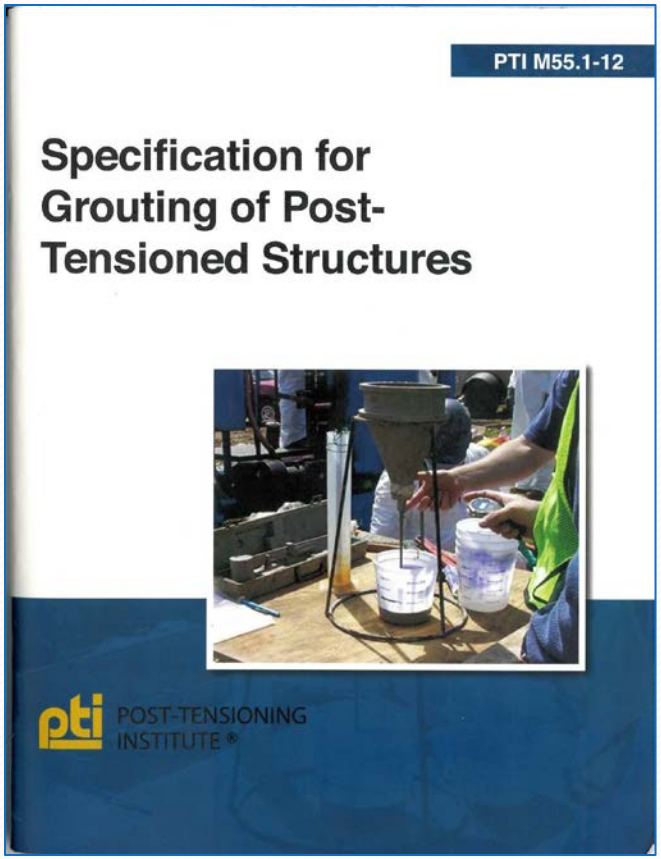
Proposed Modifications to Section 50 "Prestressing Concrete" of the Standard Specifications

By Marc Friedheim and the Post Tensioned Concrete Committee
January 2013

Reasons for changes/Problem Statement

- PTI M55.1-12
- Voids in ducts
- Excessive bleed
- Improved corrosion protection
- Uniformity of product
- Less room for error
- Consistency with other DOT's
- Construction, SP&I, PTI, and ASBI behind the changes



Benefits of well grouted tendons:

- Corrosion protection
- Bonding of strand within the duct and therefore integral behavior

Test Samples needed on each project to verify grout still complies with AML properties previously tested

50-1.01C(4) Test Samples

Submit test samples for the materials to be used as shown in the following table:

Material	Number of test samples	Test sample description
Uncoated strand[a]	1	4-foot-long sample from each reel or pack
Epoxy-coated strand:		
Uncoated strand[a]	1	4-foot-long sample of uncoated strand removed from each reel or pack before coating
Coated strand[a]	4	5-foot-long sample from each reel or pack of coated strand
Epoxy powder	1	8-ounce sample from each batch[b]
Epoxy patching material	1	8-ounce sample from each batch[b]
Bar[a]	1	7-foot-long sample of each size for each heat
Bar coupler[a]	1	Coupler from each lot of couplers with two 4-foot-long bars[c]
assemblies[a]	1	assembly from each lot of anchorage assemblies
Prepackaged grout	1	1 -60lb bag with a manufacturer's date within 6 months of planned placement in the bridge

[a]Randomly selected by the Engineer.

[b]Packaged in an airtight container and identified with the manufacturer's name and batch number.

[c]Submit coupler and bar samples assembled. The bars must be from the same bar heats to be used in the work.

Authorized Material List (AML) – PT grout

- Needed to maintain quality assurance
- In-house – in depth testing

50-1.01D Quality Control and Assurance
50-1.01D(1) General
The following items must be on the Authorized Material List:
1. Post-tensioning prestressing systems
2. Organic zinc-rich primer
3. Prepackaged grout

Minimum personnel qualifications

50-1.01D(1) General

The Department rejects any unidentified prestressing steel, anchorage assemblies, or bar couplers received at the job site or casting site.

The contractor for post-tensioned concrete must have at least one person present during all operations who is currently certified as a PTI Level 2 Bonded PT Field Specialist. In addition to the previous certification, the foreman for each grouting crew must be an ASBI certified grouting technician. Proof of these certifications must accompany the grouting plan.

Require a Grouting plan

- Additional QA/QC

50-1.01D(4) Grouting plan

At least 4 weeks prior to the start of grouting tendons, the contractor is required to submit to the Engineer a written grouting procedure for approval. This procedure must include the following elements:

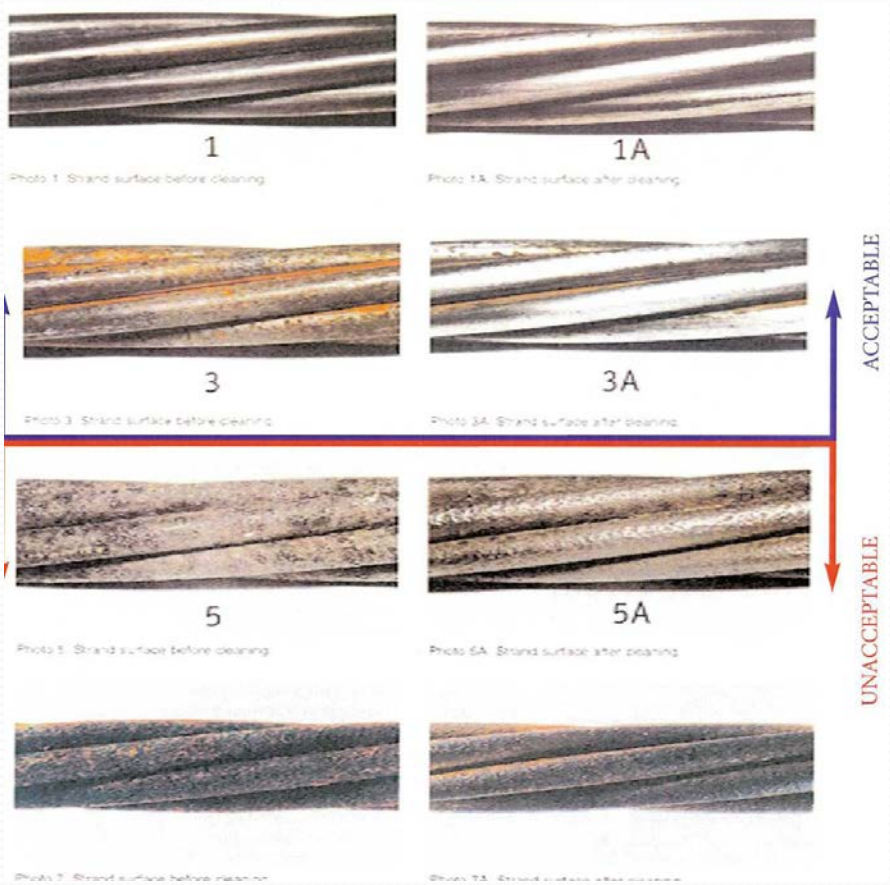
a. Type, quantity, and brand of materials used in grouting, including all certifications required.
b. Type of equipment to be used, including provisions for backup equipment and spare parts.
c. Types and locations of inlets and outlets.
d. Types and sizes of grout hoses and connections.
e. Duct cleaning methods and equipment prior to grouting.
f. Mixing and pumping procedures.
g. Direction of grouting.
h. Sequence of use of the inlets and outlets.
i. Procedures for handling blockages.
j. Procedures for possible regrouting;
k. Names of persons in charge of grouting operations as well as names of personnel who will perform the grouting operation, including their relevant experience, skill, and certifications.

The Engineer has 2 weeks to approve the grouting plan. If issues need to be addressed in the grouting plan, the contractor must suspend grouting operations until all issues are resolved at least 2 weeks prior to grouting.

Criteria for rejection based on observations of rust

50-1.02B Prestressing Steel

The Engineer may reject prestressing steel that has developed visible rust or other results of corrosion. Prestressing steel will be rejected if surface rust either cannot be removed with a fine steel wool pad, or once removed, pits larger than 0.002 in. remain.



Grout Material Criteria

- Prepackaged grout with thixotropic properties has zero bleed
- Better flow properties within the duct

50-1.02C Grout

Unless specified by the Engineer, grout shall be Class C prepackaged grout as defined by the Post-Tensioning Institute (PTI) Specification for Grouting of Post-Tensioned Structures. If grout is to be used in tendons longer than 300ft, grout must have thixotropic properties. Grout may be stored onsite no longer than 1 month. Grout must be mixed and placed within 6 months of the manufactured date printed on the packaging.

- Cement and water grout is currently used and has the following potential variations
  - HRWR agents (more bleed)
  - Water, must be carefully monitored
  - Plasticizers
  - Glenium 7500 (accelerates early strength)
- Common prepackaged thixotropic grouts:
  - Masterflow 1205
  - Euco Cable Grout PTX
  - Sika Grout 300PT
  - Masterflow 1341

- Prepackaged Grout used so far on segmental and vertical applications:
  - Devil's slide
  - Confusion Hill
  - SFOBB Skyway
  - Benicia Martinez
  - Antlers
  - Otay River Bridge
  - Pitkens Curve
  - Laural Street Overcrossing

Prepackaged grouts require the use of a high shear colloidal mixer

Water tank with overflow

Mixing hopper

Holding hopper with cont. feed to pump

Superior mixing compared to the vane (paddle type) mixers

Acknowledgment of prepackged grout issues and resolution:

- Chlorides
  - Testing is now required to confirm chloride ion content
- Soft Grout
  - Inclined tube test
  - Limit on filler content (inert materials such as limestone)
  - Limit on grouting pressure
  - Limit on grouting speed
  - New PTI addendum in March

SAFETY AND SERVICEABILITY

New Specifications for Grouting

by Theodore L. Neff, Post-Tensioning Institute

Proper grouting is essential to ensure the performance and durability of post-tensioned (PT) concrete structures. Cementitious grout provides an alkaline environment that passivates the steel and serves as a physical barrier that helps keep water, oxygen, and corrosion-causing contaminants (such as chloride) away from the prestressing steel. Thus, the grout is providing corrosion protection. In bonded, post-tensioning applications, the grout also bonds the steel and duct to the surrounding concrete so that the structural element performs integrally as a unit.

Prior to 2001, most grouts used in PT construction were a simple mixture of cement and water. Generally these grouts performed satisfactorily. However starting in the 1990s, corrosion problems were observed on several projects in Florida and around the world. These durability issues were primarily attributed to a combination of the use of high-bleed grouts and improper workmanship.

In 2001, the Post-Tensioning Institute (PTI) released *Specifications for Grouting of Post-Tensioned Structures*, which introduced many new requirements to minimize bleed water and improve grouting practices. This led to widespread use of engineered, low-bleed grout materials that were prepackaged by manufacturers. While these prepackaged grouts have been effective in minimizing the formation of voids due to bleeding, new problems related to high chloride content and segregation have recently been reported.

PTI's 3rd edition of the *Specifications for Grouting of Post-Tensioned Structures* is intended to address concerns related to high chloride content and segregation as well as strengthen the provisions to minimize bleed water and to ensure proper construction.

Control of Chlorides

Previously, the specification limited the chloride content in new grout to 0.08% by weight of cement. However for prepackaged grouts, chloride was only tested during the initial qualification testing. In the latest version, chloride must be tested more frequently: first during the qualification testing, then once per 40,000 lb of grout, with a minimum of at least once per project. In addition, the manufacturer must certify the chloride content of all constituents.

Grout Segregation or Instability

Grout segregation was observed in Europe in early 1990s. In response, research by The Technical Department for Transport, Roads and Bridges Engineering and Road Safety (SETRA), a department within the French Ministry of Transport and Infrastructure found the inclined tube test (see sidebar for more information) and a modified wick-induced bleed test to be very effective in checking the stability of grouts under conditions representative of field conditions. The tests were adopted as part of the French specification in 1996 and have subsequently been incorporated into European standards for grouting. The new edition of the PTI grout specification also includes these tests to identify grouts that are susceptible to bleed and segregation.

High pumping rates and pressures also were determined to contribute to the segregation of grout. Pumping rate must be slow enough to avoid air entrapment and segregation, and is required by the specification to be between 5 and 15 m per minute (16 and 49 ft per minute). Pumping pressures are listed in the PTI specification, and the new specification also eliminates the procedure of holding pressure for one minute after grouting.

Construction Quality

Several revisions have been made to the PTI specification to improve quality of grouting operations. Of particular significance, flushing of ducts is no longer permitted whether to clean the ducts prior to grouting or to remove grout in the event of a problem.

Photo (above) and schematic (below) of inclined tube test set up. Note the difference in level between the high-bleed grout on the left and the low-bleed grout on the right. Graphic: SETRA

Inclined Tube Test

The inclusion of the inclined tube test is a key improvement in the qualification testing of post-tensioning grouts.

Advantages of this test are that it:

- includes the effects of both pressure and the strand, and
- is used to be representative of a real environment in a duct.

The test was studied and validated by the French agency SETRA, and found to be a good indicator of a grout's susceptibility to bleeding and segregation.

The test is based on a standard procedure set forth in Euronorm EN 445—"*Grout for prestressing tendons—Test methods*." Set-up includes two clear tubes that are 5 m (16 ft) in length and 80 mm (3.1 in.) in diameter. Each contains 12 prestressing strands and is inclined 30 degrees to the horizontal. (See figure.)

Grout is injected into both tubes. When filled, the outlets are closed; after 30 minutes, the valves of the second specimen are reopened and the pump re-started until grout flows out the outlet again.

Air, water, and segregation that accumulate at the top are recorded after 30 min., and 1, 3, and 24 hr.

Because worker training and ability greatly affects grouting quality, this version of the specification requires that the work be performed and supervised by qualified personnel. The specification recommends that grouting operators, supervisors, and inspectors be certified under American Segmental Bridge Institute's Grouting and PTI's Bonded PT certification programs.

Summary

These are only a few of the enhancements that have been included in the third edition of the PTI *Specifications for Grouting of Post-Tensioned Structures*. For more information, contact PTI or visit www.post-tensioning.org.

Theodore L. Neff is the executive director of the Post-Tensioning Institute.

Admixture special requirements

50-1.02C Grout

Admixtures must comply with section 90, except admixtures (1) must not result in chloride ions in excess of 0.08 percent by weight of mixed grout and (2) must already be present in the prepackaged grout.

Grout mixing requirements

50-1.02C Grout

Mix the grout as follows:

1. Add water to the mixer followed by prepackaged grout.
2. Mix the grout with a high-shear colloidal mixer.
3. Retempering of grout is not allowed.
4. Agitate the grout continuously until the grout is pumped.

Grout must be placed within 30 min of adding the first water to the mixture.

Grout testing for prequalification to AML

50-1.02C(1) Testing of grout

The following tests must be performed in order to prequalify a prepackaged grout with METS:

1. Setting time test according to ASTM C953: Set time must be between 3hrs and 12hrs.

2. Permeability test in accordance with ASTM C1202: Test values of 2500 Coulombs or less after a 6hr test using 30V input is acceptable. Grout is to be tested at 28 days.

3. Inclined tube bleed test: Grout bleed must not exceed 0.3% of the initial volume of grout after 3 hours. This test must be performed in accordance with EN 445, "Grout for Prestressing tendons – Test Methods," American National Standards Institute, Washington DC, 2010.

4. Volume change test: If an expansive agent is used in the mix design, this test must be performed to demonstrate the vertical height change of no more than 0.2% at 28 days. This test is to be performed in accordance with ASTM C1090.

5. Strength test: Grout cubes must be tested according to ASTM C942. 7 day strength must be at least 3000psi. 28 day strength must be at least 5000psi

6. Flowability testing: Modified flow cone tests according to CTM 541. Efflux time must be between 5 and 30 seconds. Additionally, grout must be allowed to stand for 30 minutes, be remixed for 30 seconds, and demonstrate an efflux time less than 30 seconds.

7. Chloride ion test: Chloride ion content (Cl-) of the mixed grout must not exceed 0.08% by weight as measured by ASTM C1152.

Grout testing during on-site production

50-1.02C(1) Testing of grout

The following tests must be performed on-site during grouting operations:

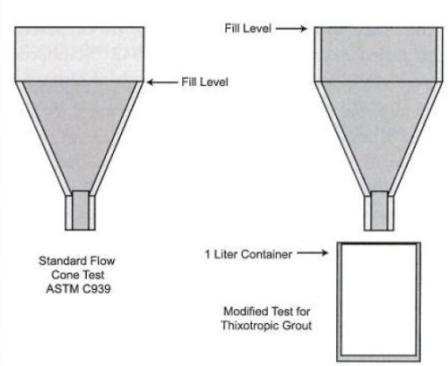
1. Grout cubes must be obtained once per day for strength testing by METS according to ASTM C942. 7 day strength must be at least 3000psi. 28 day strength must be at least 5000psi

2. Modified flow cone tests according to CTM 541 at the inlet and furthest outlet. Efflux time must be between 5 and 30 seconds. Efflux time of grout sampled at the outlet shall be remixed for 30 seconds and must be within 10 seconds of the inlet efflux. This test must be performed once every 2 hours during grouting operations.

3. Schupack pressure bleed test (See PTI M55.1-12 article 4.4.6.2) performed a least once per day.

4. Wet density test, also known as the mud balance test, (See PTI M55.1-12 article 4.4.8) performed at least twice per day.

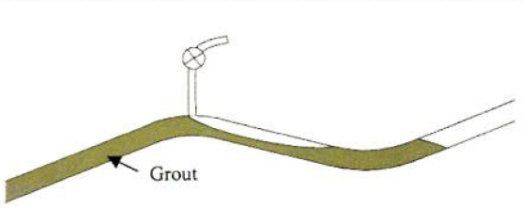
5. Chloride ion test: Chloride ion content (Cl-) of the mixed grout must not exceed 0.08% by weight as measured by ASTM C1152.



Grout temperature limitations

50-1.02C(1) Grout temperature limitations

The temperature of the grout mixture must not exceed 90 degrees Fahrenheit. Measures must be incorporated on hot days to control flash set and must be included on the grouting plan submitted by the contractor. Cold climate conditions exist when the outside air temperature is 40 degrees Fahrenheit and falling. In such conditions, planned grouting operations must be suspended.



Vents

- Specify locations to prevent voids, especially at high points
- More vents than currently used, larger diameter

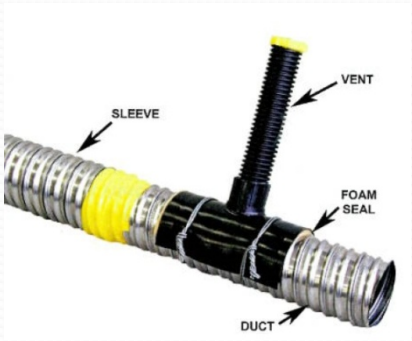
50-1.02E Vents

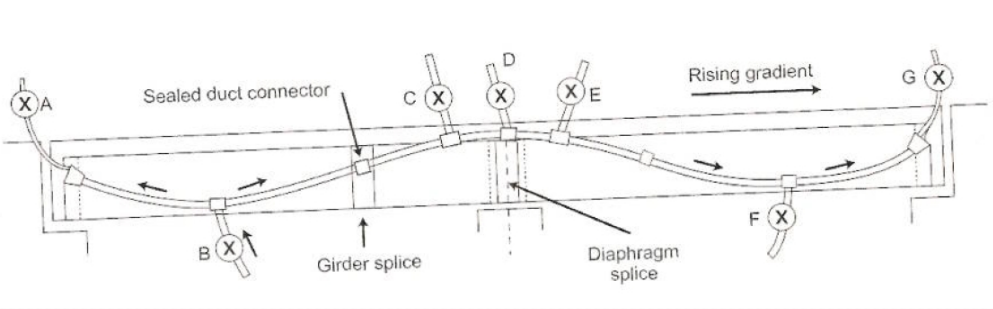
Vent all ducts having a vertical duct profile change of 6 inches or more. Place vents at the following locations:

1. At the anchorage areas at both ends of the tendon.
2. At all high points.
3. At locations 4ft upstream and downstream of each high point.
4. At each low point.
5. At any location where there is a change in the cross section of the duct.
6. At any other location recommended by the Engineer.

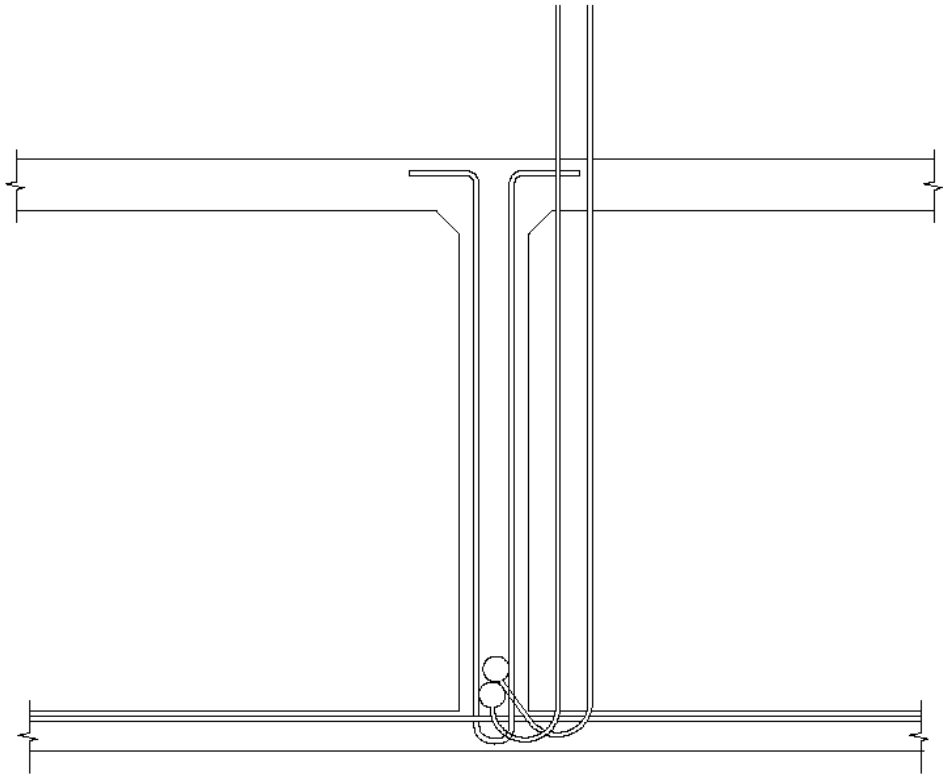
Vents must:

1. Be at least 3/4-inch-diameter standard pipe or suitable plastic pipe.
2. Be connected to ducts using metallic or plastic structural fasteners. Plastic components must not react with the concrete or enhance corrosion of the prestressing steel and must be free from water soluble chlorides.
3. Be mortar tight and taped as necessary.
4. Provide a means for injection of grout through the vents and for sealing the vents.
5. Be left open at low points in order to allow drainage of any water that may have accumulated within the duct before grouting the duct.





Possible Low Point Vent Configuration



Flushing

- No longer allow flushing
- Water will get trapped in the corrugations and act as a mechanism for corrosion

50-1.02F Flushing Water

Water is not permitted for flushing of ducts at any time. Use only oil-free compressed air to blow out ducts.

Duct Tie Spacing

- Better QC on tying ducts to prevent movement during concrete placement

50-1.03A(3) Ducts

Accurately place prestressing ducts. Securely fasten the ducts in place to prevent movement of the ducts during concrete placement. Round metal ducts must be secured horizontally and vertically at a spacing not to exceed 4ft. HDPE round duct without strands must have a support spacing not to exceed 2ft. HDPE flat duct with strand installed must have a support spacing not to exceed 2ft. HDPE flat duct without strand installed must have a support spacing not to exceed 1ft.

Duct integrity

- Pressure testing
- Compressed air to remove water/debris
- Torpedo to check for kinks/blockages
- Purpose is to ID major leaks and fix prior to grouting
- Check for cross-over
- Evaluate function of vents and valves

50-1.03B Prestressing
50-1.03B(1) General

Prior to inserting strand into a duct, the duct must be pressure tested after stem and soffit concrete placement. Pressurize ducts to 30 psi and record pressure loss for 1 minute. A loss of 50% is acceptable.

External ducts are to be pressure tested with compressed air by pressurizing to 15 psi and recording pressure loss for 1 minute. A loss of 50% is acceptable.

After all concrete placement and just prior to inserting strand into the ducts, ducts must be cleared with the application of compressed air into the duct to remove water or debris. After clearing the duct with compressed air, a torpedo (or similar device) with a cross sectional area slightly smaller than the duct, must be passed through the entire length of the duct.

Strand insertion method

- More direction on push versus pull through methods

50-1.03B Prestressing
50-1.03B(1) General

Installation of prestressing strand in the ducts may be by the push or pull through methods. In the pull through method, all strands within a duct must be pulled simultaneously. In the push through method, bullets must be attached to the leading end of each strand prior to pushing the strand through.

Pumping pressures

- Cap on allowable pump pressure to prevent blowouts
- Procedure for handling blockages (alternative to flushing)

50-1.03B(3)(d) Bonding and Grouting
50-1.03B(3)(d)(i) General

Pump pressures must not exceed 75 psi. Once grout is wasted for at least 5 seconds at the outlet, close outlet valve followed by inlet valve closure and stopping the pump. If a blockage is suspected or pressure exceeds 75 psi, close inlet valve and continue pumping from the next closest low point from which grout has already flowed unimpeded.

Corrosion prevention measures

- Limit the time between strand placement and grouting
- Function of humidity

Final note on vibration protection

50-1.03B(3)(d) Bonding and Grouting
50-1.03B(3)(d)(i) General

Grout post-tensioned tendons within the limits in the following table. Detension tendons not grouted within the following specified number of days after prestressing, as directed, to allow inspection of strand for corrosion. Alternatively, corrosion protection measures may be used if approved by the Engineer.

Time limits for grouting after inserting strand into the duct:

Very damp atmosphere or over salt water (humidity>70%)	7 days
Moderate atmosphere (humidity 40 to 70%)	20 days
Very dry atmosphere (humidity<40%)	40 days

Do not allow traffic or loads on the structure until 24 hours after completion of grouting.

Vertical Grouting

- Alert the contractor to use a special prepackaged mix

50-1.03B(3)(d)(ii) Vertical Grouting

Ducts grouted in the vertical position must use a prepackaged thixotropic grout specifically designed for this application.

Safety

- Provide some protections for the grout plant operators
- Current specs are silent on this

50-1.03B(3)(e) Safety

Personnel involved in the grouting operation must be adequately protected. They must wear NIOSH approved Tyvek suits, full-face dual cartridge respirators, earplugs, and eye protection. They are also required to wear gloves which are impermeable to grout. The grout plant must be arranged such that the grout plant operator is not required to move bags of prepackaged grout more than 30" vertically in order to place grout in the mixer.

During stressing, no personnel may stand next to, behind, or above the hydraulic jack. All personnel must be located a safe distance away from the jack and the area around the jack. The end opposite to the stressing end must be cordoned off.

Where might we go from here?

- Physical testing on existing bridges to look for corrosion and voids
- Examine PT bridge tendons which are scheduled to be demolished
- Create an AML to begin allowing prepackged grouts with performance criteria
- Identify some pilot bridges currently in design for prepackaged grout use and create a feedback loop on cost and construction issues