PTI Level 1&2 Multistrand and Grouted PT Inspector Certification Workshop

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1. GENERAL

1.1 Purpose of Training

Learning Objectives

The Multistrand and Grouted PT Inspector (Inspector) should be familiar with the PT materials commonly used in multistrand and grouted post-tensioning (PT), including common definitions, general installation techniques, and the critical inspection criteria to ensure a safe and efficient execution of the PT work. The final work product should meet all project specification requirements for the performance and durability of the work. The items listed here are considered the minimum necessary knowledge to provide a reliable inspection.

Post-Tensioning Specialty - Special Training

Post-Tensioning – Unique Construction Technique

Post-tensioning is a construction technique that most inspectors do not work with on a continuing basis. At the same time, PT introduces active forces into the members and requires more rigorous consideration in all steps of construction and inspection. Additional training is required for inspectors to become proficient in PT and to accomplish the inspection goals.

Post-Tensioning - Special Materials

High strength materials are used for post-tensioning that applies high forces on the structural members. These materials require:

- Special certification documentation and/or job specific acceptance testing
- Inspection and documentation when received at storage location or at the jobsite
- Special handling and storage to prevent deterioration
- Tracking of installation location by lot numbers
- Proper Installation and preparation

The inspector should be aware of the basic properties of materials used, their variations, and how to tell if materials are acceptable. He/she needs to be aware of all typical components used in PT systems. This information is part of the PTI Level 1&2 Multistrand and Grouted PT Specialist Certification Program. A review of those materials, properties, and testing is strongly recommended. Testing of materials on site is covered, including the test methods for different materials including frequencies and acceptance criteria. What documents on materials need to be inspected and if field testing is necessary. Effects of materials on durability of the PT system are discussed. The Tendon Protection Levels (PLs) are introduced to allow for proper determination of the exposure and the necessary materials to ensure the desired design life of the structure. An important aspect of the operation with respect to material is maintaining traceability of the components, so that in the event a non-conformance is discovered, the potential affected areas can be identified and resolved.

The necessary documentation of materials and components including acceptance guidelines are provided in this document.
Multi-Faceted / Phased Installation

The installation of PT interacts with other work activities and needs to be closely coordinated with other work. Locating post-tensioning reinforcement at the specified position is critical, as it affects the structural members with PT applied forces. Interference with nonprestressed reinforcement and other embedments must be identified and remedied, with prompt input from the LDP to determine precedence. A tendon placed at a wrong location can cause severe damage to the member.

- This requires verification at multiple critical points (hold points) beyond which quality issues would be very difficult or impossible to correct.
- It is important that the field inspector knows what the acceptance criteria are for different installation steps, so they can allow work to proceed without approvals of office staff, but also to know when to halt work. This is a crucial responsibility of the inspector.
- All of the aspects of the installation are critical and each integral to the initial quality and long-term performance. Often several of the installation phases are performed by different crews on a given project. For example, the duct and anchor placement, may be performed by a different crew than the strand install and stressing and yet another crew for the grouting. It is important for each crew to understand the proper installation procedures and impact on the overall quality.

Understanding of installation methods and procedures for anchorages, duct, strand and bar is assumed to have been gained from the PTI Level 1&2 Multistrand and Grouted PT Specialist class. This PTI Multistrand and Grouted PT Inspector workshop provides the necessary inspection points, tolerances, and acceptance criteria that supplement the acquired knowledge from the PTI Multistrand and Grouted PT Specialist Certification class. It is recommended to review the installation methods to better understand the inspection points. Key points, however, to be inspected related to the installation are provided in this document.

Variation in Post-Tensioning Plans and Specifications

The PT requirements and contract documents can be very different between jurisdictions and individual projects. The inspector must review the contract and construction documents to understand specific project requirements. To navigate these differences, a solid knowledge of the PT Systems, materials, installation techniques, and the different requirements becomes indispensable.

- PTI/ASBI M50.3 Specification for Multistrand and Grouted Post-Tensioning has not yet been universally adopted. The next edition will be published in 2019 and will include a commentary with additional information explaining the mandatory provisions. It has been renamed from Guide Specification for Grouted Post-Tensioning to better describe the scope.
- PTI M55.1 Specification for Grouting of Post-Tensioned Structures is in wider use but has also not yet been universally adopted. The next edition will also be published in 2019 and will include several significant changes in grout field testing.
- Specifications vary according to environmental conditions, local practice, but also subjective and technically unfounded differences.
- Design build projects many times have different standards
- It is good practice to review the specifications as early in the project as practical to identify any potential conflicts with current best practice, so they can be addressed by the project team.
Special Math and Measurement Skills

Post-tensioning inspection requires specialized math and measurement skills, knowledge of units of measurement, and sometimes navigate mixed units specified in Contract Documents. These skills are required to accomplish the following tasks:

- Verify duct placement is within tolerance
- Understand and perform or verify special stressing force and hydraulic gauge pressure calculations
- Verify elongation measurements and record the results of the stressing operation, and compare the measured elongations to the elongation calculations for acceptance
- Verify anchor set losses are acceptable
- Determine actual and theoretical grout volumes, verify grouting pressures, and verify pumping rates.

Stressing Equipment, Procedures, and Safety Precautions

The understanding of PT stressing equipment and procedures are assumed from the PTI Level 1&2 Multistrand and Grouted PT Specialist class. This PTI Multistrand and Grouted PT Inspector workshop will focus on the proper documentation of concrete strength, equipment calibration, safety measures, and proper recording for elongation documentation and the related items will be expanded upon in this document. An understanding of the elongation significance, elongation calculations, effects of installation on elongation, and acceptance criteria will be further addressed, including proper measurements, recording and reporting. The elongation interpretation and reconciliation will also be discussed as this is an important hold point in the post-tensioning operation.

Post-tensioning inspection during stressing operations requires knowledge of special safety precautions to avoid injury and material damage. Stressing of a post-tensioning tendon is a life safety issue and needs to be treated with the due respect. This is particularly important as the PT forces are very high although they are not visible without instrumentation. While stressing safety is often focused on within a project, it is important to note there are possible hazards associated with all of the operations in post-tensioning (i.e. installation, grouting, etc.) and they should all be properly planned for as well. Education on the proper procedures and proper equipment operation is a key component of successful and safe execution.

The following items and common sense should be diligently assessed before the start of the stressing operations.

- Ensure concrete strength and consolidation are adequate
- Verify that stressing equipment and lifting devices are adequate
- Ensure unqualified personnel and other trades are not in the stressing area

Grouting Equipment, Procedures – A Durability Factor

Grouting is very important for the durability of the tendons and thus the structure itself. Understanding the grout plant operation and the grouting procedures is assumed from the PTI Level 1&2 Multistrand and Grouted PT Specialist class. This PTI Multistrand and Grouted PT Inspector workshop will address
the grout material documentation, field testing, grout logs / operation documentation, and acceptance
criteria. The grouting procedure including contingency plans will be reviewed following a sample Grout
Plan.

The long-term durability of the PT System is especially important as a repair of bonded (grouted) post-
tensioning is very difficult and sometimes impossible. These considerations can help ensure a smooth
and proper grouting operation:

- The inspector needs to be familiar with mixing and installation procedures, specialized material
testing procedures and post-grout acceptance testing.
- The inspector needs to be familiar with common issues encountered during grouting and what steps
are appropriate and or not allowed if something doesn’t go according to the Grout Plan.
- Documentation of any potential issues and prompt remediation is critical to the long-term
performance of the post-tensioning. Since any potential issues are within the concrete and often
not externally evident, it is important that any issues encountered during the operation are
escalated to the appropriate level for remediation.

**Inspection Items and Checklists**

For each part of the process, inspection points with acceptance criteria will be presented together with
checklist.

The goal of the inspection is to verify compliance with specifications. This can only be achieved when the
inspector is knowledgeable in the principles of PT, the materials used, and the installation and grouting
techniques used. Inspection is guided by specified tolerances that are designed to allow for reasonable
construction tolerances.

**Past Industry Experience**

**Multistrand Grouted Tendon Track Record**

The vast majority of grouted post-tensioning has been providing primary reinforcement for thousands of
bridges as designed. This is important to keep in perspective; it shows that grouting of tendons can be
accomplished successfully in the field and that post-tensioning tendons have the capacity and life span
to accomplish design goals.

However, even isolated instances of failed tendons due to premature corrosion are totally unacceptable
for a reinforcement system that offers so many advantages and is, in fact, the only reinforcement type
available for many significant bridges.

**Issues Identified in the Past**

As presented in the Field Specialist Training class, there have been some issues associated with the
materials and workmanship of grouted PT in the past. The consequences have been significant on the
industry. For example, this led to a moratorium on bonded PT in the UK in the 1990s and caused several
bridges particularly in Florida to require repairs sooner than would be anticipated. Issues identified
included:
• Some tendons were left ungrouted (completely or partially)
• Some tendons had voids caused by bleed or trapped air pockets that allowed for accumulation of contaminants and led to corrosion
• Grout vents were omitted, and other mistakes made, clearly showing that competent inspection was missing, encouraging less than diligent attention to detail during crucial operations.
• One particular brand of prepackaged grout contained a chloride ion content significantly above the specification limit and was undetected for several years. The manufacturer of this prepackaged material was required by specifications to limit the chloride content, but they failed to do testing that would have detected it. This is totally unacceptable and illustrated a weakness in the system and over-reliance on the supplier’s quality control. The specification has since been changed to require redundant testing to avoid a widespread issue occurring again. High chloride ion content can lead to corrosion; in this case, luckily, it was shown by lab testing that the threshold for corrosion onset would have to be even higher than the chloride ion content found in that grout. (An FHWA Special Study: Post-Tensioning Tendon Grout Chloride Thresholds, PUBLICATION NO. FHWA-HRT-14-039 MAY 2014).
• Particularly one prepackaged grout, but also some others, were susceptible to the incidence of what has been identified as “soft grout”. As a result, the grouting specification was adjusted to address and prevent some of these issues and to avoid their reoccurrence. The main measures were the prohibition of aggregates and fillers in the prepackaged grouts and a more rigorous consideration of the water content during production, with more prequalification and production testing of the prepackaged grouts and also revision to the storage requirements.
• Underweight bags were discovered, some as much as 10% less than the stated weight. This also is totally unacceptable and illegal; sporadic checks are necessary and if the manufacturer fails to provide the stated quantities, the materials should be rejected. This will help reduce such occurrences in the future.

Present Challenges

The grout mixture is sensitive to the water content, mixing time and method, temperature, humidity, grouting pressure and speed, tendon arrangement including length, vertical head, and venting. It is important that the grout is prequalified and any time there is a change in the mix design, the manufacturer re-qualifies the grout. There is no one all-encompassing production test that would reliably confirm adequacy of the grout mix on site, however, the dosing of water is extremely important and with an adequate material and proper procedures, the dosing of the water becomes the key variable to control and test through the operation. Refer to the PTI Level 1&2 Multistrand and Grouted PT Specialist workshop materials for additional information and the latest PTI M55.1, Specification for Grouting of Post-Tensioned Structures.

Current Inspection Practices

Inspector Qualifications

Inspector qualifications may vary from jurisdiction to another significantly. Some inspectors have the PTI Level 1&2 Multistrand and Grouted PT Specialist training and other concrete construction experience.
Some others have no prior PT experience. This poses a risk that crucial factors will be missed, and the durability of the PT System will be compromised.

**Inspector Training**

Many inspectors have some inspector training related to the concrete field (ACI, ICC, NICET, or similar). Not all jurisdictions have training requirements. These are certainly beneficial, however, not a current requirement for the post-tensioning inspector.

**Field Workmanship Issues**

Post-tensioning is an installation sensitive method. The principle that not only the correct materials but also the right and competent workmanship are required for a successful job is particularly true for PT. Many issues with PT durability can be directly traced to poor workmanship and lack of competent inspection.

**Desired Inspection Practices**

**Inspector Knowledge**

The goal is to have inspectors who have knowledge of general inspection practices along with the specific items relating to post-tensioning:

- PT training to know the principles of post-tensioning; how it works, what are the materials, how is it installed, stressed, grouted, etc.
- Training that pulls together the inspection principles and the relevant inspection items from the PT point of view – this is the task of this PTI Multistrand and Grouted PT Inspector training workshop.

**Inspector Competence / Experience**

As in any job, competence increases with experience. Some minimum inspection experience should be required so that the inspector already knows what to look for and can fall back to previous experiences. Post-tensioning is complex, and some experience is necessary to quickly recognize what is relevant and what is not. The requirements are outlined in the next sections.

**Inspection Outcome**

PT installers should be trained to check materials as they are received and then to check their own work as it is installed, without relying on others to catch their mistakes. The inspection needs to ensure that no mistake goes uncovered. This is not only related to mistakes leading to concrete blowouts or other immediately demonstrated shortcomings. It should also focus on long term durability issues so that the PT Systems perform as designed over the life span of the structure. Some of the key items to ensure durability / avoid issues are:

- Number of tendons, tendon sizes, tendon geometry
- Stressing sequence, jacking forces, elongations
- Grout materials, storage, mixing, pumping, and production testing
• Temporary corrosion protection during construction
• Timing and Installation of permanent corrosion protection measures and finishing operations
1.2 Certification

Prerequisites

Before attending the PTI Level 1&2 Multistrand and Grouted PT Inspector certification workshop, the following prerequisites are required or recommended as stated below:

- **Education** – Minimum High School Diploma level or equivalent is required as inspectors need to perform some calculations during inspections and solve problems.

- **Training as Inspector** – Construction related inspector certification is strongly recommended, however, not currently required. Such inspector certification is available through ACI, ICC, NICET, and similar. An attendance certificate from a formal inspector training class will also document such training.

- **Experience as Construction Inspector** – Minimum 2 years of relevant concrete construction inspection experience is strongly recommended, however, not currently required.

- **PTI Level 1 Multistrand and Grouted PT Installation Certification** – A current PTI Level 1 Multistrand and Grouted PT Installation (previously Bonded PT Field Installation) certification is required. It is necessary for exposure to all steps of installation, stressing, and grouting of multistrand PT tendons. Or,

- **PTI Level 2 Multistrand and Grouted PT Specialist Certification** – A current PTI Level 1 Multistrand and Grouted PT Specialist (previously Bonded PT Field Specialist) certification is required.

Certification Requirements

To obtain PTI Level 1 or Level 2 Multistrand and Grouted PT Inspector certification, the following requirements must be fulfilled for the two available levels:

**PTI Level 1 Multistrand and Grouted PT Inspector:**

- Prerequisites as outlined above (Min. Level 1 Multistrand and Grouted PT Installation Certification)
- Attendance of PTI Level 1&2 Multistrand and Grouted PT Inspector Certification Workshop
- PTI Level 1&2 Multistrand and Grouted PT Inspector exam score: 80% or higher

**PTI Level 2 Multistrand and Grouted PT Inspector:**

- Prerequisites as outlined above (Min. Level 1 Multistrand and Grouted PT Installation Certification)
- Attendance of PTI Level 1&2 Multistrand and Grouted PT Inspector Certification Workshop
- PTI Level 1&2 Multistrand and Grouted PT Inspector exam score: 80% or higher
- Field work experience of a minimum of 500 hours total, with a minimum of 100 hours of installation, 100 hours of stressing, and 100 hours of grouting inspections (Affidavit with 2 verifiers)
Validity of Certification

The certification validity is four years, after which it needs to be renewed. Without renewal, the certification expires on the date shown on the certification card.

Certification Renewal Requirements

The certification can be renewed for another period of four years starting three (3) months before and ending three (3) months after the expiration date on the certification card. The steps to renew the certification are:

- Register with PTI
- Online webinar with specification updates and quiz to proof viewing of webinar
- Online exam; minimum passing score: 80%
- Continuing field work inspection experience in last 4 years: 200 hours of PT inspection (Affidavit with 2 verifiers)

1.3 Scope

Project Types

Multistrand and Grouted PT

Multistrand and grouted post-tensioning is used on many types of projects. This training focuses on the most common application of multistrand and grouted tendons for bridges. It is, however, also applicable to other uses of multistrand and grouted PT. The different types or applications are listed here:

- Cast-in-Place Bridges – Typically cast-in-place concrete bridges constructed on falsework with internal multistrand grouted PT.
• **Segmental Bridges** – Precast or cast-in-place concreted bridges constructed by the balanced cantilever or span-by-span methods, with internal multistrand bonded PT and external PT that is typically grouted, or filled with flexible fillers, and with flat duct bonded transverse PT.

• **Spliced Girders** – Precast girders of different shapes that are post-tensioned with internal multistrand grouted PT for continuity.

• **Buildings** – Typically, multistrand grouted PT transfer girders or transfer plates. Other applications use flat duct PT for two-way slabs or multistrand PT in beams and/or flat duct PT in one-way slabs.

• **Environmental Structures** – Multistrand grouted PT in all kinds of containment structures, silos, etc.

• **Other Structures** – Rock and soil anchors consist of multistrand or bar PT with bond length and a free length, and special systems for capacity testing and corrosion protection.

**Post-Tensioning Systems (PTS)**

**Multistrand and Grouted PT Systems**

• **Multistrand Tendons** – Multistrand tendons consist of one or more strands in a duct that are typically grouted or filled with a flexible filler after stressing. The strand material is 270 KSI, ASTM A416. Individual strands are typically 0.5 or 0.6 in. diameter. Typical tendon sizes are:
  o 7, 12, 19, 31 strand systems in round ducts
  o 4 or 5 strand systems in flat ducts

• **Bar Tendons** – Bar tendons consist of typically 1 bar in a duct, and grouted. The bar material is 150 KSI, ASTM A722. Typical bar sizes are:
  o Coarse thread: 1, 1-1/4, 1-3/8, 1-3/4, 2-1/2, 3 in. nominal diameter.
  o Fine thread: 1, 1-1/4, 1-3/8, 1-3/4, 2-1/4, 2-1/2, 3 in. nominal diameter.
• **Unbonded Tendons** – Multistrand tendons that are ungrouted or filled with flexible fillers, or external tendons (grouted or filled with flexible fillers and placed outside of the member cross section) are considered unbonded tendons. Unbonded single strand tendons that are coated with PT coating and sheathed with extruded plastic sheathing are excluded from the considerations of this document and training. Contact PTI for documents covering unbonded single strand tendons and for certification programs covering those tendons, typically used for buildings.

• **Cable Stays** – Cable stays are a special type of multistrand tendons used for typically large bridges as external stays. They are excluded from the considerations of this document and training. Contact PTI for documents covering cable stays.

### 1.4 Definitions

**Additive** – A general term for a material that may be used as an addition to cementitious grout.

**Admixture** – A material, usually a liquid or powder, that is used as an ingredient of the cementitious grout and is added immediately before or during mixing.

**Admixture, water-reducing** – An admixture that either increases the fluidity of freshly mixed grout without increasing the water content or that maintains the fluidity with reduced amount of water due to factors other than air entrainment.

**Anchorage assembly** – Mechanical device comprising all components required to anchor the prestressing steel and permanently transfer the post-tensioning force from the prestressing steel to the concrete.

**Anchor nut** – The threaded device that screws onto a threaded bar and transfers the force from the bar to the bearing plate.

**Anchor set** – The expected movement of the wedge into the wedge plate or nut into the bearing plate during the transfer of the prestressing force to the anchorage assembly.
Bar – Bars used in post-tensioning tendons conform to ASTM A722, Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete. Bars have a minimum ultimate tensile strength of 150,000 psi (1035 MPa). A Type 1 bar has a plain surface and a Type 2 bar has surface deformations.

Bearing plate – Any hardware that transfers the tendon force into the structure.

Bearing plate, basic – Flat plate bearing directly against concrete meeting the analytical design requirements of PTI (refer to “Acceptance Standards for Post-Tensioning Systems,” Section 3.1).

Bearing plate, special – Any hardware that transfers tendon anchor forces into the concrete and does not meet the analytical design requirements of PTI (refer to “Acceptance Standards for Post-Tensioning Systems,” Section 3.1).

Bleed – The autogenous flow of mixing water within, or its emergence from, newly placed grout; caused by the settlement of the solid materials within the mass and filtering action of strands and bars.

Cementitious materials – Materials having cementing properties.

Confinement reinforcement – Nonprestressed reinforcement in the local zone, usually in the form of spirals, which provide concrete confinement and are considered part of the bearing plate.

Construction engineer – The person, firm, or organization engaged by the Owner to act as the Owner’s representative and be responsible for the overall technical oversight and contract administration to ensure that the project is constructed in accordance with the contract plans, specifications, and other contract documents.

Contractor – The person, firm, or organization who has entered into a contractual agreement with the Owner to construct the project and who has the prime responsibility for the overall construction of the project in accordance with contract documents.

Coupler – A device transferring the prestressing force from one partial-length tendon to another.
Design engineer – The person, firm, or organization engaged by the Owner to prepare the design, contract plans, specifications, or other contract documents for the construction of the project.

Duct – Enclosure forming a conduit to accommodate prestressing steel installation and provide an annular space for grout that protects the prestressing steel.

Duct coupler – A device that connects individual lengths of duct forming a continuous enclosure around the prestressing steel.

Electrically isolated tendon (EIT) – Tendon demonstrating sufficient electrical resistance between the tensile elements and the structure.

Engineer (Licensed Design Professional, Engineer of Record, Design Engineer) – The person, firm, or organization engaged by the Owner to prepare the Contract Documents for the construction of the project.

Fluidity – A measure of time, expressed in seconds necessary for a stated quantity of grout to pass through the orifice of the flow cone.

Friction – The force resisting the relative lateral (tangential) movement of material elements that are in contact.

Grout – A mixture of cementitious materials and water, with or without mineral additives, admixtures, proportioned to produce a pumpable consistency without segregation of the constituents; injected into the duct to fill the space around the tendon strand or bar. Refer to PTI’s “Specification for Grouting of Post-Tensioned Structures,” Table 3.1, for classes of grout.

Grout, basic – Cementitious material consisting of cement and water that is proportioned and mixed on site. Class A (refer to PTI’s “Specification for Grouting of Post-Tensioned Structures”).
Grout, engineered – Grout designed and tested for specific performance characteristics (refer to PTI’s “Specification for Grouting of Post-Tensioned Structures”). Class B (designed by the manufacturer and mixed on site), Class C (designed by the manufacturer, prepackaged, and mixed on site solely with water), or Class D (special) determined by design engineer.

Grout cap, temporary – A device that contains the grout by covering the post-tensioning steel at the wedge plate or anchorage; intended to be removed following completion of grouting.

Grout cap, permanent – A device covering the posttensioning steel and wedge plate at the anchorage that contains the grout and forms a protective cover, sealing the post-tensioning steel and wedge plate at the anchorage.

$f_{pu}$ – The nominal ultimate tensile unit stress sometimes referred to as GUTS. When stated as force, $F_{pu}$, the nominal ultimate tensile unit stress is multiplied by the nominal cross-sectional area of strand or bar.

Hydrogen embrittlement – Brittle cracking process caused by the conjoint action of tensile stress and hydrogen ions (atomic hydrogen).

Inlet – Tubing or duct used for injection of the grout into the duct.

MUTS – Acronym for Minimum Ultimate Tensile Strength – measured as force, $F_{pu}$ – for a single strand or bar breaking outside of the anchorage; or the multiple of those single strand or bar forces for multi-strand or bar tendons.

Outlet – Tubing or duct to allow the escape of air, water, grout, and bleed water from the duct.

Owner – The person, firm, or organization that initiated the design and construction of the project, provides or arranges for funding, is responsible for partial and final payments, and who will take possession and ownership of the project upon completion.

Permeability to chloride – A measure of the grout’s ability to resist chloride ion penetration.
**Post-tensioning** – A method of prestressing in which prestressing steel is tensioned after the concrete has reached a specified strength.

**Post-tensioning scheme or layout** – The pattern, size, and locations of post-tensioning tendons in a structure.

**Post-tensioning system (PTS)** – A particular size tendon, including prestressing steel, anchorages, local zone reinforcement, duct, trumpets, couplers, grout caps, inlets, outlets, all supplied by a single supplier.

**Potable water** – Water as defined by the Environmental Protection Agency (EPA) drinking water standards.

**Pourback** – Blockouts created for tendon anchorage and/or vent access that are to be filled with concrete, nonshrink grout, or epoxy at a later date.

**Pressure rating** – The estimated maximum pressure that water in a duct or in a duct component can exert continuously with a high degree of certainty that failure of the duct or duct component will not occur. Commonly referred to as maximum allowable working pressure (MAWP).

**Prestressing element** – The tension element of a posttensioning tendon, which is elongated and anchored to provide the necessary permanent prestressing force.

**Prestressing steel** – High-strength steel strand or bar.

**Profile** – Vertical deviation (path) a tendon follows from end to end.

**Quality assurance (QA)** – Actions taken by the Owner or his/her representative to provide assurance to the Owner that the work meets the project requirements and all applicable standards of good practice.

**Quality control (QC)** – Actions taken by the Contractor to ensure that the work meets the project requirements and all applicable standards of good practice.
Set (Grout), final – A degree of stiffening of the grout mixture greater than the initial set, indicating the
time in hours and minutes required for the grout to stiffen sufficiently to resist, to an established
degree, the penetration of a weighted test needle.

Set (Grout), initial – A degree of stiffening of the grout mixture less than the final set, indicating the
time in hours and minutes required for the grout to stiffen sufficiently to resist, to an established
degree, the penetration of a weighted test needle.

Set time – The lapsed time from the addition of mixing water to a cementitious mixture until the
mixture reaches a specified degree of rigidity, as measured by a specific procedure.

Setting – The process, due to the chemical reactions, occurring after the addition of mixing water to a
cementitious mixture, which results in a gradual development of rigidity of the cementitious mixture.

Sheathing – General term for the duct material surrounding the prestressing element to provide
corrosion protection or conduit for installation.

Strand, seven-wire – Strand conforming to ASTM A416 and consisting of seven wires having a center
wire enclosed tightly by six helically placed outer wires with a uniform pitch of not less than 12 and not
more than 16 times the nominal diameter of the strand.

Stress corrosion cracking – Brittle cracking process caused by the conjoint action of tensile stress and a
corrodent.

Stressing jack – Hydraulic jack designed for the explicit purpose of stressing one or more strands or bar
to the desired load; sometimes also referred to as a ram.

Subcontractor – A person, firm, or organization engaged by the Contractor to provide select
construction activities, materials, or other specialized construction or engineering services.
Tendon – A single or group of prestressing elements and their anchorage assemblies, which impart the prestress force to a structural member or to the ground. Also included are ducts, grouting attachments, grout, and corrosion protective materials or coatings.

Tendon size – The number of individual strands of a certain strand diameter or the diameter of a bar.

Tendon type – Description of tendon relative to location in the concrete element and/or functional use (that is, internal, external, cantilever, transverse, longitudinal, continuity, stem wall, top slab, and so on).

Thixotropic – The property of a material that enables it to stiffen in a short time while at rest, but to acquire a lower viscosity when mechanically agitated, the process being reversible.

Trumpet – Transition piece between bearing plate and duct, which collects the strands into a tight bundle that fits inside the duct.

Volume change – The change in volume produced by continued hydration of cement, excluding effects of the applied load and change in thermal or moisture content.

Wedge – A conically shaped device typically containing two or three pieces, which anchors the strand in the wedge plate.

Wedge plate (anchor head) – The hardware that holds the wedges of a multi-strand tendon and transfers the force from the strands to the bearing plate.

Wet density – A measure of the relative water content of fresh grout.

Wobble – Friction caused by unintended duct deviations between profile control points.

Zone, anchorage – The portion of the member through which the concentrated prestressing force is transferred to the concrete and distributed more uniformly across the section. Its extent is equal to the largest dimension of the cross section.
For anchorage devices located away from the end of the member, the anchorage zone includes the disturbed regions at both sides of the anchorage.

Zone, general – Region adjacent to the anchorage device within which the prestressing force spreads out to an essentially linear stress distribution over the cross section of the structure (Saint Venant Region).

Zone, local – The volume of concrete that surrounds and is immediately on the bearing side of the anchorage device.

2. CONTRACT DOCUMENTS

Before any work commences it is imperative to understand the order of precedence of the documents. Often there are several documents that reference the post-tensioning and related operations. The project contract documents govern the order of precedence and typically clearly identify the order. In the case of a conflict the order of precedence should be considered first, however if there is a clear conflict it is good practice to understand and resolve the source of the conflict. The PTI Specifications may or may not be part of the project documents. In the case where they are not part of the project documents, they may be a good resource as a point of discussion however do not override a project document without the proper submittal and approval. The best opportunity to resolve conflicts or outdated practices is as early as possible before the post-tensioning operations. The typical precedence is provided below, however varies by project.

2.1 Order of Precedence of Contract Documents

- The Project Contract provides an overall description of the scope and terms of the contract. Within this document the order of precedence of all other documents will be identified. This may or may not include reference to the PTI specifications. The contract should also identify how conflicts are resolved.
The Project Plans and Specifications are governing PT documents on a project and supersede all other documents. The Project Engineer (the designer) produces the Structural Drawings with the results of the design; the information will include all concrete dimensions, construction and/or expansion joints, nonprestressed reinforcement, and the PT forces and profiles. The Engineer also produces the Project Specifications to ensure that all materials meet the needs of the project and that they are installed in the correct way. The contract should identify if the plans or specifications take precedence.

Special provisions may be additional or different requirements, typically particular to a specific project, and are incorporated in the Project Specifications.

Reference Specifications may be included such as ASTM, PTI or PTI/ASBI.

- PTI/ASBI M50.3, Specification for Multistrand and Grouted Post-Tensioning, provides provisions on all aspects of installation and stressing of multistrand PT tendons.

- PTI M55.1, Specification for Grouting of Post-Tensioned Structures, provides provisions on grout materials and grouting procedures for successful grouting of post-tensioned structures.

2.2 Post-Tensioning Documents

- PT Installation Drawings – The PT Installation Drawings contain information necessary to successfully install, stress, and grout multistrand and grouted PT systems. They are prepared by the PT System Supplier and are based on the Structural Drawings and Project Specifications.

- PT Materials Data Sheets and Certifications – Materials may include specific instructions for handling and application; they should be reviewed ahead of construction to avoid injuries or improper installation or application. PT System components need to have material certification available for review such as mill certificates for strand.
• PT Method Statements Plans and Procedures - Detailed method statements, work plans, etc., outlining the means and methods to successfully install, stress, grout, inspect and project specific testing shall be prepared by the PT System Supplier and Installer, submitted and approved prior to the start of PT related work and implemented during execution.

3. MATERIALS

The materials for post-tensioning applications are very specialized and designed for the application. It is important the entire system is used as originally designed and tested, and that materials are not substituted. This includes even temporary components such as grout accessories. One of the key items within the inspection of materials is to ensure the materials that were approved are indeed what is being used. In addition, it is necessary to ensure the materials are being stored properly both long term and during the phases of construction.

3.1 General

The components of the post-tensioning systems (PTS) are required to meet the requirements of PTI/ASBI M50.3. The typical submittal for the given PTS will include drawings and test reports. In some cases, the system may already be pre-qualified through the Post-Tensioning Institute’s CRT-70 program or an Owner’s program such as a Department of Transportation’s Approved Products List (APL) or Qualified Products List (QPL). In this case the amount of effort to review the system is nearly eliminated. The focus in this case would be to review the materials to make sure they match what is on the drawings and also to ensure there is no damage or degradation of the materials prior to and during installation. The specifics of the system approval are not addressed in detail in this course, however the PTI CRT-70 Post-tensioning System Certification provides very detailed guidance and checklist for the acceptance criteria if further information is needed.

Below are some of the primary points to review and inspect:

• Inspection of materials (duct, anchorages, strand, bar, nuts, etc.)
1. Verify that materials to be installed are the same as called for in the Project Specification and as shown on the PT Installation Drawings.
2. Inspect material certifications and other material documentation.
3. For materials with specified shelf life, verify that materials are not expired.
4. Inspect condition of materials (corrosion, damage, etc.)

- Storage of materials
  1. Verify that materials are stored as called for in the Project Specifications.
  2. Verify that materials are adequately protected against corrosion and damage.
  3. Verify that grout materials are not exposed to excess humidity, temperature, etc.

- Handling of materials
  1. Verify that handling methods do not cause damage to materials being handled, such as excessive bending or lifting devices indenting of ducts, etc.

- M50/M55 – Review and follow relevant sections

### 3.2 Tendon Protection Level (PL)

The Project Specification should list the selected the Tendon Protection Level (PL) for the project. As noted in the PTI Level 1&2 Multistrand and Grouted PT Specialist Certification Program, the systems need to meet one of the required PL’s. They are listed below again for reference. Any variance within these PL’s from what is required should be specifically approved by the Owner/Engineer. The Tendon Protection Level (PL) governs the materials, installation, and long-term protection for the tendons. There are four PLs:

**PL-1A: M50.3, 3.1**

- Strand and bar, M50, 4.2.1 and 4.2.2
- Galvanized duct, M50, 4.3.5.1
- Duct connections for 10 ft concrete fluid pressure, tape-sealed, M50, 4.3.6
- Basic grout Class A, M55, 3.3
• Temporary grout caps
• Complete duct grout filling with no voids

**PL-1B:** M50.3, 3.2

• Strand and bar, M50, 4.2.1 and 4.2.2
• Galvanized duct, M50, 4.3.5.1
• Duct connections for 10 ft concrete fluid pressure, concrete-paste tight, M50, 4.3.6
• Permanent grout caps, M50, 4.3.3
• Engineered grout Class B, M55, 3.3
• Complete duct grout filling with no voids

**PL-2:** M50.3, 3.3

• Strand and bar, M50, 4.2.1 and 4.2.2
• PTS pressure test, M50.3, 4.4.5
• Bearing plate galvanized or epoxy coated
• Bearing plate with inspection grout vent
• Plastic duct, M50.3, 4.3.5.2
• Duct connections for 10 ft concrete fluid pressure, airtight, M50, 4.3.6
• Precast segmental duct couplers, M50, 4.3.8
• Permanent grout caps, M50, 4.3.3
• Engineered, thixotropic, prepackaged grout Class C, M55, 3.3
• Complete duct grout filling with no voids

**PL-3:** M50.3, 3.4

• Strand and bar, M50, 4.2.1 and 4.2.2
• PTS pressure test, M50.3, 4.4.5
• PTS to provide electric isolation for tensile element
• PTS to be monitorable or inspectable
• Bearing plate galvanized or epoxy coated
• Plastic duct, M50.3, 4.3.5.2
• Duct connections for 10 ft concrete fluid pressure, airtight, M50, 4.3.6
• Precast segmental duct couplers, M50, 4.3.8
• Permanent grout caps, M50, 4.3.3
• Engineered, thixotropic, prepackaged grout Class C, M55, 3.3
• Complete duct grout filling with no voids

3.3 Strand, M50, 4.2.1

The properties of strand are clearly identified in ASTM A416. Within the ASTM specification, there is
also reference to the ASTM A700 specification which provides general guidance on transport of the
material. Important aspects are to ensure all packs have tags and a unique coil number. The coil
number should be matched to a material certification that lists all required information. All of this
information should match what is required for the project.

The strand should be stored in such a way to protect it from the elements, however, it also should not
trap moisture and cause issues associated with condensation. There is some guidance provided by the
specification, however it is the Contractor’s responsibility to determine how it will store the strand. If
the strand does develop corrosion, it should be evaluated using the photos within PTI/ASBI M-50 figures
11.5. It is important to note, that often the strand can be manufactured and stored well in advance or
when it is needed (duration of years in some cases). It is therefore important that any specific
requirements for witnessing fabrication, requirements on material certifications, advance samples or
testing, etc. are clearly defined and also defined very early on, typically during the bid phase. This varies
by jurisdiction and, in some cases, there may even be a pre-approval necessary for strand suppliers
before fabrication.

Traceability is particularly important for the strand as this is the main component within the system. If
there is a problem identified with the material (in the near or long term) by knowing which heats/lots
were installed in which areas of the structure can significantly limit the investigation and remediation
necessary since the areas with suspect material can be narrowed down. Alternatively, the whole
structure could be in question if the traceability is not maintained.

Governing documents and Items to look for:
3.4 Stress Bar, M50, 4.2.2

Governing documents and Items to look for:

• ASTM A722
  o Properties, Grade 150
  o Dimensions
  o Material test reports
  o Testing per Project Specifications
  o Acceptance criteria

3.5 Anchorage
The anchorages should be the correct material and dimensions verified to ensure everything is as shown on the drawing. In general, the parts are relatively large and some of the big issues that may be encountered would be corrosion or defects to a casting that were not caught by the manufacturer. Also, any coatings such as galvanizing could affect the dimensions or function of the part (such as blocking holes, drips, affecting threads, wedge cavities, etc.). The traceability of the items below is also important however may not always be required to be tracked to the location in the structure. This is however good practice. The traceability of the components below may include lot numbers or date stamps on individual components, however many may not be individually identified. At a minimum, quantities such as boxes or crates should be segregated into traceable quantities and clearly identified. For example, wedges may not be individually stamped with a heat number, however they should be delivered in a bucket of say a few hundred parts that clearly identifies the heat number of all wedges within the bucket.

**Bearing Plate**

- Size and type
- Holes clear and threaded holes function
- Dimensions are within tolerance, typically by spot check.
- Coatings are correct (i.e. galvanizing)
- Bearing surface (face of bearing plate) is flat and no surface irregularities, defects, etc.
- Inspection port is in place and useable.
- Material is correct.
- ID marking for traceability to heat and corresponding material certificate.

**Wedge plate**

- Size and compatible type
- Wedge cavities are correct and free of corrosion or defects
- Dimensions are correct and fit up with bearing plate
- Material is correct
- ID marking for traceability to heat and corresponding material certificate.
Wedges (Part of the PTS)

- Gross dimensions
- No corrosion or obvious flaws (missing teeth, damage, does not match drawing).
- Material is correct (Material certifications and heat treatment certifications are provided).

Grout Vents and Grout Accessories

In many cases the grout accessories are external to the concrete, however they play an important role in ensuring the grouting can be done properly and reliably. Substitution of components in the past was common practice and, as could be imagined, this could lead to deficiencies, leaks, lack of ability to hold pressure, etc., if an alternate accessory was substituted. Furthermore, some components remain in the concrete and it is important they have the long-term performance capability as specified. There are several types of grout hose and it is important to ensure the grout hose matches what was approved. The same goes for valves, couplers etc.

Grout Cap

- Dimensions are correct
- Grout ports are in the right location and threaded properly and can be assembled with the accessories
- Holes are clear
- Material is correct
- Stored out of the sun and any requirements for temperature from the manufacturer are followed

3.6 Duct

Items to consider with duct are to ensure that the duct matches what was submitted. This includes some general dimensional checks, comparison of the material certifications and overall comparison with.
the general appearance. In addition, duct can be damaged in shipping and storage and it is important any damaged pieces are discarded or repaired. Duct should also be stored under cover (tarps, indoors, or similar) and capped to prevent debris, water and deleterious materials from entering the duct. It should be stored off the ground.

**Metal (Corrugated, Galvanized)**

Metal duct, if mishandled, is prone to dents and dings. It also is prone to punctures and holes. Make sure any damaged pieces are discarded or repaired. Also, any burrs at the end should be repaired before installation as they can affect the installation of the couplers and worse, the installation of the strand after concreting.

**Plastic (Corrugated and Smooth HDPE)**

Plastic duct is also prone to the same damage as metal if not handled appropriately. In addition, extreme heat or extreme cold can further affect the duct and make it more prone to damage. Although the ducts typically will have some UV protection, it is best practice to limit the exposure to the sun.

### 3.7 Prequalification Testing Documents

(Not included, Refer to PTI CRT-70 for more information)

- PTS prequalification (based on DOT; or PTI CRT-70)
- Strand (sample testing; verify methods)
- Stress Bar
- Anchorage
- Duct
- Grout

### 3.8 Field Testing

Testing of material is done in the field as outlined below:
• In-place friction test: Described in detail in stressing section
• Grout field trial testing: Described in detail in grouting section
• Grout mock up testing: Described in detail in grouting section
• Pre-grouting duct air testing: Described in detail in grouting section

Production testing

Duct/Anchor profile, Stressing Records, Grout testing before and during production.

Record keeping

Several records are important to maintain and then pass along with the other documents when the structure is put into service for future reference. Good records can allow for a future minor repair in one area, with a known cause, documented on the logs with good “clues”, or perhaps the issue was related to one bad batch of material, which through good documentation of various lot numbers and the location in the structure, may lead to isolating the problem to a very small contained area. Who is required to keep the logs and maintain traceability will typically vary by Owner / Engineer, however, best practice is for the Owners Representative / Inspector and the Contractor’s Representative to keep redundant logs.

Material Certifications (Mill Certificates) / Traceability

Material certifications provide documentation for materials of a given run (lot number, heat number, daily production, etc.). These specific numbers provide traceability in the field and also traceability back to the raw materials when necessary. In the immediate case, they also provide a means to compare what is on the drawings and specifications with what was actually provided. One note with material certifications is they are almost always representative of a given point within a production run and are only representative. They should never be used as an absolute for all materials in a given production run.

Logs (Component Installation, Strand Installation, Stressing Records, Grout Logs)
3.9 Inspection Items / Checklist

Sample checklists – see Table 1

4. INSTALLATION

4.1 General

What is described as “installation” includes several different phases, including installation of the anchorages/local zone reinforcement, duct installation, grout vent installation, and strand installation. Each of these phases are critical to be installed correctly and have a significant impact on the quality and success of subsequent activities. On some projects the duct installation may be done from a different crew than the strand installation, stressing, or grouting. It is therefore especially important to have adequate training for all crews regardless of the activity. For example, if the duct installation is done without proper procedures it can lead to difficulty in installing strand and/or additional friction during stressing and potentially strand breakage. As with any activity, how any issues are addressed when they arise is extremely important. Non-conformances should be documented and a plan for remediation be developed and approved. Some examples of cases of problems will be addressed herein.

- Tricks of the trade… letting inspectors know upfront (lubricating strand, effects of deleterious material, corrosion inhibitors, etc.)

- Validating/ensuring quantities – strand, grout, wedges. Not all PTS sizes are used with full strand quantities that the system can accommodate. For example, a PTS designed and tested for 19-0.6” strands may only have 17-0.6” strands for a particular application. A careful verification of the strand quantities is essential to ensure the right forces are applied.
The approved detailed PT method statements, work plans, procedures, etc., outlining the means and methods to successfully install, stress, grout, inspect and project specific testing shall be followed. Any deviation from the approved plans shall be documented and subject to review and approval.

4.2 Anchorage Installation

Anchorage installation includes the components that are embedded in concrete such as the bearing plate, trumpet and local zone reinforcement. The bearing area of the anchorage, especially on the stressing anchorage, is very sensitive to issues with placement such as kinks or damage. If these issues are not resolved they can lead to problems during stressing such as broken strand or lower force in the tendon. Important points to check are ensuring the correct system is being installed and then ensuring the tendon profile is smooth and bearing plates are installed perpendicular to the tendon path. The blockouts should be detailed with enough information to be installed correctly and checked.

Bearing Plates

- **Verify anchorage materials and PL**
  - Verify anchorage system and size
  - Verify bearing plate placement, blockout or buildout dimensions, tendon axis angle, placement tolerances, etc.

- **Details**
  - Verify bearing plate spacing requirements
  - Verify bearing plate confinement reinforcement (typically spiral) requirements (local zone reinforcement-PTS supplier is responsible for the local zone reinforcement; see PT installation drawings). Verify Diameter, Bar Diameter, Pitch, Length, Location at the bearing plate, coatings and proper installation. It is also important to ensure there is sufficient clearance between the bars of the local zone and other reinforcement in the area to ensure that there will be good consolidation. This area is often congested and can lead to honeycombs / rock pockets in the area which could lead to blowouts during stressing.
  - Verify general zone reinforcement requirements (general zone – design Engineer is responsible for the general zone reinforcement; see structural drawings).
• **Tolerances**

  1. Check bearing plate placement
  2. Review structural and PT installation drawings
  3. Check Project Specifications for placement tolerances
  4. Verify dimensions of installed bearing plate including blockout or buildout and tendon axis
     (bearing plate is always to be placed perpendicular to the tendon axis)
  5. Check that all items are securely fixed and will not be subject to displacement during
     concrete placement.

### Wedge Plates

- The wedge plates are installed after the concrete is cured, the strand is installed and prior to
  stressing. They are addressed here, however, since they are part of the anchorage installation.
  One of the key items to look for during installation of the wedge plate and wedges is to ensure
  that there is no corrosion, damage, or debris in the wedge cavities or on the wedges themselves.
  It is also important to ensure there is no concrete paste on the bearing plate, or any other
  damage or inconsistency, that would interfere with the proper seating of the wedges.

  - No Corrosion, Debris to wedge plate (particularly in the wedge cavity) or wedges
  - No paste or problems on face of bearing plate
  - Correct wedge plate and wedges installed
  - Wedges are hand-seated and double counted.
  - Crossing of strands behind the wedge plate should be avoided and carefully monitored during
    wedge plate installation since excessive crossing can lead to wire/strand breakage during
    stressing.

### 4.3 Duct Installation

#### Installation Details

- Allowances for moving things without special approval – rebar, congestion.
  o Check Project Specifications for project-specific requirements
What is typical

- PT tendon placement has precedence over nonprestressed reinforcement (rebar) location
- Movement of nonprestressed reinforcement may be necessary to avoid PT ducts. All adjustments require the Engineer’s approval; however, it is good practice to establish ground rules for field adjustments early in the planning phase of the project (For example, it may be feasible to establish a tolerance for moving nonprestressed reinforcement up to 3 inches in certain areas without approval)

PT duct support spacing

- Spacing is not to exceed dimensions in M50, 9.6. Sometimes control points for duct height may be given at intervals exceeding the spacing, however the support spacing is still required as per the specification.
- Check Project Specification for project-specific requirements; if these requirements exceed the dimensions in M50, 9.6, contact the Engineer for clarification. While it would be obviously OK to use a tighter spacing, the maximums identified in M50.3 should not be exceeded.
- Verify that ducts are securely fastened to the support system, preventing them from being displaced (stepped down, etc.), or from floating during concrete placement
  - Duct bending radius
    - Check PT installation drawings for PTS requirements, at anchorage and at other deviation locations
    - Check Project Specification for project-specific requirements; if these requirements exceed the dimensions in M50.3, 9.6, contact the Engineer for clarification
    - Verify straight portion of the tendon exits all anchorages before the start of any curvature. Especially kinks at the end of the transition trumpet and the duct should be avoided

Couplers

- Check duct coupler requirements for the PL and other project requirements
- Typically, taped connections are only acceptable for PL-1A
o PL-1B typically requires heat-shrink sleeves over duct couplers
o PL-2 and PL-3 require airtight connection, which can only be achieved with specifically
designed couplers
o Verify that proper duct coupler system is used
o If anchorage couplers are used, check details on the PT installation drawings
o Verify that couplers are placed in accordance with the PT installation drawings including any
transition trumpets, oversized ducts; verify sufficient space for movement of bar couplers in
the direction of stressing

• Support system / support heights
  o Support heights at high and low points as well as end anchorages are critical. These should
be verified in the field. The typical vertical tolerance at these locations per the M50.3
Specification is +/- ¼”. At locations between these areas, the curves should be smooth and
avoid any kinks or unanticipated deviations.
  o The height is typically relative to the soffit of the structure and measured perpendicular to
the soffit, however it is important to confirm this is what is specified on the drawing.
  o Verify dimensions specified on the PT installation drawings; typically, dimensions given are
from the soffit of the member to the top of the support bar (underside of the duct)
  o Verify support spacing and dimensions before other reinforcement is installed that would
prevent access to supports
  o Verify support spacing and dimensions again before concrete placement.

• Tolerances
  o Measuring – Duct profiles, layout, knowing how to read shop drawings, “e”, tolerances
    ▪ Reconcile CGS (center of gravity of strands) on structural drawings with the support
    heights indicated on the PT installation drawings. The difference between those two
    at the control points amounts to the dimension “e” that is tendon size specific and
    shown on the PT installation drawings. The “e” dimension is the distance from the
    center of gravity of strands to the top of the support bar.
  o Repair procedures (dented/crushed ducts, duct repair, vent repairs, rock
    pockets/honeycomb)
If repair of dented duct is possible, it should be restored to the original shape before concrete placement.

If duct is damaged beyond repair (kinks, etc.), that section needs to be replaced, with the use of couplers approved for the PTS and for the PL.

- Verify that the control points (high points and low points) of ducts are placed within the tolerances specified in M50, Table 9.1

**Grout vents**

- Check for grout vent (inlets and outlets) locations
  - Check minimum requirements of M50, 9.9 (high points, 3ft both directions from high point, low points, bearing plates, with inspection port where required, grout caps, change of duct size such as couplers)
  - Check project-specific requirements; these requirements cannot be less stringent. Contact Engineer in case of discrepancy

- Couplers
  - Duct couplers include ports for grout vent attachment, typically for PL-1B, PL-2, and PL-3
  - Verify that couplers with grout vents at the high point don’t create a kink in the duct path. Where feasible, avoid using couplers in curved areas and stagger couplers for closely spaced ducts when practical.

- Proper venting of anchorages
  - Bearing plate with a grout vent at the top part facing forward
  - For PL-2 and PL-3, an inspection port at the top of the bearing plate is required, facing upward
  - Grout caps required separate venting with possibly smaller diameter grout vent, always at the top part of the grout cap

- Saddles
  - For PL-1A, saddles with grout attachment can be used
  - Verify hole is drilled in the duct at the vent location; no duct burrs should protrude into the duct, potentially hindering strand placement or proper grouting.
  - Check requirements for sealing saddle to duct
Grout vents and valves

- Check requirements for grout vent sizes, M50.3, 4.3.12. Typically, a ¾” minimum diameter inlets for multistrand tendons is required. Smaller diameters are acceptable for air vents and inlets used for 4-strand transverse and stress bar tendons.
- Verify grout vent locations, inlet and outlet sizes, and positive shut off valves

Protection

- Grout vent locations (drains out the bottom, how to address if not)
  - Verify high point vent protection per project requirements
  - Verify low point drains at or near the lowest point of the duct as practical
- Keep vents closed / capped until ready to grout.

4.4 Strand Installation

During strand installation, it is important to ensure that the strand is the correct type, traceability maintained, and that it is free from corrosion (or minimal corrosion as per the M50.3 Specification criteria).

Pushing Method

Most of the requirements for strand installation will fall into the contractor’s means and methods, however some key things to look at are how is the strand being tracked as it is installed. Samples ay be required to be submitted and a plan should be developed for how this is to be done, labelled, etc. Some other things to check during installation are is the strand deburred or strand caps used to ensure the installation goes smoothly and does not damage the duct. Also, strand caps should be installed to minimize the potential for being lost in the duct as this can lead to issues with stressing and grouting.

Double checking the number of strands installed by counting the tendon tails (at both ends of the tendon) should be completed before installation of the wedge plates.

The following items should be pre-planned to ensure safe and smooth strand installation:
Pulling Method

As with the pushing method the actual installation is primarily means and methods of the contractor. A few items are important to track however and as with the pushing method, the condition of the strand must be acceptable. Generally, the strand should be free of corrosion (or only minimal corrosion as defined as acceptable per M50.3). In some cases, the tendon may be prefabricated well in advance of the work at an offsite location. It is therefore very important that the prefabricated materials are stored properly and protected during shipping. The individual prefabricated tendons should be labelled and maintain traceability back to the original coil numbers.

The following items should be pre-planned to ensure safe and smooth strand installation:

- Equipment
- Set up
- Welding to strands
- The welding of strands is acceptable per the M50.3 specification however the ends must be cut off at the length as noted in the specification.
- Precautions
- Procedure
- During installation, there should be softeners or rollers provided at points of deviation to protect the strand from damage. Also, the method should not allow the bundle to damage the duct or vents during installation.
- Quality assurance
The ends of the tendons and tendon tails should be protected as much as possible (i.e. wrapped with plastic sheeting to avoid corrosion of the strand and prevent debris and water from getting into the ducts).

Record Keeping

Permanent records – Strand Logs should be kept that track the coil number of each tendon. In some cases, there may be more than one coil number in a tendon.

4.5 Inspection Items / Checklist

The attached installation checklist provides guidance on items to inspect / verify during the strand installation.

5. STRESSING

5.1 General

The stressing operation is obviously very critical as we are delivering the required force to the structure. It is important to note however that the proper execution of all the previous steps, for example duct installation will largely determine how smoothly the operation will go. In general, some of the key things to look at during the operation are is the correct jack and calibration being utilized, was the correct jacking force achieved and are the source of any elongation discrepancies being determined and resolved. It is good practice to have a pre-work meeting for the stressing operation to go over the expectations and review items such as the blank stressing record form. In this meeting it is a good time to also discuss what will be the steps if any elongation issues are encountered. Development and approval of a tendon elongation disposition procedure prior to the start of stressing operations can expedite resolution of initial elongation measurements outside tolerance.

5.2 Preparations
• Notifications
• Safety meeting
• Safety barriers
• Access
• Concrete strength
  o It is important the minimum concrete strength and consolidation is achieved and verified before stressing. This value should be documented on the PT Supplier’s drawings and should not be less than the minimum concrete strength prior to stressing required by the contract documents without the prior approval of the Design Engineer. It should be noted that although a given local zone configuration and minimum concrete strength at stressing may be shown on a data sheet or similar, the requirements are job specific and need to be verified for the conditions on the project such as edge distance.
  o Project requirements
    ▪ Strength
    ▪ Maturity
    ▪ Cracking
    ▪ Honeycombs
• Strand quantity
  o Ensuring all wedges (and pieces) are installed on both ends.
• Data sheets/logs – assumed parts of calculations (coefficients, dead-end seating, wedge seating). Measurement techniques. How were measurements calculated (Jack length, DE movement, 20% of jacking force, understanding the Elongation Records form).

5.3 Safety
• Access
• Barriers
• Rigging
  o The jack should be maintained parallel with the path of the tendon. This is required so the strands within a tendon elongate equally and end up with near the same force in each. If the jack is too high, or too low, it can lead to differential elongations as well as safety issues such as pulling down on the crane or breaking strands.
• Communication

• Safety – Where to stand, where not as an inspector. Need to watch and verify the gauge but should be out of the “danger zone”

• PPE (stressing)

5.4 Personnel Qualifications

• Specification requirements

• Operator qualification

• Experience

• Certification

5.5 Stressing Equipment

• Calibration
  o It is important to ensure the calibrations are performed per the PTI M50.3 specifications. This includes proper number of intervals, traceability to NIST, and within the allowable timeframe. It is also good practice to verify the formula / calculations. A quick check is by taking the jacking force and dividing by the ram area. This value should be typically within 1-2% of the gauge pressure on the calibration chart. If this is off more than this amount, it is a good idea to at least discuss the cause of the discrepancy.

• Size adequate for tendon size and forces

5.6 Jacking Forces

• Force verification

• The most important part of the operation from an inspection point of view it to ensure the proper jacking force gauge pressure was achieved.

• Tendon verification (no. of strands on both sides)

5.7 Stressing Operations

• Strand slippage, wedge failure – identifying and how to respond/troubleshoot
5.8 Elongation

- Method of measurement
- Calculation
- Marking
- Measurement
  - Confirming gauge readings, who is taking them.
- Elongation reconciliation (info; troubleshooting)
- Calculation
- Force Verification; lift-off
    Refer to the pre-approved tendon elongation disposition procedure to review and quickly resolve initial elongation measurements exceeding tolerances.
- Elongation acceptance (Inspector authority when within tolerance; engineer approval)

5.9 Cutting Tendon Tails

- Timing
  - Tendon tails are to be cut, and grout caps installed within one day of obtaining the Engineer’s approval, per M50.3, 12.9. If longer than this, temporary protection, such as wrapping the tails in plastic should be done. If this is a recurring issue, the source should be determined and reconciled.
- Methods
  - Cutting may be performed with abrasive saw, plasma torch, or mechanical shear. The proper length of strand tail as shown by the PT supplier must be achieved. If the strand tail is too long it will interfere with proper seating and sealing of the grout cap. If the strand tail is cut too short, there is a concern that in the process the strand/wedge may be damaged.
- Tolerances

5.10 Record Keeping
• Permanent records – Stressing records should be submitted promptly to the Engineer for review and approval.

5.11 Inspection items / Checklist

• Complete checklist

6. GROUTING

6.1 General

As has been stressed throughout the PTI Multistrand and Grouted Field Installation Course, the grouting is extremely important to be performed correctly in order to ensure the long-term durability of the system. When the operation is properly planned and all the steps followed, the grouting operation should be successful. The inspection crews have a crucial role in this operation to ensure the operation is being performed per plan and any issues are documented and remediated. Refer to PTI M55.1 Specification for Grouting of Post-Tensioned Structures for grouting materials, testing including ASTM test methods, and grouting procedures.

6.2 Grout Plan

The grout plan should be submitted at least 4 weeks in advance of the grouting operations and should include all of the items as identified in the M55.1 specification. The plan should be site specific and should call out any special cases and identify the specific material, equipment, personnel, and procedures that will be utilized on the project.

• Items covered
• Submission and approval

The plan should be approved before work commences. Any inconsistencies with current best practice should be reconciled before work commences as well.

• Adherence
It is important for the inspection crew to verify the crews are working in accordance with the grouting plan and any deviations addressed promptly.

### 6.3 Personnel Qualifications

- **Experience and Certification**
  - The foreman of the grouting crew is required to have current PTI level 2 Multistrand and Grouted PT Specialist Certification as well as ASBI Grouting Field Technician Certification. Both have experience requirements to get certified. The person in this role is required to be present on site and involved during the grouting operations. It is good practice to designate a backup if that person is unavailable for some reason.
  - At least 25% of each crew is required to be certified in PTI Level 1 Multistrand and Grouted PT Installation.

### 6.4 Grout Plant

Most of the operation of the grout plant will fall into the means and methods of the PT System installer, however the specs of the grout plant should be submitted to demonstrate conformance with the specification requirements.

Items to plan for:

- Type optimized for grout class
- Size optimized for grout quantity
- Power supply
  - This is very important, especially with air operated plants, and a compressor with a lower supply than required should not be used.
- Backup
  - Equipment failure

### 6.5 Field Trial Testing
Field trial batches are a great opportunity for all the stakeholders to get together and go over some of the key aspects of the grouting operation and make sure things like the testing procedures, frequency, etc. are agreed upon and demonstrated. This may be done with a small batch, may be done in conjunction with the pre-grout meeting and may or may not be done with a mockup.

- **Timing**: At least one week before production grouting, under similar conditions.
- **Objective**: Verify grout materials performance, mixing, crew experience, etc.
- **Grout**: Same materials as for production grouting.
- **Equipment**: Same equipment as for production grouting.
- **Personnel**: Same crew as for production grouting.
- **Procedures**: Same procedures as for production grouting.

### 6.6 Mock-Up Testing

While requiring a significant amount of effort in the setup and execution, mockups have proven on many projects to provide an opportunity to confirm everyone is on the same page among all of the stakeholders. The mockups also have proven useful to find issues ahead of the production grouting in either miscommunication, material issues, procedural issues, etc.

Similar criteria as for field trial testing, with a mock-up of the tendon in the structure:

- **Timing**
- **Objective**
- **Tendon configuration**
- **Grout**
- **Equipment**
- **Personnel**
- **Procedures**

### 6.7 Grout

- **Grout class**
• Qualification testing
  Qualification testing needs to be performed well in advance for the grouts and should clearly identify all the required aspects in the specification.

• Grout expiration dates, lot number recording, storage of grout
  As grout more than 6 months after manufacture can suffer detrimental performance changes, it is important on site to check the expiration dates of the grout. It should be noted what system of marking the bags the supplier uses as these can vary from supplier to supplier.

• Bag Weights – Bags should be spot checked at the rate of at least one per pallet. Anything over 1% variance should be reconciled and resolved with the supplier.

• Temperature considerations

  o Hot weather grouting
    The method for keeping the grout cool will ultimately be up to the contractor (iced water, shade, etc.) however the inspector must frequently measure the grout temperature to check conformance with the specification (below 90 degrees F). The inspector should also note that ice should not be used directly in the mix.

  o Cold weather grouting
    In cold weather grouting, the inspector will be required to monitor air temperature during the period of initial cure (>800 psi) should be above freezing in the ducts. When it is cold, the initial cure may take up to a few days. It is noted that the contractor may heat the structure in order to proceed even in very cold temperatures. If the contractor has decided to delay grouting until more favorable temperatures, the tendons must be sealed. This is the primary line of defense. In addition, the contractor must use either a corrosion inhibiting oil or VPI powder. In both cases, the contractor should submit a detailed description of how they will achieve adequate performance long term.

6.8 Safety

The grouting operation contains several hazards and compounded with the typical noise, it can make communication difficult. Also, the operation is fast paced since the grout is going to set. Decisions therefore need to be made quickly and that is why it is so important to have a detailed and approved
plan and experienced and certified personnel. Also, pressures in the hoses and components can spike very quickly and without notice which creates a burst hazard. While steps should obviously be taken to avoid this, as a precaution one should be prepared in terms of where to stand, correct PPE, etc.

- **Access**
  - Ensure there is safe access to all the work areas. This includes the grout plant, end anchorages, high point vents and low point drains. On some projects this is relatively straightforward. On others, people may be working off a barge to access the work, working from a lift, etc. Consider the access and develop a plan with the contractor in advance to avoid problems once the work commences. The high point vents most often will be easily accessed, however in some cases it may be more challenging for example with a need for tie-off points. Consider access when planning the work.

- **Communication**
  - Communication early and agreeing on the plan are important as with any of the operations, however the different personnel involved in the operation are often not in the line of sight of each other (grout plant operator, vent technicians, inlet technician, inspectors), it can be loud, and fast paced. All these lead to potential challenges if not planned. Good practice is that a grouting vocabulary is established early on so there is no misunderstanding, including getting confirmation that instructions and warnings were heard.

- **PPE for Grouting**
  - The jobsite of a particular project will have minimum standards that all will need to comply with, however these may or may not be above what one would typically use with respect to grouting. With grouting, all hazards should be considered even with inspection, and consider the what ifs: grout accessories or caps burst, high pressure air hoses bust/disconnect, caught up in moving parts in the grout plant, falls, inhalation hazards. For these, skin protection, respiratory protection, eye protection, and hearing protection have to be considered used. Consider your own site and perform a hazard analysis to ensure everything is covered.
  - Eye washing station / Skin Washing
- Make sure there is adequate eye washing and skin washing available. For an effective eye-wash, one may need to flush for 15 minutes. This may seem like a lot longer when going through it and uses a lot of water/eye-wash solution. A small bottle of eye wash will be nowhere near enough supply to properly flush one’s eyes.

- Waste collection
  - Waste collection may not fall within the grouting inspectors’ responsibilities; however, some important points are having adequate containers in terms of proper construction and size. There is a lot of waste grout, especially compared to some of the older practices. There is also a lot of water associated with cleanup that typically needs to be collected and disposed of properly. The disposal would most likely be similar to how the concrete is handled in the Environmental Plan or Stormwater Plan.

### 6.9 Grout Mixing

- Ingredients
  - Most often, prepackaged grouts are used. When working with a Class B, site-mixed engineered grout, the order of addition of ingredients should be specified ahead of time and based on experience and testing – for example water, half the admixtures, cement, remaining admixtures. With a prepackaged grout, the typical order is adding all of the water and then adding the bags of grout. One note is not to mix the grout for too long in warm climates as it can add heat unnecessarily to the system before even getting started with pumping. Partial bags should never be used.

  - Water (Quality and quantity)
    Verifying the water amount and w/c ratio is of the utmost importance in grouting. This should be verified when the equipment water measuring system is calibrated, periodically and any time it is moved. The water content is also validated through the use of the mud balance test. Any inconsistency or values outside the allowable range should be immediately resolved. Water should be potable water.

- Testing
During the mixing, the key tests are the mud balance (wet density) (API Recommended Practice 13B-1) and flow cone (fluidity) ASTM C939 (modified as shown in PTI M55.1-19 Section 4.4.7). The mud balance test provides a measurement of the water content. This is a quick, low waste, repeatable test that provides an indication if too much water was added. A range should be established by the manufacturer, or through trial batches, at the corresponding range of min and max water for the given grout. If too much water is added inadvertently, the mud balance will help identify it. This could be because of residual water in the grout plant, water measured or calibrated incorrectly, or grout bags underweight. This would show up as a lower than expected wet density value. A good rule of thumb to help remember this is a good grout is approximately 2 g/cm$^3$ while water is 1 g/cm$^3$. Therefore, if the measured wet density is lower than the established range, this is an indication that too much water was added.

As a quality control test, also the flow cone provides some indication of the water content, however it measures primarily the flowability that has some variability with respect to temperature, how it is performed, and has some limitations in its precision when used as water content indicator. It does provide some indication of the pumpability of the grout, especially when used over time with a given grout and operation. The grout would be more easily pumpable when the observed efflux time is lower, however, this could also be an indication that there is possibly too much water is in the mixture. If the efflux time is higher, it will not be as easily pumpable, but it also shows that there is not too much water. The M55.1 Specification requires the use of the “modified” flow cone test. The modified flow cone is used as the standard flow cone did not yield proper and repeatable results with thixotropic grouts.

The combination of the mud balance and the flow cone tests provides indication of the water content both for quality control of the water amount as well as the pumpability. The frequency requirements for conducting these tests is relatively sparse in the current specification, but it is common and a good practice, to test more frequently. In the upcoming specification update, there will be a requirement for testing with a mud balance at the last outlet of every tendon. This provides a direct read of the quality of the grout,
with respect to water content, for every single tendon. This represents a huge improvement in the grouting.

- Other tests that are required on site are the wick-induced bleed test ASTM C940 (modified as shown in PTI M55.1-19 Section 4.4.8.1) and the Schupack pressure bleed test (ASTM C1741). Especially when there is a concern about grout bleeding (i.e. tall tendons), the Schupack pressure bleed test will provide a better and much faster indication of the bleed resistance than the wick-induced bleed test. The Schupack pressure bleed test will provide a simulation of the effects of a vertical rise through varying the testing pressure, whereas the wick-induced bleed test is only 1 meter tall and will just give an indication of bleed due to a gross error since it has only a small pressure head.

- Compressive strength tests (ASTM C942) are still required by M50.1 Specification, however, this will change in the upcoming specification update. The current focus is on the water content tests such as mud balance since that is the biggest risk for grouting issues. Generally, the compressive strength of the prepackaged grouts is well above the minimums required if the correct amount of water is added. The other issue is the compressive strengths are taken at 7 and 28 days and, therefore, the results are known significantly after grouting and for documentation purposes only.

- Another site test that needs to be performed is for the chloride content levels. This test is done at a frequency of minimum of once per project and for every 40,000 lbs (truckload) of dry materials. This can be done well in advance of the grouting and involves mixing a small sample with the same grout and water source that will be used on the project. Once the sample is cured drill fines from the sample are collected and delivered to a lab for chloride level testing. The chloride ion level needs to be below the limits in the specification. This is not truly a site test as it is done in a lab, however the important part is it needs to be conducted independently from the grout supplier. This should be a redundant check when considering the supplier is already checking these levels. The goal is to check for and mitigate the potential for a widespread systematic problem with high chloride levels. This occurred for several years in the industry and not having a redundant check was found to be
an area where this relatively easy check could be added to avoid it from happening in this
magnitude again.

- The other testing that should be done frequently is checking the temperature of the grout,
especially in hot or in cold periods of time. While the components do not have a specified
temperature, it is good practice to check and record these as well. The temperature of the
operation, cooling/heating, temperature of ingredients, shade, etc., all fall into the scope of
the contractors means and methods. Grout temperature should be kept at or under 90
degrees F to avoid pumppability or grout setting issues before it is pumped. Cooling of
ingredients including water, shade, etc. should be planned and monitored, also considering
that mixing increases the temperature of the grout. Monitoring allows for adjustments for
the next tendon when grout temperature temporarily increases over the limit.

- Timing of Mixing
  - The timing for mixing is typically 2-3 minutes for a high speed colloidal mixer. This is
    based on time after the last bag is added. It is therefore important that the grout is
    added quickly; otherwise the overall time it is mixed can be too long and lead to
    issues. On the other hand, if the grout dry ingredients are added too quickly it can
clog the machine or lead to issues as well; a balance of a reasonable and consistent
mixing time is important to maintain.

6.10 Grout Caps

- Temporary
- Permanent

- Most often, permanent grout caps are used. The grout cap must be vented. In some cases,
  there may be screw that seals a venting hole in the cap, however the trend in most cases is
to supply a hose with a shut-off valve to vent the cap. This allows a larger volume of grout
to be discharged and a cleaner operation. The caps should be completely filled once
grouted. After grouting, the outlet vent can be inspected for complete filling. Sometimes
sounding will also provide evidence of a larger void. Typically, the grout caps should not be
removed unless there is reason to believe that there is an issue and need to inspect further.
6.11 Grouting Procedures

The grouting procedure should be well defined in the grout plan. In the field the inspectors should verify the plan is being followed. This includes noting any non-conformities or problems that were encountered and ensure they are followed up on.

- Inlets and Outlets
  - Some of the things to watch out for here are cracks or broken off hoses and fittings.

- Grouting Pressure
  - Pressures should be kept as low as possible and below the specification limits. Excessive pressures can lead to bleed/segregation of the grout as well as safety issues with components bursting. The what-if scenarios of what should be done if high pressures are encountered should be addressed on the grout plan and discussed in the pre-grout meeting.

- Grouting Speed
  - Like many of the items in grouting the speed is a proper balance. Too fast can lead to turbulence, trapping air and higher pressures. Too slow can lead to the grout setting up before pumping and can also lead to high pressures. To control the speed, first thing is to ensure the equipment can perform within the specification requirements. The requirement of using the grout within 30 minutes of adding water and the speed of 15-50 ft/min should be checked against the equipment specifications and also verified while pumping.

- Testing
  - The testing is described in detail above and should be carried out throughout the operation, as required by M55.1.

- Record keeping
  - The grout logs are extremely important for both remediation and future traceability. If an issue were to occur in the future, it would be very valuable to have records that indicated a problem with a given tendon potentially isolating the problem and remedy to a specific
area, versus having the entire tendon suspect because there is limited history available on
why and where the issues encountered were located. Unfortunately, while stressing
records were almost always recorded and submitted in the past, the grouting logs were not
always kept. Grouting records are required by the PTI M55.1 Specification, with sample logs
provided in the Commentary. It is now becoming standard practice to maintain these
records with the project documents after completion of the project. Again, these should be
complete, and any issues noted. It is important any issues are expeditiously remediated.

- Outlet closing
  - The closing at the outlet should happen under pressure similar to, or just slightly above, the
    final pumping pressure. Past practice included burping (opening the tendon and repumping
    after 10 minutes) as well as holding a high pressure spike of approximately 100 psi, however
    current practice indicates to just lock off the tendon and not re-open it unless there is an
    issue.

6.12 Problem Solving/Troubleshooting

While a lot on time is spent on discussing grouting problems and failures, it is important to note that the
vast majority of operations go very well without issue. And in those cases where problems are
encountered, if there is a solid plan of how to address them considered ahead of time, they can be
remediated, and a sound product still delivered.

The following should be considered and discussed in the pre-grout meeting:

- Inlet change (i.e. moving from the end anchorage to another low point if the need arises)
- No flushing
- What to do when blockage occurs
- Backup equipment

6.13 Vacuum Grouting
If a void is discovered, depending on the magnitude of the void, the typical approach will be to remediate it with vacuum grouting. On the one extreme, if the void is very large, it may be more appropriate to drill multiple ports and allow venting as the grout flows into the void. This method can be used in combination with vacuum grouting as vacuum assisted grouting. On the other extreme, if the void is very small (i.e. all strands covered) it may be reasonable to gravity fill / tremie grout or epoxy into the void.

• Equipment
  o The equipment will be specialized for this operation. One note is that each case however will be unique and often require some troubleshooting. While the goal is to get as close to a perfect vacuum as possible and fill the void 100%, sometimes there are interconnected voids, cracks, or small leaks that are hard to seal completely. As such there may be less than a perfect vacuum and some judgement involving experienced personnel will need to be made.

• Record keeping
  o Just as with typical grouting, records should be kept of the repairs showing the type of grout, date, volume of void, volume of grout to fill the void, percent vacuum achieved and other standard grout log requirements.

6.14 Post-Grouting Inspection

To inspect the grout at the conclusion of grouting, a couple of key items are typically employed. The first and most general is to look at the end anchorages, high and low points, segment joints, and closures and look for any puddles of grout or grout leaks. The next step is to (after 24 hours) break off the grout vents and ensure they are full at the break location and with no water, soft grout of other noted deficiency. Generally, the grout should be good below, however on occasion, the grout can setup in the grout tube or port of the bearing plate. This could potentially disguise a void in the grout below in the tendons. To check for this, the most common method would be to drill into the grout vents at the tendon high points and bearing plates. A 3/8” Drill with an automatic stop is typically employed for this,
however, it is also best practice to measure the anticipate distance and mark the bit with tape before drilling. The drill bit punches through the grout plug in the vent and gets to the void below, if it exists. If the grout is sound, it won’t punch through and the drill hole just needs to be repaired such as with an epoxy. If there is a void, a borescope can be inserted into the hole and help evaluate the size of the void. The typical frequency this is done at is with a sampling rate at the beginning to establish comfort that there are no voids. If none are discovered, the frequency can be decreased or ultimately eliminated. If some voids are discovered, the frequency will be increased until comfort is gained at which point it can be reduced. One reason to minimize the frequency is obviously avoid putting holes in the structure and even though repaired, it is best to avoid them where possible.

Records of the inspection should be kept and submitted. The following should be included:

- Visual (borescope)
- Anchorages
- High points
- Statistical approach
- Record keeping

**6.15 Inspection Items / Checklist**

- Refer to checklist for relevant items

**7. TEMPORARY PROTECTION AND FINISHING**

**7.1 General**

The finishing includes a few different steps. Once the grouting is complete and inspected, best practice is to perform the finishing operations as quickly as possible. If for some reason the finishing needs to be delayed, measures should be taken to provide temporary protection for the tendons until they can be completed. The finishing details have improved significantly over the last 10-20 years. They provide an
important layer at critical areas. There are two main areas for finishing, the first is the end anchorages. The second is at the high point vents.

7.2 Pourbacks (Refer to PTI M50 for illustrations of pour backs and proper approaches.)

The pourback protection of the tendon should be in accordance with the Tendon Protection Level (PL) for the particular project.

Photos of anchorages with and without grout caps in blockouts illustrate where the “finishing” work is viewed prior to closing up of the completed tendons. Also, in some cases, such as at a stressing blister for an external tendon, the anchorage may not have a pourback and only have a grout cap covered by a protective coating. In these cases it is assumed the waterproof structure is providing a layer of protection.

Fig. 7.1 –

In Figure 7.1, the tendon has been stressed, however no finishing work yet done. Inspection of the anchorage area, surfaces, rebar, overall condition contributes to the quality of the final finishing works. Concerns with the anchorage area or concrete of the structure could be addressed and corrected here if not prior to this step.
Fig. 7.2 –
In Figure 7.2, the tendon tails have been removed/cut and a grout cap has been installed. Inspection of this work certainly would be addressed during the grouting phase, but post grouting, it should be verified if there was anything that happened that would affect the final protection or encasement of the tendon/ anchorage. (i.e. voids, cracked caps, a leak of grout from the cap that collected to the concrete impairing a full bond.) Condition of the grout cap, including damage or cracking, surface contamination, proper bolting of the cap can be factors that negatively impact the sealing of the system and should be confirmed before pour backs or application of coating. If epoxy coated rebar is utilized and the coating has been damaged, it should be touched up before placing the pourback.
Not all anchorages are encased within concrete. Figure 7.3 shows an end anchorage that is not poured back. Once properly prepared the surface and the grout cap may be coated with a protective coating, typically an elastomeric coatings.

It is important to ensure that the protective coating over the grout cap and/or pourback has complete coverage, was properly applied and achieved a good bond. Inspection would also include verifying that the surface is fully cured, and has not be damaged by subsequent work activities.

The key before the pourback is completed is to ensure proper preparation and that all laitance, grease, debris, etc. is removed and the surface prepared per the manufacturer’s requirements (i.e. sandblast). It is now acceptable per the M50.3 Specification to use a good quality concrete similar to the structure in lieu of an epoxy grout pourback. In both cases, the preparation will determine the success of the bond and how well it can defend against the intrusion of water and deleterious materials. The next key
is ensuring the detail is constructed as shown on the plans including any reinforcement. Finally, the
materials need to be mixed and applied as per the manufacturer’s recommendation including a detail to
ensure a sound bond and free of voids.

Once the pourbacks are completed, the next step typically employs the use of an elastomeric coating.
As with the pourback, the preparation is very important and must be in accordance with the
manufacturer’s requirements. Also, the application must be in accordance with the manufacturer’s
recommendations. For example, are the temperature and humidity requirements in range, is it brushed
on, rolled or sprayed, is the mil thickness correct and how is it verified?

There should be a log kept for the finishing operations as well.

7.3 Inspection items / Checklist

- Refer to checklist for relevant items

8. SAFETY

8.1 General

Inspection personnel are often reliant on the access and work environment established by the
Contractor and Subcontractors, in compliance with OSHA. This includes safe access to the work area
and a safe work environment while there, and includes special considerations for working over water.
It is best practice to be knowledgeable in the hazards and how to address them prior to showing up for
the work. This allows the inspector to discuss the safety related items up front and hopefully everyone
plan the operation to account for the safety of the workforce inclusive of the inspection crew. The
following items are a bullet point list to be considered however not all inclusive and will vary by site.
The other item that may fall into the inspector’s responsibility is adequate waste disposal. Often this
would be required in the Environmental and Stormwater Plan, similar to how the concrete waste is
handled. A key in the safe operation is that it is OK to ask questions when it comes to safety of oneself
and others; one should never just assume something is OK, especially when one noticed something; a
question about it should always be brought forward.
8.2 Access

- Articulated lift, Swing Stage, Man basket – In all of these cases, tie-off is typically required, ensure all comply with this requirement. If anyone is asked to operate lift, one should ensure that the person has received adequate training and is competent to operate it. This also goes for that person that they would state that they are not trained to be operating the lift.
- Scaffold, Shoring, Stair Towers, Ladders – With these items, things to check are was there a plan designed by a competent individual, was it installed correctly, is it inspected. Realistically one will not be re-checking everything, however one needs to be confident that the scaffold and shoring were done properly and, again, if something does not look right, one should at a minimum ask the question.
- Fall Protection – It is recommended that all working above ground have specific fall protection training. Fall protection training addresses more than just proper tie-off and harness use. It also describes proper tie off point construction, handrail requirements, ladder/access requirements, hole covering, etc. This awareness will help provide the tools to identify any deficiencies when approaching the site or while working. In addition, it is important to be aware of and protect oneself from overhead loads/hazards.

8.3 Communication

- Early communication can be very helpful in ensuring a smooth and safe operation. Letting the contractor know any expectations up front and understanding their requirements and expectations provides ample time to plan and avoid discrepancies during execution of the work. Some contractors may be open to having the inspection crew at their daily safety meeting and provides another opportunity for communication if that is an option. Regardless, most contractors are generally open to identifying hazards and constructive feedback when it comes to safety.

8.4 PPE
• Each jobsite will have minimum standards that all will need to comply with, however, these may or may not be above what one would typically use. All hazards should be considered even with inspection and consider the what ifs: Hazard analysis should be considered and performed for each different site.

• Eye washing station / First Aid Station

### 8.5 Emergency Action Plan

• All projects should have a plan indicating what should happen in the event of an emergency or injury. How are the different locations accessed, what is the site address, who gets called, where are the emergency facilities, muster points, SDS location, etc. This information should be given to all and it is good practice to ask for it or, if necessary, come up with one’s company’s own plan and coordinate with the contractor.