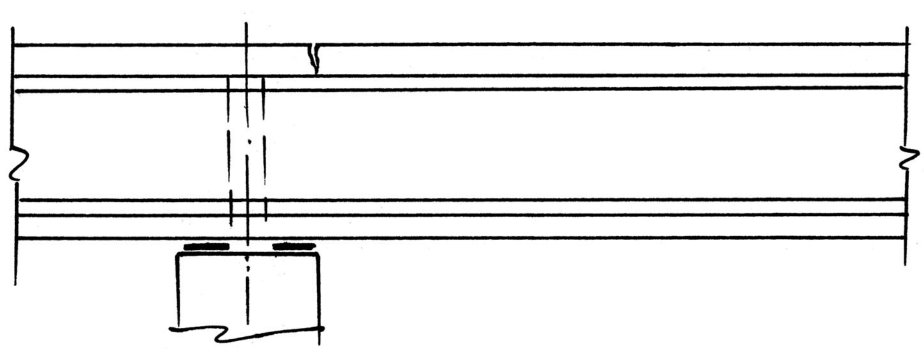

Figure A.29 - Transverse crack at construction joint in deck slab of I-girder

(30) Cracks at mid-span closures (during construction)

Occasionally, a crack may occur during construction at a transverse closure pour or joint between that connects the tips of two cantilevers at midspan. The effect is usually transient, i.e. temporary and only during construction. It is a consequence of thermal gradient induced by overnight cooling of the structure, or cooling and shortening of temporary supports or closure devices. Once the continuity post-tensioning is installed, and stressed such effects are generally eliminated and there should be no permanent cracks.

If such cracks close completely during construction, then there is no loss of protection to any internal tendons passing through the closure.

Seal cracks and deck slab

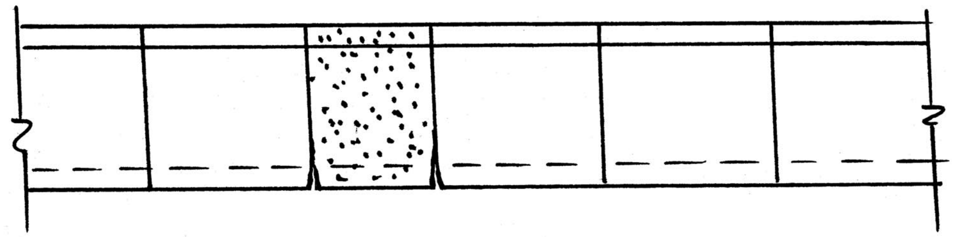

Figure A.30 - Cracks at mid-span closures (during construction)

(31) Surface crazing of massive diaphragm from thermal-shrinkage- curing

Rapid cooling of the surface of a relatively massive piece of concrete that has built up considerable heat of hydration during curing will cause the surface to crack irregularly to about the depth of the cover. This occurred with the large diaphragm segment of a precast segmental box (I-595) – the segment was not used in the bridge. Controlled curing with a gradual rise and slow fall is the way to avoid such cracks.

Minor thermal-shrinkage cracks reduce the effective concrete cover and may allow water into the concrete and to any internal post-tensioning. Damaged precast components should not be used.

If such cracks are found on an existing structure, then seal them.

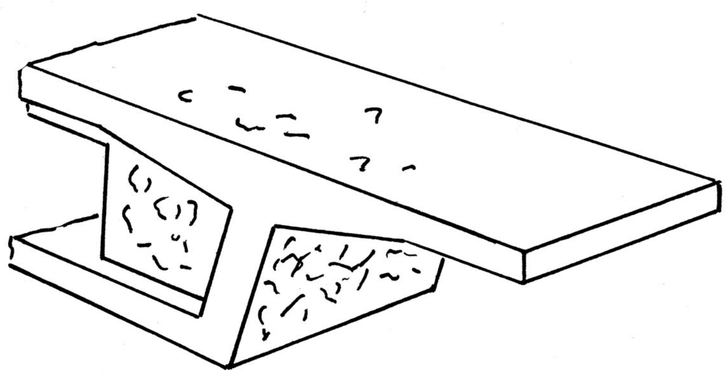

Figure A.31 - Surface crazing of massive diaphragm from thermal-shrinkage- curing

A.3 Cracks - Inspection Procedure

A.3.1 Inspection – Tools and Equipment

Access is needed to visually examine both sides of a member from close range. Use a special inspection and access vehicle such as a "cherry-picker" or man-lift as necessary

Tools – tape measure, crack width measuring tool, light hammer, notebook, photographic camera or video, post-tensioning shop drawings, as-built plans or copies of previous records – For work inside boxes, flashlights or other illumination. For further (invasive) examination, a power drill or small core cutting tool, probe (long thin, stiff wire), borescope and cover meter (to help find rebar, locate steel ducts or tendon) - Also - tools to make repairs to inspection – powered concrete saw, (up to 3" depth of cut), core cutter to enlarge pilot hole to approximately 2-1/2" to 3" diameter to depth of cover for making seal – miscellaneous containers and tools for mixing and applying repair materials to invasive inspection ports

Materials – provide a supply of materials for filling and sealing inspection holes (until proper repairs can be made as necessary)

A.3.2 Inspection Procedure for Examination and Recording of Cracks that may Breach Post-Tensioning Protection in Member

- Examine each side of member (inside and outside), and top and bottom of a member at close range (within a few feet)
- Seek evidence of cracks or deterioration that may breach post-tensioning ducts or anchors
- Identify or locate longitudinal post-tensioning tendons, transverse post-tensioning (if any) and reinforcement
- Measure and record the location of the crack – i.e. beginning and end (by distance and height from a suitable reference point – such as distance from end of member and height from a soffit or slab)
- For long cracks repeat measurements at intervals of 3 to 4 feet (on each side of member as appropriate)
- Also, measure crack widths – record the maximum width and, - for long cracks, record the width at above intervals (on each side of member as appropriate) – for short cracks (less than 2 feet long) record the maximum width
- For transverse cracks (across width of a member) measure and record width – take at least three measurements - one on each side and one in center of member – (take additional measurements at intervals of 3 to 4 feet on wide members)
- Record if there is any rust staining from embedded pre-tensioning strands – (i.e. longitudinal stains at frequent intervals across width of soffit of an I-girder)
- Note any isolated (point) rust stains on soffit from rebar supports or tie-wire
- Look for symptoms associated with cracks at or near post-tensioning ducts and anchors - in particular, examine crack to see if it is dry or has evidence of water leaks (dark water stains), efflorescence (white powdery or crystal-like (calcite) substance) or iron rust (yellow-red-brown) stains – (corrosion product from galvanized duct is also white (zinc-oxide) but is usually accompanied by iron rust stains too)
- Record that which best describes crack:
    - Crack is dry with no evidence of leaks, efflorescence or rust stain
    - Crack has signs of water leaks or efflorescence (but no rust)

  - Crack has rust-stains (with or without water leaks or efflorescence)
- Take photograph(s) or video and record in notebook

A.3.3 Cracks - Prognoses

If the crack is dry with no evidence of any leaks, efflorescence or rust stain then it is likely that the duct or tendon has not been breached and may not be corroded
If the crack has signs of water or efflorescence (white powdery substance) but no rust stain, then either, the duct has not been breached, the tendon itself has not yet corroded or is probably protected by grout, even if voided
If the crack has rust stains (with or without signs of water leaks or efflorescence) then it is probable that the tendon has been breached and suffers corrosion

A.3.4 Invasive Investigation (borescope) and Remedial Action

Proceed with further invasive investigation (below – e.g. drilling inspection holes, using borescope or removal of exploratory concrete surface area) - <u>only if</u> invasive examination can be properly repaired and sealed during the inspection or soon after. For remedial work – such as vacuum assisted grout injection - that will be done later - new injection ports and evacuation vents may be made at that time.

For cracks in general that breach cover concrete to PT ducts when the ducts are close to surface (i.e. approximately within twice the nominal depth of local cover), then proceed as follows.

Dry cracks with no efflorescence or rust stains:

- Dry cracks with no efflorescence or rust stains of any width up to 0.025” – seal (according to FDOT Specification for sealing of cracks)

- Dry cracks with no efflorescence or rust over 0.025” wide at any point – first perform invasive investigation by drilling an inspection port to check if duct is fully grouted. Follow appropriate Repair Procedure:
  - 4.5 **“Drill Grout Port or Inspection Port into Internal Duct”**
  - 4.6 **“Create Grout Port or Inspection Port at Anchor”**

- If fully grouted (no void in duct) then seal inspection hole using an approved procedure (below).

- If not fully grouted (void in duct) then probe to determine extent of void. For long cracks (over 6 ft) then drill similar inspection holes at intervals of approximately 6 to 8 feet. Insert borescope and check for any sign of exposed or rusted strands

- Observe and record conditions (i.e. are strands covered with grout? / are strands exposed? / are any wires seriously corroded or broken?) evaluate according to appropriate Inspection and Assessment Procedures:
  - 3.1 **“Assess Internal Tendon (at location in length)”**
  - 3.3 **“Assess Tendon at Anchor**”
  - 3.4 **“Assess Overall Integrity Level of Prestress**”

- Dry cracks with no efflorescence or rust over 0.025" wide at any point – seek opinion of Engineer for any structural implications prior to making repairs

- Upon completion of inspection, using approved procedures, repair crack by epoxy injection and/or surface sealing, fill any duct voids by vacuum grouting and seal all grout injection (inspection) ports and vents. Follow (as appropriate) Repair Procedures:
  - 4.8 ***"Inject Grout to Long Void in an Internal Duct"***
  - 4.9 ***"Vacuum Inject Grout into Local Void of Internal Tendon"***
  - 4.10 ***"Vacuum Inject Grout at an Anchor"***
  - 4.12 ***"Seal Grout Ports and Vents"***

Cracks with water leaks or efflorescence (but no rust):

- Cracks with water leaks or efflorescence (but no rust) and less than 0.012" wide at any point – seal (according to FDOT Specification for sealing of cracks)

- Cracks with water leaks or efflorescence (but no rust) and over 0.012" wide at any point – first perform invasive investigation by drilling an inspection port to check if duct is fully grouted. Follow appropriate Repair Procedure:
  - 4.5 **"Drill Grout Port or Inspection Port into Internal Duct"**
  - 4.6 **"Create Grout Port or Inspection Port at Anchor"**

- If fully grouted (no void in duct) then seal inspection hole using an approved procedure (below).

- If not fully grouted (void in duct) then probe to determine extent of void. For long cracks (over 6 ft) then drill similar inspection holes at intervals of approximately 6 to 8 feet. Insert borescope and check for any sign of exposed or rusted strands

- Observe and record conditions (i.e. are strands covered with grout? / are strands exposed? / are any wires seriously corroded or broken?) evaluate according to appropriate Inspection and Assessment Procedures:
  - 3.1 **"Assess Internal Tendon (at location in length)"**
  - 3.3 **"Assess Tendon at Anchor**"
  - 3.4 **"Assess Overall Integrity Level of Prestress**"

- Cracks with water leaks or efflorescence (but no rust) over 0.025" wide at any point – seek opinion of Engineer for any structural implications prior to making repairs

- Upon completion of inspection, using approved procedures, repair crack by epoxy injection and/or surface sealing, fill any duct voids by vacuum grouting and seal all grout injection (inspection) ports and vents. Follow (as appropriate) Repair Procedures:
  - 4.8 **"Inject Grout to Long Void in an Internal Duct"**
  - 4.9 **"Vacuum Inject Grout into Local Void of Internal Tendon"**
  - 4.10 **"Vacuum Inject Grout at an Anchor"**
  - 4.12 **"Seal Grout Ports and Vents"**

Cracks with rust stains (with or without signs of water leaks or efflorescence)

- Cracks with rust stains (with or without signs of water leaks or efflorescence) – lightly sound the surface for hollowness that might indicate a spall, honeycombed concrete or similar avenue to the PT duct

- Perform invasive investigation by drilling an inspection port to check if duct is fully grouted. Follow appropriate Repair Procedure:
  - 4.5 ***"Drill Grout Port or Inspection Port into Internal Duct"***
  - 4.6 ***"Create Grout Port or Inspection Port at Anchor"***

- If not fully grouted (void in duct) then probe to determine extent of void. For long cracks (over 6 ft) then drill similar inspection holes at intervals of approximately 6 to 8 feet. Insert borescope and check for any sign of exposed or rusted strands

- Observe and record conditions (i.e. are strands covered with grout? / are strands exposed? / are any wires seriously corroded or broken?) evaluate according to appropriate Inspection and Assessment Procedures:
  - 3.1 **"Assess Internal Tendon (at location in length)"**
  - 3.3 **"Assess Tendon at Anchor**"
  - 3.4 **"Assess Overall Integrity Level of Prestress**"

- However, if duct at pilot hole appears to be fully grouted then drill a second pilot hole a few inches away and check again (repeat a third time if necessary) – if duct still appears to be fully grouted (no void in duct) then undertake further investigation only at the direction of the Engineer. This may require removal of cover or spall concrete or non-invasive methods (Ultra-sound or Radiography)

- Cracks with rust stains (with or without signs of water leaks or efflorescence) – over 0.025" wide at any point – seek evaluation by Engineer for any structural implications prior to making repairs

- Upon completion of inspection, using approved procedures, repair crack by epoxy injection and/or surface sealing, fill any duct voids by vacuum grouting and seal all grout injection (inspection) ports and vents. Follow (as appropriate) Repair Procedures:
  - 4.8 **"Inject Grout to Long Void in an Internal Duct"**
  - 4.9 **"Vacuum Inject Grout into Local Void of Internal Tendon"**
  - 4.10 **"Vacuum Inject Grout at an Anchor"**
  - 4.12 **"Seal Grout Ports and Vents"**

Appendix B – Overview of Inspection Methods

B.1 Visual Inspection

B.1.1 Introduction

Visual inspection is the most important, convenient and economical method of inspection. It provides the greatest amount of information for the least amount of effort and expenditure. It is always the first method of inspection.

Visual inspection cannot and does not reveal everything – but it does reveal a lot.
Visual inspection immediately identifies whether a superstructure is a box section, I-girder, double-T or some type of slab (solid, voided or precast plank).

The type of post-tensioning tendons and locations within the superstructure are characteristic of the type of bridge and construction method. Consequently, knowing the type of bridge, tells where to look for tendons. The type of bridge and tendons, in-turn, tells what type of deficiencies to look for.

Follow the visual inspection procedure of Flowchart 1.1 to identify the bridge type (by the superstructure) and likely post-tensioning. (Refer to Sections 1.3 and 1.4 for greater detail.) This Flowchart (1.1) refers to Tables 1.2, 1.3, and 1.4 listing characteristics of bridge and post-tensioning with guidance on the likely types of deficiencies according to bridge type. Table 1.5 lists the various substructures according to superstructure type.

Although a visual inspection cannot necessarily reveal all potential deficiencies hidden within the concrete – such as grout voids in ducts or corrosion of tendons – visual evidence of such deficiencies reveals itself in ways that are characteristic of the different types of bridges and tendons.

In summary, a visual inspection reveals the type of superstructure, the likely method of construction and type of tendons. The type of bridge and tendons indicates the type of evidence of deficiencies to look for.

B.1.2 Deflections

Loss of permanent post-tensioning in a superstructure will, eventually, reveal itself through a permanent change in deflection under dead load. In order to detect a significant change, deflection measurements should be taken under the same environmental conditions – i.e. constant or similar daily cyclic temperature and humidity – from one set of measurements to the next. Also, ideally, observations must be made with no traffic on the bridge to eliminate the effects of live load.

During the first few years in the life of a post-tensioned structure, deflections under self-weight and prestress will change significantly as a consequence of long-term shrinkage and creep of the concrete and relaxation of the prestress steel. Eventually, these effects dissipate and a stable condition is reached after about ten years. Thereafter, if no additional superimposed load (e.g. wearing surface) is applied, any subsequent deflections must be due to a change in internal forces – most probably, prestress.

Variations induced by daily changes in temperature and humidity are much greater than any initial deflection caused by a small loss of prestress. Consequently, it would be necessary to take a series of readings over a period of several days at each set of observations. Alternatively, permanent monitoring points could be established and checked daily throughout the year – possibly through remote monitoring.

For a structure with many internal tendons (e.g. a segmental cantilever or spliced I-girder), changes in deflection from a loss of prestress occur slowly over a period of time. Hence, observations should be made at least annually, or, for a structure suspected of suffering loss from corrosion, more frequently – at quarterly intervals. Comparison of results over time, against theoretical estimates can help – along with other evidence – confirm or refute suspicion. However, if corrosion of an internal tendon or group of tendons is localized, and if there is sufficient grout to transmit some bond, the loss of prestress force may be very local. In which cast, the overall change of shape and deflection in may not be very great. Consequently, deflection observations alone cannot furnish conclusive evidence of corrosion.

Structures with external tendons (e.g. span-by-span segmental) would behave in a similar manner. However, with only a few (6 to 8) longitudinal tendons per span, the effect on deflection of the loss of one tendon would be small but may be noticeable by careful measurement – absent other variations due to live load and environmental conditions.

In summary, deflection measurements, taken over time (after creep and shrinkage has ceased) and under stable seasonal conditions, offer a means of monitoring a structure for potential loss of prestress from corrosion. Significant changes would be small and only noticeable over a long period. Therefore it is important to establish base-line elevations and monitor them regularly. Deflection measurements need to be supported by other evidence for loss of prestress due to corrosion.

B.1.3 Importance of records

Visual inspection alone can reveal a great deal about the type of bridge, type of post-tensioning and likely deficiencies to look for. Obviously, visual inspection alone will not necessarily reveal all deficiencies since many tendons are hidden within the concrete. Some deficiencies - such as voids in the grout or corrosion of strands within the ducts or anchorages – may eventually be revealed by evidence of water leaks, stains, or efflorescence. On the other hand, they could remain hidden indefinitely.

Consequently, it is best to have a good visual record of photographs, video, sketches, or physical marks made on the structure for comparison from one inspection to the next. Changes – such as an intensifying rust stain and the appearance or growth of efflorescence – become apparent – so further more detailed inspection and appropriate action can be taken.

In making comparisons from one inspection to another, it is important to know what the structure looked like originally, just after completion. For example, in some cases, when anchorages remained exposed in precast components during storage, rain made rust stains on the concrete. Rust stains may also arise from the use of steel forms. Consequently, all such stains must first be identified and eliminated as evidence of long-term corrosion of any post-tensioning.

If there is doubt, then either photograph (in color) the stains or efflorescence and mark and date their extent on the part of the structure at one inspection and then look for changes at the next. Alternatively, clean off the stains at one inspection and examine the area for any returning evidence at the next. For convenience, possibly leave a sealed copy of the photograph attached close to the location within the structure for quick reference by the next inspection crew.

Also, it is very useful to maintain a good record of bridge deck elevations tracked over time to help identify any potential changes in internal forces that might occur with a loss of prestress caused by corrosion.

B.2 Overview of Non-Invasive Methods

B.2.1 Introduction

The most common non-invasive methods are:

- Covermeter
- Vibration of External Tendons
- Magnetic Flux Exclusion
- Ultrasonic
- Impact Echo
- Electric half-cell
- Acoustic Monitoring
- Vibration monitoring
- Radiography
- Radar
- Thermography
- Electrical Reflectometry

However, non-invasive methods are time consuming and expensive compared to a visual inspection. In any event, intrusive inspection by bore-scope is often needed along with non-invasive inspection to examine the tendons for incomplete grout or corrosion. (There is no way to see corrosion without visual examination with a bore-scope.)

An overview of each of the above non-invasive methods is given below, followed by a comparison on the application and use of the appropriate ones to some various types of bridges and post-tensioning. This sets the background for the use of such methods in the following “Inspection and Assessment” procedures.

B.2.2 Covermeter

A covermeter uses magnetic induction to determine the depth of steel (reinforcing or PT). It can indicate the size or presence of congested steel. It is by far the most useful tool to aid and supplement visual examination.

B.2.3 Vibration (of External Tendons)

In many cases, a typical external tendon drapes from an anchor in a diaphragm at one end of the span to a deviator approximately at the third point, passes horizontally to another similar deviator approximately at the two-thirds point and then rises to anchor in the diaphragm at the other end. Between the diaphragms and deviators, the tendon is external to the concrete and is readily accessible for inspection.

External tendons conveniently lend themselves to vibration analysis. In a manner similar to the tensioned string of a musical instrument, portions of each external tendon between points of attachment has a characteristic natural frequency of vibration that depends upon mass per unit length, the free length, the fixity at each end and the tension force in the tendon. The fixity of the tendon as it passes into steel pipes at deviators and at diaphragms effectively shortens the length that can vibrate freely. The effective fixity and the length free to vibrate can be estimated and verified by observations.

Both the first mode (single mode or fundamental tone) and second mode (2nd overtone) of vibration are measured. The observations are given equal weight and averaged to provide an accurate estimate of the frequency of vibration.

The mass per unit length of the tendon is made up of the mass of the strands, surrounding grout (if any), and external polyethylene pipe. With the exception of the grout, these are accurately known. However, the difference between a fully grouted tendon and an empty tendon, or one that is only partially grouted is known or can be estimated to be within a certain range. The only remaining unknown variable is the tension in the tendon.

In order to improve the accuracy of the observations, vibration measurements are made on each free length of each tendon. If the distance between the diaphragm and deviator at one end (A) a particular tendon is the same as that at the other end (C), then, if the tension is constant, the frequency of vibration should be the same. Any difference in frequency between these two portions indicates a difference in tension. This in turn, indicates a measure of the loss of force in the tendon originally induced by friction in the deviators at the time of stressing. (Tendons are typically stressed only from the leading end as span-by-span erection proceeds)

Taking into account the actual free lengths of each portion of a tendon, measurements of the frequency of vibration can be compared for similar tendons. Knowing that a variation of a few percent is possible depending upon the amount of grout in a tendon – which may or may not be known - analysis of the results provides significant information on the general tension level in each tendon. Observations indicate that results for similar portions of similar tendons should lie within $\pm$ 6% of each other – although a few may range up to $\pm$10%. However, any outside this range, with a lower frequency of vibration, is an indication of a potential problem and a significant loss of force.

The loss of force may be due to a loss of wires or strands to corrosion. Such a tendon should be investigated further for evidence of possible corrosion such as a breach of the pipe, a hole or split that might have opened up an avenue for local corrosion – or any evidence that deviator pipes may have slipped longitudinally through the deviators or diaphragms. This would be a certain indicator of a failed or partially failed tendon.

If there is no such evidence, then the tendons can be checked as they enter the diaphragms by releasing and sliding aside the neoprene boots. If there is no evidence of corrosion or significant strand failure, then the problem may lie in the anchorage and the pipe through the diaphragm. To confirm this requires an invasive borescope examination – either along the tendon from the boot, if possible, or by removing the anchor pour-back and drilling in through the anchor grout port.

Vibration analysis, when properly applied and analyzed can indicate potential problem tendons. It is limited to those portions of external tendons that are readily accessible for monitoring. Some portions of external tendons may not be accessible or may be so close to a web face, top of the bottom slab or be otherwise restricted from free vibration – this depends upon the individual bridge and tendon configuration. A vibration analysis on an isolated tendon, an individual span, or even a single continuous-span unit of structure can, clearly, provide useful information – but an analysis offers more confidence if there are many similar tendons available to measure and compare.

It is possible to perform vibration measurements in a relatively short time with a small, yet skilled and trained team. For example, the entire length (3-1/2 miles) of the Mid-Bay Bridge was examined in about two weeks under emergency conditions with a two 4-man crews working separate shifts around the clock. (There are 141 spans with six tendons per span and three portions per tendon. Some additional effort was expended on cleaning tendons and attaching transducers.) It is believed that such a survey could be done in two to three months of more normal work conditions by a dedicated crew.

Analysis of the results is performed by knowledgeable persons with access to appropriate computer software. Results can be interpreted with some confidence so potentially deficient tendons should be detected.

Vibration analysis is best used in conjunction with other systems in order to confirm the results – such as magnetic flux (below) or the use of invasive examination (removing duct) or borescope of anchors. However, unlike magnetic-flux methods that can only access about 85% of an external tendon, vibration analysis measures the force in the whole tendon – so a failure in an anchorage block may be detected by vibration whereas it would not by magnetic–flux.

Vibration analysis can be used as a screening test to identify tendons that ought to be examined more thoroughly. It offers significant and relatively reliable information for a relatively modest effort and cost.

B.2.4 Magnetic Flux Exclusion

A constant magnetic field is applied to detect the presence of small flaws or fractures as they disturb the field when the field generator and detector device moves along the member. It is suitable for laboratory applications and external tendons (or cable stays) under uniform and controlled conditions. The device runs on rollers along the external duct (pipe) - preferably at a constant distance from the tendon itself.

The smooth outside duct surface of an external tendon is convenient – so the technique is suited to external tendons with smooth pipes. However, once external pipes have been repaired with shrink-wrap material, the surface is irregular and consistent, reliable results may not be possible. In such cases, it may be necessary to fabricate an artificial, smooth, rolling support surface over the wrap using non-magnetic materials.

The technique is very sensitive and capable of detecting small flaws in tendons. It is not suited to internal tendons since the presence of miscellaneous reinforcement and tie-wire significantly affects the field. It is possible to detect local corrosion in an external tendon – for example, a small (holiday) patch of corrosion on three strands was detected under a nail puncture of the external polyethylene pipe on the Mid-Bay Bridge.

The device can run only on the smooth polyethylene pipe between diaphragms and deviators. It cannot run beyond the neoprene boot connecting the polyethylene pipe to the steel pipe. Also, the device itself is a couple of feet long. As a result it is only possible to examine about 85% of the external tendon – and none of it within the concrete. Nevertheless, this is a significant portion of the tendon. Furthermore, it is relatively quick and simple to perform an examination. For example, the entire length (3-1/2 miles) of the Mid-Bay Bridge was examined in about one week under emergency conditions by a single 5-man crew working up to 14 hours per day. (There are 141 spans with eight tendons per span and three portions per tendon).

The main advantage of this technique is the relatively large amount of information provided for a relatively small investment – even though at most, only 85% of an external tendon can be examined. In conjunction with vibration analysis and limited invasive inspection, it is a useful method.

B.2.5 Ultrasonic

The travel time of an ultrasonic pulse through the thickness of a member is measured.
It indicates the relative quality of concrete - the shorter the time, the better concrete.
Alternatively, a delamination (spall), crack or significant void can be detected.

The technique was used successfully on the Edison Bridge (Fort Myers), to check a spall in the web of a post-tensioned bulb-T girder initiated by an oval duct, oriented vertically.

Partially successful attempts have been made to detect fractures in tendons by sending a pulse along the tendon from the anchor. It requires a lot of energy, since much is lost into the surrounding structure, and only fractures within a few feet of the anchor can be detected.

Use of the method appears to be limited to detecting spalls, cracks or similar distinctive defects. It might or might not be able to detect grout voids in internal ducts since the pulse would reflect from the duct (metal or plastic) or a void itself. Application may be limited to detecting distinct defects in the concrete itself.

B.2.6 Impact Echo

Stress waves from the mechanical impact of a small object echo from the opposite side of a member or from the surface of a defect (e.g. spall), or discontinuity of materials, and are collected by two receivers.

This technique can locate defects such as spalls or delaminations, voids and internal cracks. Also, by analysis of return signals, it is possible to determine elastic properties of layers. It is suitable for member thicknesses up to about 6 feet.

It has been used for the survey of voids in the top continuity and cantilever tendons of a few precast segmental bridges in south Florida (I-595). Indications of voids were found and correlated with known leaks at joints between segments and suspected areas of poorly grouted tendons. Impact echo can detect voids, but does not necessarily always return reliable feedback. It estimated to have had a success rate of 30 to 40 % on the above project.

The technique requires partial closing of lanes to traffic for some time to set up and perform the tests on a top slab. The cost is relatively high for the information returned.

B.2.7 Electric Half-Cell

The negative potential is measured between the steel reinforcement and the concrete surface. A large negative potential indicates increasing corrosion. A direct contact has to be established with the reinforcing, so drilling into the cover is usually necessary – i.e. this is invasive and proper repairs are needed.

It facilitates mapping of the corrosion of reinforcement in reinforced concrete elements. Application to existing post-tensioned structures is of doubtful value, because galvanized metal ducts and the presence of reinforcing masks the tendons and it is not possible to determine whether a potential (or current) is via the tendons or rebar. For this reason, electric half-cell is not recommended for monitoring corrosion of post-tensioned tendons.

Nevertheless, the technique was successfully used to map corrosion potentials, correlate them to chloride penetration measurements and enable the anticipated onset of future corrosion to be assessed for possible replacement of the V-piers to the Long Key Bridge in the Florida Keys. A similar technique is being used to monitor and install corrosion suppression systems on other substructures in the very corrosive environment of the Florida Keys.

B.2.8 Acoustic Emission

Most structural materials (steel and concrete) emit tiny sound signals created by the rapid release of energy from local sources produced by cracking or delamination, fracture or fatigue. These microscopically generated sounds can be detected by microphones so sensitive as to pick up the impact of wind-borne grains. Sensors are able to detect signals over long distances, making it possible to monitor a structure by means of network of sensors and to be able to isolate problem areas.

Acoustic emissions have characteristics that can be filtered from background sounds by means of high-powered computerized signal pre- and post-processing. In this way it is possible to, over a period of monitoring, to eliminate environmental background noise – such as traffic – and focus upon the actual structural behavior. Unlike systems such as strain gages that monitor only the surface behavior at the gage location, the sound detected by acoustic systems originate from stress induced effects (micro-cracking) within the body of the structure. A multitude of sensors are needed to monitor a structure – with some installed to help detect and filter out background signals.

Sensors are linked to computer processors that, in turn, enable the structural behavior to be monitored from a remote office location with appropriate security. Furthermore, the technique is non-invasive, involving no damage to the bridge to install the system.

Acoustic emissions are an indication of the internal structural response to overstress at the microscopic scale. However, relating this to an overall state of stress on a larger scale (such as beam behavior) requires further engineering correlation through structural analyses.

Currently acoustic monitoring systems are relatively expensive to install and operate. Outside of the petrochemical, nuclear and similar industries, applications to bridge infrastructure to date have mostly been for long-span cable-stayed, suspension or similar major structures where the investment and benefits are more readily justified.

B.2.9 Vibration Monitoring of Structure

Sensitive accelerometers attached to the structure monitor structural vibrations. The accelerometer contains an inertial mass whose motion is detected by and electrical sensor. Signals are transmitted to computers for processing.

When vibration of the structure is monitored over a long period of time background signals can be filtered and processed to provide characteristic signature of the structure. Vibration characteristics can be compared to those from advanced structural dynamic analysis models to correlate field observations to engineering analyses.

Vibration systems are relatively expensive to install and monitor and require calibration using dynamic structural models.

B.2.10 Radiography

Radioactive source of cobalt or iridium gives off gamma rays. These are detected on a photographic plate on the opposite side of the member from the source. Materials absorb different amounts of gamma rays according to their density. Hence steel rebar, post-tensioning strands and ducts are seen in contrasting shadows on the plate.

Gamma rays flare out from a point source, so there is distortion of the image with distance from the normal to the surface against which the plate is held. Multiple images with the source in different locations can reveal something of the relative 3-D positions of the embedded make-up with careful and skilled interpretation.

Ducts, grout voids and honeycombed concrete can be located. However, it is not possible to detect corrosion unless there is considerable loss of section or many broken strands or wires.

The range is limited to relatively thin concrete sections depending upon the source of the gamma rays and time of exposure. An iridium (192) source is suitable for a thickness up to about 12 inches. Cobalt (60) can reach 2 feet.

High energy X-rays offer an alternative, less hazardous, technique capable of producing good quality images through thickness up to 4 feet in relatively shorter exposure times. The x-rays are produce by a linear accelerator.

Limitations of the method include:

- Must be access to both sides of the member for the equipment
- Interpretation of photographic plates is difficult in areas of congestion

- Also, more than one duct in line from the source makes interpretation difficult
- The source needs to be perpendicular to the plane of the tendons
- Radiation is a minor hazard that needs careful safety precautions
- Only a short length of tendon can be exposed
- Process is expensive

Radiography with gamma rays successfully confirmed discontinuous and displaced ducts inside an 8" web of a spliced AASHTO I-girder bridge near West Palm Beach. Large displacement of the ducts occurred during casting, but was not discovered until tendons could not be installed only after the girders had been erected and the deck slab cast. The approximate location to radiograph was found by probing the ducts from the end anchors so only a couple of exposures were necessary and costs were limited. Supplementary post-tensioning bars were added to augment the capacity so it was not necessary to remove the deck and replace the affected girder.

B.2.11 Ground-Penetrating Radar

Electromagnetic (radio) waves are used to detect differences in materials with different dielectric properties.

The method can locate metal (reinforcement or metal ducts), and may indicate the thickness of elements. However, it cannot penetrate metal ducts. It might detect voids in plastic ducts (there is limited evidence from Canada and the U.K. to support this). However, the detection of ducts is confounded by the presence of reinforcement, so interpretation is difficult in congested areas. Consequently, useful application is of limited value in post-tensioned structures.

B.2.12 Thermography

Thermography measures the small differences in infrared radiation given off in heat signatures of different materials that arise under naturally occurring thermal gradients. It is not sufficiently sensitive to detect voids or corrosion of tendons.

B.2.13 Electrical Reflectometry (Reflectometric Impulse Measurement Test – RIMT)

An electrical signal is sent along a tendon from the anchor. The time of arrival of the reflected pulse is purported to be able to detect flaws in the tendon or voids. However, this has met with little practical success so far.

B.3 Comparison of Non-Invasive and Invasive Methods

The following refer to low to medium technology instrumented non-invasive methods as opposed to visual or, for example, simple manual monitoring of deflections. Also, refer to Table B.1 for an overall summary and comparison of various methods.

B.3.1 Precast Segmental Balanced Cantilever – non-invasive versus invasive methods

Cantilever tendons, internal to the concrete deck slab and face anchored at segment joints are inaccessible for inspection without drilling into the ducts or anchors from the deck. This is invasive and may itself lead to corrosion if the inspection ports are not properly sealed. Nevertheless, it may be the most effective method and may even be necessary to confirm non-invasive inspections, since the latter have limitations.

Non-invasive methods:

- Impact Echo – may indicate voids in internal tendons in the top or bottom slab but the method is expensive and not entirely conclusive.
- Radiography – might reveal a void but cannot reveal corrosion or broken wires
- Ultrasonic – will reveal a spall (delamination) or crack – may not reveal a grout void and cannot reveal corrosion or broken wires.
- Magnetic Flux – not suitable for internal tendons embedded several inches in reinforced concrete
- Vibration – not applicable - only applies to external tendons.

Hence non-invasive methods provide limited information. It may be useful, but may have to be confirmed by invasive inspection anyway.

Invasive inspection (bore-scope):

It is not possible to know for certain the corrosion condition of internal cantilever tendons anchored with embedded face anchors buried under a pour-back in a deck block-out without invasive inspection. However, internal cantilever tendons anchored in blisters and internal continuity tendons (which are always anchored in blisters, ribs or diaphragms inside a box) are accessible for borescope inspection at the anchors.

In order to be able to assess the integrity of the internal tendons in a precast segmental cantilever, sufficient, reliable, inspection is needed to provide confidence in the overall condition. At a minimum, this requires visual inspection. It may require visual inspection and confirmation by bore-scope into selected tendon ducts or anchors. Or, it may require visual inspection with a non-invasive method (impact-echo) backed up by invasive confirmation (by bore-scope).

Occasional invasive inspection using bore-scopes may be necessary as part of an in-depth (major) inspection (say at 6 to 10 year intervals) or if there is visual evidence of corrosion. However, once any corrosion has been detected and repaired (with fully grouted tendons) it is unlikely that further invasive inspection would be needed.

B.3.2 Precast Segmental Span-by-Span – non-invasive versus invasive methods

Most precast segmental span-by-span structures utilize external post-tensioning tendons.

However, some may have internal tendons – for example, where a main-span-unit contains a long main span cantilevered from the side spans. And some may have tendons that drape external to the webs but enter the bottom slab in the middle portion of the span. (Internal tendons should be inspected and assessed as for a precast segmental balanced cantilever.)

In a typical span, external tendons anchor in the diaphragms at the end of each span and drape through deviator blocks (or ribs) at the bottom slab to web intersection.

External tendon ducts can be inspected from within the box. However, the strands themselves cannot be seen without (invasively) removing the ducts or boots connecting the external (plastic) pipes to the steel pipes embedded in the deviators or diaphragms – or by drilling into the ducts. This is destructive and will itself lead to corrosion if not properly restored and sealed.

Non-invasive methods

- Vibration – Measurement of the frequency and comparison of results from several similar tendons, and to theoretical values, offers an indication of the condition – i.e. if there is a substantial grout void (less mass than anticipated) or if some wires or strands have broken (loss of force). This method can provide reliable results and is cost-effective for the information obtained.

- Magnetic flux will detect corroded strands within the free length of a tendon. This limits application to, at most, approximately 85% of the tendon lengths. It is a cost-effective method.

- Radiography – may reveal a grout void or broken strand. Images are not clear and are difficult to interpret. Many images would be needed to cover the length of a tendon.

Invasive inspection (bore-scope)

Anchors of an external tendon are usually accessible for inspection by bore-scope – although it may require removal of a pour-back to do so. If there is visual evidence of deterioration since the last inspection, then such further investigation may be warranted.

If external PT ducts (plastic pipes) have split or holes then, prior to repair, it may be possible to insert a bore-scope and check the condition of the grout and strand at those locations.

A combination of visual inspection and invasive inspection (bore-scope) at selected locations may suffice to assess the condition of the tendons. When further information is needed, a ***vibration*** analysis is effective in revealing incomplete or loss of force due to failure of wires from corrosion and ***magnetic flux*** can detect corrosion or failures in the free length of a tendon. The latter methods are effective and appropriate for major inspections.

B.3.3 Spliced I-Girder – non-invasive versus invasive methods

All tendons are internal to the webs of the girders. In many cases anchors are embedded in the ends and covered by a pour-back that makes them inaccessible from the expansion joint diaphragm – or they are in the top of the girder under a pour-back or secondary pour in the deck slab. In all cases, anchors are inaccessible without removal of pour-backs or structural concrete.

Non-invasive methods:

- Impact Echo – might detect voids but the technique is not really suited to girders
- Radiography – might reveal a grout void or broken wires in the thin part of the web - but not in the thick parts of the end blocks or flanges
- Ultrasonic – will reveal a spall (delamination) or crack – not likely to reveal a grout void – and cannot reveal corrosion or broken wires

- Magnetic Flux – has limited range and is not very suitable for internal tendons – observations are affected by reinforcement
- Vibration – not applicable

Invasive inspection (bore-scope)

Invasive inspection is effective when and where there is a suspected defect, grout void or honeycomb. Drilling into the concrete either into the duct or the anchor cone (trumpet) is unavoidable and must be properly repaired and sealed. Inspection of anchors may be possible from the side, entering the anchor cone within the end block if it is possible to avoid the anchor reinforcing.

Invasive inspection of the ducts and anchors may be appropriate for a major inspection or would be suitable when there is visual evidence of grout voids or corrosion.

B.3.4 Cast-in-Place Segmental Cantilever – non-invasive versus invasive methods

The methods of inspection are the same as for a precast segmental cantilever with internal tendons. If there are external tendons, then approach is as for a precast segmental span-by-span structure with external tendons

B.3.5 Cellular Box Cast-in-Place on Falsework – non-invasive versus invasive methods

The methods of inspection are the same as for a precast segmental cantilever with internal tendons. If there are external tendons, then approach is as for a precast segmental span-by-span structure with external tendons.

B.3.6 Slabs and Voided Slabs – non-invasive versus invasive methods

With internal tendons and inaccessible anchors, the methods of inspection are the same as for a spliced I-girder with internal tendons.

B.4 Conclusions

Appropriate inspection methods depend on whether the tendon is internal or external and if the anchor is readily accessible or not for inspection. Although only the needs of superstructures are considered above, the same applies for transversely post-tensioned superstructures and for post-tensioned substructures.

From the foregoing considerations, for cost-effectiveness and simplicity of approach to inspection the following priorities are adopted in this Volume:

- First - visual inspection
- Second - visual inspection with bore-scope examination (as needed or selected)
- Third - visual inspection with an appropriate non-invasive method confirmed by bore-scope at selected locations.

In general, “Inspection and Assessment Procedures” are based on the first two – recognizing that any inspection using non-invasive methods is special and would be part of a major inspection or “as-needed” investigation.

B.5 References

Corven, J.A., “Mid-Bay Bridge Post-Tensioning Evaluation,” Florida Department of Transportation Report, Corven Engineering, Inc., Tallahassee, Florida, 2001.

Anglo-French Liaison Report, “Post-Tensioned Concrete Bridges/ Ponts en Beton Precontraint par Post-Tension,” Highways Agency, Service d’Etudes Techniques des Routes et Autoroutes, Transport Research Laboratory, and Laboratoire des Ponts et Chaussees, Thomas Telford Publishing, London, 1999.

Davis, A.G., “Nondestructive Evaluation Helps Maintain Concrete Structures,” Structure Magazine, September 2001.

TABLE B.1 Invasive and Non-Invasive Examination and Evaluation Methods

INVESTIGATION METHODS INVASIVE AND NON-INVASIVE ? = reliable technique n/a = not applicable or not able **Technique**	**Principle / Means or Method**	**INV**	**NON**	Able to provide information for **Internal Tendon** Grout Voids	Location of Tendon	Corrosion of Internal Tendon	Fracture of Wires or Strands	Loss of Force in Tendon	Able to provide information for **External Tendon** Grout Voids	Location of Tendon	Corrosion of External Tendon	Fracture of Wires or Strands	Loss of Force in Tendon	Able to detect defects in concrete Spalls, (Delam's) Cracks	Voids or Honey-combing	Able to sense active corrosion	Approx effective range / thickness of conc member	Relative Costs $ = routine = 1 $$ = low = 2 $$$ = mod = 3 $$$$ = high = 4 ? = no info = 5		SUBJECTIVE Relative Value* of Info re: PT high = 3 good = 2 low = 1 n/a = 0		Relative Value of Info/Cost (higher is better) highest is 3.00	SUBJECTIVE Relative Ratio of Value to Cost highest is 1.00	
LOW TECH																								
Visual																								
Visual - seek (surface) symptoms for diagnosis			?	symptoms	indirect	symptoms	no	no	symptoms	obvious	symptoms	(maybe)	no	?	?	maybe	surface	$	1	high	3	3.00	1.00	
Invasive Visual																								
Open external ducts	Manual or Borescope	?		n/a	n/a	n/a	n/a	n/a	?	n/a	?	?	n/a	n/a	n/a	?	surface	$$	2	high	3	1.50	0.50	
Drill or core into int'l ducts	Manual + Borescope	?		?	?	?	?	(inferred)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	inches	$$	2	high	3	1.50	0.50	
Drill into anchors	Manual + Borescope	?		?	?	?	?	(inferred)	?	n/a	?	?	n/a	n/a	n/a	?	inches	$$	2	high	3	1.50	0.50	
Extract grout sample and analyze chemistry		?		?	n/a	(inferred)	n/a	n/a	?	n/a	(inferred)	n/a	n/a	n/a	n/a	maybe	inches	$$	2	high	3	1.50	0.50	
Extract core in concrete or at epoxy joint		?		(maybe)	?	(inferred)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?	maybe	inches	$$	2	high	3	1.50	0.50	
Deflections	Manual		?	n/a	n/a	(inferred)	(inferred)	(inferred)	n/a	n/a	(inferred)	(inferred)	(indirect)	n/a	n/a	n/a	n/a	$	1	good	2	2.00	0.67	
Cover Meter	Magnetic / Manual		?	n/a	(maybe)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	inches	$	1	good	2	2.00	0.67	
MEDIUM TECH																								
Vibration of Tendon	Transducer		?	n/a	n/a	n/a	n/a	n/a	(inferred)	n/a	(inferred)	(inferred)	?	n/a	n/a	(inferred)	n/a	$$	2	high	3	1.50	0.50	**
Magnetic Flux	Magnetic Field Effect		?	n/a	n/a	(maybe)	(maybe)	(inferred)	no	n/a	?	?	n/a	n/a	n/a	no	inches	$$	2	high	3	1.50	0.50	**
Ultrasonic																								
Through concrete	Speed of sonic pulse		?	(maybe)	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?	no	inches	$$	2	good	2	1.00	0.33	
Along tendon	Speed of sonic pulse	?		n/a	n/a	(maybe)	?	(inferred)	n/a	n/a	(maybe)	?	(inferred)	n/a	n/a	(inferred)	a few feet	$$$	3	high	3	1.00	0.33	***
Impact-Echo	Reflected sound of mechanical impact		?	(some)	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	?	?	no	< 6 ft	$$$	3	high	3	1.00	0.33	***
Electric Half-Cell	Electrical potential between locations	?		n/a	n/a	(rebar/PT)	n/a	n/a	n/a	n/a	(rebar/PT)	n/a	n/a	n/a	n/a	?	surface	$$	2	good	2	1.00	0.33	
HIGH TECH																								
Acoustic Emission	Sound created by structural effects		?	n/a	(maybe)	(maybe)	?	n/a	n/a	n/a	(maybe)	?	n/a	?	no	(maybe)	unlimited	$$$	3	good	2	0.67	0.22	
Vibration Monitoring	Structural vibrations monitored		?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	(inferred)	structure	$$$$	4	low	1	0.25	0.08	
Radiography	Gamma rays or X-rays		?	?	?	n/a	(maybe)	n/a	?	n/a	(maybe)	?	(inferred)	(maybe)	?	no	< 2 ft	$$$$	4	good	2	0.50	0.17	
Radar (Ground-Penetrating)	Electromagnetic (radio) waves		?	n/a	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	limited	$$$$	4	low	1	0.25	0.08	
Thermography	Infra-red radiation from natural effects		?	n/a	(maybe)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no	limited	?	5	n/a	0	0.00	0.00	
Electrical Reflectometry	Timed reflected of electrical pulse	?		n/a	n/a	(not yet)	(maybe)	n/a	n/a	n/a	(not yet)	(maybe)	n/a	n/a	n/a	no	limited	?	5	low	1	0.20	0.07	

*** value is reliability of and confidence in results**
**** External PT only** ***** Internal PT only**

Appendix C - Definitions

Definitions used in this and subsequent Volumes pertaining to increased durability of post-tensioned bridges are in accordance with the AASHTO *Standard Specifications for Highway Bridges*, the AASHTO *Guide Specifications for Design and Construction of Segmental Concrete Bridges*, and the Post –Tensioning Institute *Specification for Grouting of Post-Tensioned Structures*. Additional definitions not in these referenced documents are given in the following sections.

C.1 Post-Tensioning Systems

Anchorage: An assembly of various hardware components that secure a tendon at its ends after it has been stressed and imparts the tendon force into the concrete.

Anchor plate: That part of the anchorage hardware that bears directly on the concrete and through which the tendon force is transmitted to the structure.

Bar: Post-tensioning bars are high strength steel bars, normally available from 5/8-inch to 1 3/4-inch diameter and usually threaded with very coarse thread.

Coupler: The means by which the prestressing force may be transmitted from one partial-length prestressing tendon to another.

Post-Tensioning: The application of a compressive force to the concrete by stressing tendons or bars after the concrete has been cast and cured. The force in the stressed tendons or bars is transferred to the concrete by means of anchorages.

Post-Tensioning Scheme or Layout: The pattern, size and locations of post-tensioning tendons provided by the Designer on the Contract Plans.

Post-Tensioning System: A proprietary system where the necessary hardware (anchorages, wedges, strands, bars, couplers, etc.) is supplied by a particular manufacturer or manufacturers of post-tensioning components.

Strand: An assembly of several high strength steel wires wound together. Strands usually have six outer wires wound in long-pitch helix around a single straight wire of a similar diameter.

Tendon: A single or group of prestressing elements and their anchorage assemblies, which impart a compressive force to a structural member. Also included are ducts, grouting attachments and grout. The main prestressing element is usually a high strength steel member made up of a number of strands, wires or bars.

Wedge: Small conically shaped steel components placed around a strand to grip and secure it by wedge action in a tapered hole through a wedge plate. (FDOT requires 3-part wedges).

Wedge Plate: A circular steel component of the anchorage containing a number of tapered holes through which the strands pass and are secured by conical wedges.

Wire: A single, small diameter, high strength steel member and, typically, the basic component of strand.

C.2 Grout Related Definitions

Contamination: Any foreign material found in a tendon at any point in time, the effects of which, if not negated could lead to a lessening of effectiveness of the tendon.

Cavitation: Air trapped during the grouting process through an irregular flow of grout through the duct. Cavitation can occur when grouts are injected from high points in the tendon profile or through a combination of grouting rate and the workability of the material, where the grout does not completely fill the duct, trapping air as it moves to the low point.

Recharge: The ability of water, outside of the post-tensioning tendon, to migrate through some path and enter the tendon, usually, through the anchorage or at a breach in the duct.

C.3 Continuous and Spliced I-Girders

Camber: The amount by which a precast beam deflects under the action of its own self-weight and the pretensioning applied at the plant and post-tensioning applied on site. (This is technically different to "camber" in the context of segmental construction).

Dapped hinge: A point where the end of one beam or box girder is supported by another by a simple bearing resting upon a seat or step formed by extending the bottom half of the support beam under the top half of the supported beam.

Splice: A cast-in-place connection between the end of one precast I-girder and another. A splice may be short and unreinforced or long and contain reinforcing. Usually, longitudinal post-tensioning is made to pass through a splice between I-girders. A splice of this type makes the beams structurally continuous – as opposed to being able to rotate separately as at dapped hinges.

C.4 Segmental Bridges

Balanced Cantilever (Erection): A method whereby the segments are sequentially erected, in cantilever, alternately on either side of the pier to a point where a closure is cast in place with an adjacent span or cantilever.

Camber: The amount by which the concrete profile at the time of casting must differ from the theoretical geometric profile grade in order to compensate for all structural dead load, post-tensioning, all long-term, time dependent deformations (creep and shrinkage) including all the intermediate erection stages and effects. (The opposite of deflections.)

Casting Cell: Refers to a special formwork arrangement usually consisting of a fixed vertical bulkhead of the cross-section shape at one end and adjustable soffit, side and cores form all designed and assembled into a machine for making a single superstructure segment. A casting cell for a substructure pier shaft segment would consist of exterior and interior side forms and a soffit form that has the cross-section shape.

Casting Curve or Casting Curve Geometry: the curve of casting geometry that has to be followed in the casting cell or bed in order to achieve the theoretical bridge profile and alignment after all the final structural and time dependent (creep and shrinkage) deformations have taken place. The casting curve is a combination of the theoretical bridge geometrical profile grade, alignment and the camber.

Closure Joint: A cast-in-place concrete joint between precast segments used to complete a span.

Deviation Segment: A precast segment within a span that contains a block, rib, or diaphragm for the purpose of deviating (deflecting or changing the path of) an external post-tensioning tendon.

Dry Joint: Where epoxy is not applied between the match cast surfaces of adjacent precast segments during erection. (Dry joints are not allowed in Florida).

Epoxied Joints: Where epoxy is applied to the match cast surfaces of adjacent precast segments before assembling into the final structure.

Erection Elevation: the elevation to which a segment is to be set in the structure at the time it is erected. (This is not necessarily the profile grade but rather the profile grade corrected by the amount of deflection calculated to occur from that stage onwards, at that location.)

Expansion Joint (EJ) Segment: An end segment of the superstructure that rests upon a bearing at an abutment or intermediate expansion pier and that carries a block-out to receive the expansion joint device (finger joint, modular joint, etc.)

Form Traveler: Specialized erection equipment used to erect cast-in-place balanced cantilever bridges comprised of wing, soffit and core forms and supporting trusses. The specialized equipment rests on previously completed portions of bridge superstructure while concrete of the next cast-in-place segment is poured.

Long Line Casting: A method of casting segments on a casting bed of sufficient length to permit the cumulative casting of segments for the entire length of a span or cantilever between field closure pours without repositioning the segments on the casting bed. With this method, the first segment is cast between bulkheads and successive segments are cast between a movable bulkhead on one end and the previously cast segment on the other.

Match Cast: Refers to a precast concrete fabrication process whereby a segment is cast against the preceding segment producing a matching interface that will permit the reestablishment of the cast geometry at the time of erection. Match casting may be accomplished by either the short line or long line casting method.

Modified Cantilever (Erection): A method whereby segments are erected in cantilever from the end of a span previously erected using the span-by-span method.

Pier Segment: That segment of the superstructure resting atop a substructure pier, column or support.

Pier Table: In precast cantilever construction, usually the pier segment and first one or two segments on each side of the pier that are used to provide a beginning platform and accommodate the temporary stability system for the erection of the remainder of the balanced cantilever. In cast-in-place cantilever construction, it is that portion of the structure over the pier, usually 24 to 40 feet long, completed first using formwork; it is then the platform from which form travelers advance to complete other typical cantilever segments.

Progressive Cantilever (Erection) A method whereby segments are erected progressively in cantilever, in one direction, using intermediate temporary or permanent piers or other means, as required, to support the advancing cantilever.

Segment: Refers to a modular section of the superstructure and/or substructure consisting of a certain cross-section shape and length as detailed on the plans.

Short Line Casting: A method of casting segments one at a time in a casting cell between a bulkhead at one end and a previously cast segment at the other. The first segment is cast between the bulkhead and another temporary bulkhead.

Span-by-Span (Erection): A method whereby the segments for one complete span are sequentially erected by aligning them on a support frame, such as a truss, until one or more closures are cast in place. Closures are usually made between the end segments in the span and the adjacent pier or expansion joint segments.