ORIGINATION FORM

THE INFORMATION BELOW IS TO BE PROVIDED BY THE ORIGINATOR
(The person who receives or originates the issue and needs to forward the issue for action.)

☐ Modify Specification _____.
Section/File number

☐ New Section _____462_____.
Section number

Subject: Post - Tensioning

Origination date: September 18, 2002

Originator: Robert Robertson
Office/Phone: State Structures Office/SC 994-4267 (850) 414-4267
Email address/ Userid: robert.robertson2@dot.state.fl.us

Problem statement: Severe corrosion in some structures and voids in the tendon grout.

Information source: State Structures Office.

Background data: Recent inspections of post-tensioned structures revealed we were having severe corrosion in some of the structures and most had voids in the tendon grout. In an effort to improve the corrosion protection and assure fully grouted tendons the new specifications were developed along with new design details.

Desired implementation date: Bridge projects beginning with the July 2003 letting.

Florida Department of Transportation

JEB BUSH
GOVERNOR

605 Suwannee Street
Tallahassee, FL 32399-0450

THOMAS F. BARRY, JR.
SECRETARY

M E M O R A N D U M

DATE: November 14, 2002

TO: Specification Review Distribution List

FROM: Duane F. Brautigam, P.E., State Specifications Engineer

SUBJECT: **Proposed Specifications Change – D4620000.D01 - Post-Tensioning**

In accordance with Specification Development Procedures, we are sending you a copy of a proposed specification change to Section B460.

This change was proposed by Robert Robertson to completely rewrite the Section to reflect current practices. The Section Number was also changed from B460 to 462.

Please share this proposal with others within your responsibility. Review comments are due within four weeks and should be sent to Mail Station 75 or to my attention via e-mail at SP965DB or duane.brautigam@dot.state.fl.us. Comments received after December 12, 2002 may not be considered. Your input is encouraged.

DFB/jf

Attachment

COMMENTS:

Submitted by: Phone #:

POST-TENSIONING.
(REV 10-30-02)

PAGE 468. The following new Section is added after Section 460:

SECTION 462
POST-TENSIONING

462-1 ~~Gereral~~*General*.

462-1.1 Description: Furnish and install all post-tensioning systems and any other pertinent items necessary for the particular prestressing system used, including but not limited to ducts, anchorage assemblies and supplementary reinforcement. Furnish all components of a post-tensioning system, including steel pipes and not including the prestressing steel, from a single supplier.

Install prestressing steel, which may be strands or bars, through ducts in the concrete. Stress to a predetermined load and anchor directly against the hardened concrete. Grout ducts to fill all voids and install protection at end anchorages.

Submit shop and working drawings and manuals in accordance with ~~instructions herein~~ *this Specification* and Section 5. The Contractor's ~~Speciality~~*Specialty* Engineer shall produce all shop drawings related to post-tensioning which shall bear the signature and seal of the responsible engineer.

462-1.2 Qualifications and Inspection: Perform all post-tensioning field operations under the direct supervision (crew foreman) of a qualified post-tensioning and grouting technician*. Provide a crew foreman and crew members in accordance with Section 105.*~~s that is qualified through the Department's Construction Training Qualification Program (CTQP). In addition to the crew foreman, provide a minimum of two crew members which are also qualified post-tensioning and grouting technicians through the Department's CTQP. For information about how to become qualified, consult the following CTQP website: http://ctqp.ce.ufl.edu . Construction operations that require a qualified technician must not begin until the Department verifies that the technician is on the CTQP list of qualified technicians. All personnel involved in grouting must attend a grouting training session provided by the Department not less then seven days prior to the start of the first stressing or grouting operation of the project.~~

~~Perform all vacuum grouting operations under the direct supervision of a crew foreman who has been trained and has experience in the use of vacuum grouting equipment and procedures. Submit the crew foremans~~*foreman's* ~~creditials~~*credentials* ~~to the Engineer prior to performing any vacuum grouting operations.~~

~~Conduct all stressing and grouting operations in the presence of the Engineer. Coordinate and schedule all post-tensioning activities to facilitate inspection by the Engineer.~~

~~**462-1.3 Penalties:**~~

~~All provisions of this Section are particularly important; therefore, the provisions in this Section 8-6 "Temporary Suspension of Contractor's Operations" and Section 9-6.3 "Withholding Payment" will be vigorously enforced.~~

462-1.4*3* Shop Drawings: Prepare shop drawings to address all requirements stated in the plans and the requirements stated herein. Indicate the approved post-tensioning systems to be used. Show tendon geometry and locations complying with the plans and the limitations of the selected post-tensioning system. Show all inlets, outlets, high point outlet inspection details, anchorage inspection details and permanent grout caps, protection system materials and application limits.

462-1.5*4* Alternate Post-Tensioning Designs: Alternate designs using a post-tensioning scheme other than that shown on the plans may be submitted for the Engineer's approval provided that the proposed alternate scheme fulfills the following requirements:

(1) The prestress system is a type described in and meeting the requirements of this ~~s~~*S*pecification.

(2) The net compressive stress in the concrete after all losses is at least as large as that provided by the post-tensioning shown on the Plans.

(3) The distribution of individual tendons at each cross section generally conforms to the distribution shown on the ~~P~~*p*lans.

(4) The ultimate strength of the structure with the proposed post-tensioning scheme meets the requirements of Section 5 of the "AASHTO LRFD Bridge Design Standard Specifications" and shall be equivalent to or greater than the ultimate strength provided by the original design.

(5) Stresses in the concrete and prestressing steel at all sections and at all stages of construction meet the requirements of the Design Criteria noted on the ~~P~~*p*lans.

(6) All provisions of the Design Criteria noted on the ~~P~~*p*lans shall be satisfied.

(7) The Contractor fully design and details, the elements where the alternate post-tensioning scheme is proposed to be used.

(8) The Contractor submits complete shop drawings including post-tensioning scheme and system, reinforcing steel, and concrete cover; and design calculations (including short and long term prestress losses) for the Engineer's approval.

(9) Any alternate post-tensioning system approved by the Engineer, which results in a change in quantity from that shown on the Contract Documents, will be paid based on the quantity actually used and accepted or the plan quantity, whichever is less, and at the unit bid price. If the approved alternate post-tensioning scheme or system is under a VECP (Value Engineering Change Proposal), the method of payment will be in compliance with the VECP agreement.

(10) Alternative post-tensioning shall be designed and sealed by the responsible Specialty Engineer.

462-1.6*5* Material Storage: Store all materials in a weatherproof building, shed or container until time of use.

462-2 Certification of Post-Tensioning Systems.

Use only post-tensioning systems that are approved by the Structures Design Office. Manufacturers seeking evaluation of their post-tensioning systems ~~shall~~*must* submit test results to the Structures Design Office and include certified test reports from an independent laboratory audited by AASHTO Materials Research Laboratory (AMRL) which shows the post-tensioning system meets all the requirements specified herein. If any component of the post-tensioning system is modified or replaced, the entire system must be retested and a new application made to the Structures Design Office. As an alternate to an AMRL, certification of test reports may be performed by an independent laboratory located outside the U.S. if the independent laboratory is approved by the State Materials Office.

Perform certification test for the plastic on a sample cut from the finished product. Provide the Engineer with certification that the plastic from the duct sample complies with all requirements of the specified cell class and the specified amount of the ultraviolet light stabilizer. Certify to the Engineer that the post-tensioning system being furnished is in compliance with all requirements stated herein.

Ensure that ~~A~~*a*ll components of a system ~~shall be~~*are* stamped with the suppliers name, trademark model number and size corresponding to catalog designation. Post-tensioning systems consist of an assembly of components for various sizes of strand or bars assembled and pressure tested. Post-tensioning systems will have to be developed and tested for bar systems and both internal (corrugated duct) and external (smooth duct) applications for each of the following*:*

-Department standard tendon sizes 4x0.6"ø, 7x0.6"ø, 12x0.6"ø, 19x0.6"ø and 27x0.6"ø strand. Systems utilizing 1/2 inch [13 mm] strand and providing equivalent force to these standard sizes may also be proposed for approval.

462-3 Definitions.

Anchorage Assembly: An assembly of various hardware components which secure a tendon at its ends after it has been stressed imparting the tendon force into the concrete.

Anticipated Set: ~~Anticipated set is that~~ *The* set which was assumed to occur in the design calculation of the post-tensioning forces immediately after load transfer.

Bar: Post-tensioning bars are high strength steel bars, normally available from 5/8 to 1 3/4 inch [15 to 46 mm] diameter and usually threaded with very coarse thread.

Bearing Plate: Any hardware that transfers the tendon force directly into a structure or the ground.

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.

Coupler: The means by which the prestressing force may be transmitted from one partial length prestressing tendon to another. (Strand couplers are not allowed.)

Duct: Material forming a conduit to accommodate prestressing steel installation and provide an annular space for the grout which protects the prestressing steel.

Family of Systems: Group of post-tensioning systems for various tendon sizes and unique tendon type with similar tendon components produced by a single supplier.

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

Grout: A mixture of cementitious materials and water with or without mineral additives or admixtures, proportioned to produce a pumpable consistency without segregation of the constituents, when injected into the duct to fill the space around the prestressing steel.

Grout Cap: A device which contains the grout and forms a protective cover sealing the post-tensioning steel at the anchorage.

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

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

Post-tensioning: A method of prestressing in which the tendons are tensioned after the concrete has reached a specified strength.

Prestressing Steel: The *s*teel element of a post-tensioning tendon, which is elongated and anchored to provide the necessary permanent prestressing force.

Post-Tensioning Scheme or Layout: The pattern, size and locations of post-tensioning tendons provided by the Designer on the Contract Plans.

Post-tensioning System: An assembly of specific models of hardware, including but not limited to anchorage assembly, local zone reinforcement, wedge plate, wedges, inlet, outlet, couplers, duct, duct connections and grout cap, used to construct a tendon of a particular size and type. The entire assembly must meet the system pressure testing requirement.

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 (sometimes referred to as working pressure).

Set (Also Anchor Set or Wedge Set): Set is the total movement of a point on the strand just behind the anchoring wedges during load transfer from the jack to the permanent anchorages. Set movement is the sum of slippage of the wedges with respect to the anchorage head and the elastic deformation of the anchor components. For bars, set is the total movement of a point on the bar just behind the anchor nut at transfer and is the sum of slippage of the bar and the elastic deformation of the anchorage components.

Strand: An assembly of several high strength steel wires wound together. Strands usually have six outer wires helically wound around a single straight wire of a similar diameter.

Tendon: A single or group of prestressing steel elements and their anchorage assemblies which imparts prestress to a structural member or the ground. Also, included are ducts, grouting attachments, grout and corrosion protection filler materials or coatings.

Tendon Size: The number of individual strands of a certain strand diameter or the diameter of a bar.

Tendon Type: The relative location of the tendon to the concrete shape, internal or external.

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.

Wedge Plate: The hardware that holds the wedges of a multi-strand tendon and transfers the tendon force to the anchorage assembly.

Wedge: A conically shaped device which anchors the strand in the wedge plate.

462-4 Materials.

Meet the requirements of following:

Wire Strand*	ASTM A 416
Bar**	ASTM A 722
Water	Section 923
Grout	Section 938
Epoxy Grout	Section 926
Magnesium Ammonium Phosphate Concrete	Section 930
Elastomeric Coating System	Section 975

462-4.1 Prestressing Steel:

(a) Strand: Unless otherwise noted on the plans, use uncoated strand meeting requirements of Section 933 (Grade 270 [1,860 MPa], low relaxation 7-wire strand meeting the requirements of ASTM A 416).

(b) Bar: Unless otherwise noted on the plans, *uncoated* ~~bars shall be uncoated~~, Grade 150 [1,035 MPa], high strength, coarse thread bar meeting the requirements of ASTM A 722, Type II.

462-4.2 Post-Tensioning System: Use approved post-tensioning systems, of the proper size and type to construct tendons shown on the ~~c~~*C*ontract ~~d~~*D*ocuments. Substitution of components of approved post-tensioning systems ~~are~~ *is* not allowed. For permanent applications, the use and location of bar couplers is subject to approval by the Engineer. Use only post-tensioning systems that utilize tendons fully encapsulated in anchorages and ducts. Systems which transfer prestress force by bonding the pretress steel directly to concrete are not allowed. Systems utilizing "Diablos" are not allowed.

462-4.2.1 Post-Tensioning Anchorages: *Ensure that* ~~T~~*t*he anchorages ~~shall~~ develop at least 95% of the actual ultimate tensile strength of the prestressing steel, when tested in an unbonded state, without exceeding the anticipated set.

Design anchorages so that the average concrete bearing stress is in compliance with the "AASHTO LRFD Bridge Design Specifications". Test and provide written certification that anchorages meet or exceed the testing requirements in the AASHTO LRFD Bridge Construction Specifications.

Galvanize the body of the anchorage in accordance with ASTM 123. Other components of the anchorage including wedges, wedge plate and local zone reinforcement are not required to be galvanized. Construct the bearing surface and wedge plate from ferrous metal. Equip all anchorages with a permanent fiber reinforced plastic grout cap that is vented and bolted to the anchorage.

Cast anchorages with grout outlets suitable for inspection from either the top or front of the anchorage. The grout outlet will serve a dual function of grout outlet and post-grouting inspection access. The geometry of the grout outlets must facilitate being drilled using a straight bit to facilitate endoscope inspection directly behind the anchor plate. Anchorages may be fabricated to facilitate both inspection locations or may be two separate anchorages of the same type each providing singular inspection entry locations.

462-4.2.2 Bar Couplers: Use couplers meeting the requirements of AASHTO LRFD Bridge Design Specifications and Bridge Construction Specifications. Test and provide written certification that the couplers meet or exceed the testing requirements in the AASHTO LRFD Bridge Construction Specifications.

462-4.2.3 Inlets, Outlets, Valves and Plugs: Provide permanent grout inlets and outlets made of polypropylene meeting the requirements for materials used for plastic corrugated duct. All inlets and outlets will be equipped with pressure rated mechanical shut-off valves or plugs. Threaded plugs may be made of stainless steel or any non-metallic material with antioxidant stabilizers added and having an

environmental stress cracking less than 192 hours as determined by ASTM D 1693, Condition C. Inlets, outlets, valves and plugs will be rated for a minimum pressure rating of 150 psi [1.03 MPa]. Use inlets/outlets with a minimum inside diameter of 3/4 inch (20 mm) for strand and 3/8 inch (10 mm) for single bar tendons and four-strand duct.

Use dual mechanical shutoff valves when performing vertical grouting. 1 inch [25mm] diameter inlets and outlets may be used on vertical bar tendons.

Temporary items, not included in the permanent structure, may be made of any suitable material.

462-4.2.4 Permanent Grout Caps: Use permanent grout caps made from fiber reinforced plastic which completely covers and seals all exposed metal parts of the anchorage. Seal the cap with neoprene "O" ring seals against the bearing plate and place a grout vent on the top of the cap. Ensure the permanent grout caps have sufficient anti-oxidant additives for a maintenance free life of 75 years. Test the cap material for environmental stress cracking per ASTM D 1693, Condition C. Caps ~~shall~~*must* have an endurance rating of 192 hours and be rated for a minimum pressure rating of 150 psi [1.03 MPa]. Use 316 stainless steel bolts to attach the cap to the anchorage.

462-4.2.5 Duct and Pipe:

462-4.2.5.1 General: Use only plastic duct, steel pipe or a combination of plastic duct and steel pipe. Ensure that all connectors, connections and components of post-tensioning system hardware are air and water tight and pass the pressure test requirements herein. Use smooth plastic duct in all post-tensioning systems used for external tendons. Use corrugated plastic duct in all post-tensioning systems used for all internal tendons except where steel pipe is required or in the webs of concrete I-girders. Use corrugated ferrous metal ducts in the webs of concrete I-girders. The use of "Diablos" is prohibited.

462-4.2.5.2 Duct or Pipe Minimum Diameter: Provide duct with a minimum internal diameter of at least 1/2 inch [13 mm] larger than the outside diameter, measured across the deformations, of the prestressing bar. For prestressing bars with couplers, size the entire length of duct to be 1/2 inch [13 mm] larger than the diameter of the coupler.

For multi-strand tendons, provide ducts with a minimum cross-sectional area 2 1/2 times the cross-sectional area of the prestressing steel.

Provide flat ducts with a minimum internal height of 1 1/4 inch [32 mm].

462-4.2.5.3 Connection Tolerance Between Pipe and Duct: Steel pipe and plastic duct may be connected directly to each other when the outside diameters do not vary more than ± 0.08 inch [2.0 mm]. Use a reducer when the diameters of the steel pipe and the plastic duct are outside of this tolerance.

462-4.2.5.4 Steel Pipes: Use galvanized schedule 40 steel pipes where shown in the plans and in all deviation blocks. Ensure that steel pipes used in the tendon anchorage zones are equipped with shear transfer devices shown in the plans.

462-4.2.5.5 Corrugated Plastic Duct: Do not use ducts manufactured from recycled material. Use seamless fabrication methods to manufacture ducts.

Use corrugated duct manufactured from non-colored, unfilled polypropylene meeting the requirements of ASTM D4101 " Standard Specification for Polypropylene Plastic Injection and Extrusion Materials" with a cell classification range of PP0346B44544 to PP0346B65884, having a minimum thickness of 0.08 inch [2.0 mm]. Also, meet these additional requirements: 0.2 % hindered amine light stabilizer non-yellowing type; environmental stress cracking as determined by ASTM D 1693, Condition C, not less than 192 hours.

462-4.2.5.5.1 Minimum Bending Radius for Corrugated Plastic Duct: Through testing, the manufacturer will establish the minimum bending radius for the duct. The test consists of a 1/2 inch [13 mm] diameter 270 ksi [1,860 MPa] strand stressed to 75 % GUTS bearing on an un-grouted duct for a length of not less than 2 feet [610 mm] nor more than 4 feet [1.22 m]. The test will *be of seven days duration*~~have a duration of seven days~~. Upon completion of the test period, the duct will be removed and the minimum thickness along the strand path must not be less than 0.06 inch [1.5 mm].

462-4.2.5.5.2 Testing Requirements for Corrugated Plastic Duct: Ensure that the duct system components and accessories meet the requirements of Chapter 4*,* Articles 4.1 through 4.1.8 of FIB Technical Report, Bulletin 7, titled "Corrugated Plastic Duct for Internal Bonded Post-Tensioning". To order the technical report, contact the International Federation of Structural Concrete (FIB) at fib@epfl.ch.

462-4.2.5.5.3 Corrugated Duct Connections and Fittings: Make all splices, joints, joints between segments (segmental construction), couplings and connections to anchorages with devices or methods (i.e. mechanical couplers, plastic sleeves in conjunction with shrink sleeve) producing a smooth interior alignment and an airtight sealed connection with no lips or kinks. Duct tape is not permitted to join or repair duct connections.

Construct connections and fittings of materials containing antioxidant stabilizers and having an environmental stress cracking not less than 192 hours as determined by ASTM D 1693, Condition C.

462-4.2.5.6 Smooth Duct: Use smooth duct manufactured from 100% virgin polyethylene material meeting the requirements of ASTM D 3350 with a minimum cell class of 344464C, having a dimension ratio (DR) of 17.0 as established by either ASTM D 3055 or ASTM F 714 as appropriate for the manufacturing process used.

Use smooth duct meeting the minimum pressure rating of 100 psi [0.69 Mpa] and manufactured to either of the following Specifications: ASTM D 3035 "Standard Specifications for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter" or ASTM F 714 "Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter".

462-4.2.5.6.1 External Duct Connections: *Use heat welding techniques in making* ~~Make~~ all splices between sections of plastic duct*,* ~~using heat welding techniques~~ in accordance with the duct manufacturers instructions or with mechanical couplers meeting the requirements of this ~~s~~*S*pecification. Ensure all connections have a minimum pressure rating of 100 psi. [0.69MPa], produce a smooth interior alignment and a connection with no lips or kinks.

Ensure all connections between steel pipe embedded in concrete and plastic duct are made by using a circular neoprene sleeve or other mechanical couplers, having a minimum pressure rating of 100 psi [0.69 MPa].

Neoprene sleeves ~~shall~~*must* have minimum wall thickness of 1/2 inch [13 mm] and be reinforced with a minimum of one layer of fabric reinforcement made of 100 percent glass fibers of "E" type yarn. Use a 1 inch [25.4 mm] wide power seated band and clamps constructed from 316 stainless steel on each end of the boot to seal against leakage of grout. Install~~ed~~ the band with an 80 to 120 lb [356 to 534 N] seating force. After installation, place heat shrink sleeve over the neoprene sleeve to protect the neoprene from long term exposure to the atmosphere.

462-4.2.5.7 Corrugated Ferrous Metal Ducts: Use galvanized corrugated ferrous metal ducts in the webs of all concrete I-girders. Manufacture ducts with either welded or interlocked seams with sufficient strength to maintain correct alignment during concrete placement and which will bend without crimping or flattening. Joints between sections of ducts shall have positive metallic connections which do not result in angle changes at joints.

462-4.2.5.8 Shipping and Storage of Ducts: Furnish duct with end caps to seal the duct interior from contamination. Ship in bundles which are capped and covered during shipping and storage. Protect ducts against ultraviolet degradation, crushing, excessive bending, dirt contamination and corrosive elements during transportation, storage and handling. Do not remove end caps supplied with the duct until the duct is incorporated into the bridge component. Store duct in a location that is dry and protected from the sun. Storage must be on a raised platform and completely covered to prevent contamination. If necessary, wash duct before use to remove any contamination.

462-4.2.6 Mechanical Couplers and Shrink Sleeve Requirements: Construct mechanical couplers with stainless steel, plastic or a combination of these materials. Use plastic resins meeting the requirements for plastic ducts to construct plastic couplers. Use 316 stainless steel to make metallic components.

Use shrink sleeves manufactured specifically for the size of the duct being coupled consisting of an irradiated and cross linked high density polyethylene backing with an adhesive layer that will withstand 150° F [66° C] operating temperature. The fully recovered sleeve thickness ~~shall~~*must* be a minimum of 111 mils [2.8 mm].

Use sleeve materials meeting the following requirements:

Property	Test Method	Minimum Requirements
Peel Strength	ASTM D 1000	46 pli [80N]
Softening Point	ASTM E 28	216° F [102°C]
Lap Shear	DIN 30 672M	58 psi [40 N/square cm]
Tensile Strength	ASTM D638	3480 psi [24 MPa]
Hardness	ASTM D2240	52 Shore D
Water Absorption	ASTM D570	less than 0.05%

462-4.2.7 System Test Requirements: For each family of post-tensioning systems, assemble systems representing one of each duct diameter in the family and perform the pressure test defined herein. The post-tensioning assembly includes at least one of each component required to make a tendon. For systems designed for use in precast segmental structures include duct couplers to be used at segment joints and steel pipes in the test assembly.

462-4.2.7.1 External Duct Systems: Condition the assembly by maintaining a pressure of 150 psi [1.03Mpa] in the system for 3 hours. After conditioning, the assembly ~~shall~~*must* sustain a 150 psi [1.03 MPa] internal pressure for five minutes with no more than 15 psi [103 kPa] reduction in pressure.

462-4.2.7.2 Internal Duct Systems: Test the assembly for compliance with the requirements of Chapter 4, Article 4.2, Stage 1 and Stage 2 Testing contained in FIB Technical Report, Bulletin 7, titled "Corrugated Plastic Duct for Internal Bonded Post-tensioning". For systems being tested for use in precast segmental construction, modify this test to include one duct coupler which is to be used at the segment joint. Cast the coupler into a two part concrete test block joined with epoxy. Maintain 40 psi [276 kPa] on the block cross-section until the epoxy has fully cured.

462-4.3 Grout: Use only grouts *that are* on the Department's Qualified Products List (QPL) meeting the requirements of Section 938. Select the post-tensioning grout for use by the proper application either repair, horizontal or vertical. Grout will be mixed with potable water meeting the requirements of Section 923. Maintain grout fluidity in strict compliance with the grout manufacturer's recommendations and test with a flow cone.

462-4.3.1Grout Storage: Store grout in a location that is both dry and convenient to the work. Storage in the open must be on a raised platform and with adequate waterproof covering to protect the material. On site storage of grout is limited to a maximum period of one month.

462-4.4 Samples for Testing and Identification:

462-4.4.1 General: Testing ~~shall~~*must* conform to the applicable ASTM Specifications for the prestressing material used.

Furnish all material samples for testing at no cost to the Department.

Consider the job site or site referred to herein*,* as the location where the prestressing steel is to be installed, whether at the bridge site or at the casting yard.

462-4.4.2 Prestressing Steel: Furnish samples for testing as described below for each manufacturer of prestressing strand and bar to be used on the project.

With each sample of prestressing steel strand or bar furnished for testing, submit a certification stating the manufacturer's minimum guaranteed ultimate tensile strength of the sample furnished.

The Engineer ~~shall~~*will* sample the following materials, at the plant or jobsite, from the prestressing steel used for post-tensioning operations:

(a) For strand: three randomly selected samples, 5 feet [1.5 m] long, per manufacturer, per size of strand, per shipment, with a minimum of ~~1~~*one* sample for every ten reels delivered.

(b) For bars: three randomly selected samples, 5 feet [1.5 m] long, per manufacturer, per size of bar, per heat of steel, with a minimum of one sample per shipment.

One of each of the samples furnished to represent a ~~lot~~*LOT,* will be tested. The remaining sample(s), properly identified and tagged, will be stored by the Engineer for future testing. In the event of loss or failure of the component the stored sample will be utilized to evaluate for minimum strength requirements. For acceptance of the LOT represented, test results must show ~~that~~ 100% of the guaranteed ultimate tensile strength.

462-4.4.3 LOTs and Identification: A LOT is that parcel of components as described herein. All bars, of each size from each mill heat of steel, and all strand from each manufactured reel to be shipped to the site ~~shall~~*must* be assigned an individual LOT number and ~~shall~~*must* be tagged in such a manner that each such LOT can be accurately identified at the job site. Submit records to the Engineer identifying assigned LOT numbers with the heat, or reel of material represented. All unidentified prestressing steel, or bars received at the site will be rejected. Also, loss of positive identification of these items at any time will be cause for rejection.

Provide a copy of the grout Quality Control Data Sheet *to the Engineer,* from the manufacturer*,* for each LOT number and shipment sent to the job site ~~to the Engineer~~. Materials with a total time from manufacture*r,* in excess of six months*,* ~~shall~~*must* be retested and certified by the supplier before use or ~~shall~~ be removed from the project and replaced.

462-4.5 Approval of Materials: The approval of any material by the Engineer ~~shall~~*will* not preclude subsequent rejection if the material is damaged in transit or later damaged or found to be defective.

462-5 Testing by the Contractor: (Not Required on Post-tensioned, Precast Flat Slab Bridges and Double Tee Bridges)

462-5.1 Tendon Modulus of Elasticity Test: If required in the Contract Documents or ordered by the Engineer, perform a tendon modulus of elasticity test in accordance with the following procedure.

For the purpose of accurately determining the tendon elongations while stressing, bench test two samples of each size and type of tendon to determine the modulus of elasticity prior to stressing the initial tendon.

For the purpose of this test, the bench length between anchorages ~~shall~~*must* be at least 40 feet [12 m] and the tendon duct ~~shall be~~ at least 2 inches [50 mm] clear of the tendon all around. The test procedure ~~shall~~*must* consist of stressing the tendon at an anchor assembly with a load cell at the dead end. Tension the test specimen to 80% of ultimate in ten increments and then detention from 80% of ultimate to zero in ten decrements. For each increment and decrement, record the gauge pressure, elongations and load cell force. Note elongations of the tendon for both ends and the central 30 feet [9 m], measured to an accuracy of ± 1/32 inch [±1 mm]. Correct the elongations for the actual anchorage set of the dead end.

Calculate the modulus as follows:

E = PL/Adl

where;

P= force in tendon,

L= distance between pulling wedges and dead end wedges or exact length in center 30 feet [9 m] of the tendon.

A= cross sectional area of the tendon based on nominal area.

dl= strand elongation for load P.

If the bench test varies from the modulus of elasticity used for the shop or working drawings by more than 1%, submit revisions to the theoretical elongations to the Engineer for approval.

When the observed elongations of the tendons in the erected structure fall outside the acceptable tolerances or to otherwise settle disputes, additional Tendon Modulus of Elasticity Tests may be required to the satisfaction of the Engineer.

If the source of prestressing steel changes during the project, additional test series or substantiation from previous projects, not to exceed two per source ~~shall~~*will* be required.

The apparatus and methods used to perform the test must be submitted to the Engineer for approval. Tests ~~shall~~*must* be conducted in the Engineer's presence.

462-5.2 In Place Friction Test: For tendons in excess of 100 feet [30 m] long, ~~the Contractor shall~~ test in place a minimum of one tendon in tendon group performing the same function. Functional tendon groups are cantilever tendons, continuity tendons, draped external tendons or continuous profiled tendons passing through one or more spans, etc. The selected tendon ~~shall~~*will* represent the size and length of the group of tendons being tested. The in-place friction test is not required on projects with straight tendons used in flat slabs or precast voided slabs.

The test procedure ~~shall~~ consist*s* of stressing the tendon at an anchor assembly with a load cell or a second certified jack at the dead end. Stress the test specimen to 80% of ultimate tendon strength in eight equal increments. For each increment, record the gauge pressure, elongations and load cell force. Take into account any wedge seating in both the live end (i.e., back of jack) and the dead end (i.e., back of load cell) and any friction within the anchorages, wedge plates and jack as a result of slight deviations of the strands through these assemblies. For long tendons requiring multiple jack pulls with intermediate temporary anchoring, keep an accurate account of the elongation at the jacking end allowing for intermediate wedge seating and slip of the jack's wedges.

If the elongation's fall outside the ±5% range compared to the anticipated elongations, investigate the reason and make detailed calculations confirming the final tendon forces are in agreement with the approved Plans.

In reconciling theoretical and actual elongations, do not vary the value of the expected friction and wobble coefficients by more than ±10%. Significant shortfall in elongations is indicative of poor duct alignments and/or obstructions. Correct or compensate for such elongations in a manner proposed by the Contractor and reviewed and approved by the Engineer at no additional cost to the Department.

The Engineer will require one successful friction test for each tendon group for the project.

If there are irreconcilable differences between forces and elongations, or other difficulties during the course of routine stressing operations, the Engineer may require additional in place friction tests.

The apparatus and methods used to perform the test must be submitted to the Engineer for approval. Tests ~~shall~~*must* be conducted in the Engineer's presence.

462-5.3 Tests Reports Required: If required, submit two test reports of the "Tendon Modulus of Elasticity Test" to the Engineer at least 30 days ~~prior to~~*before* installing the tendon.

Submit two test reports of the "In Place Friction Test" to the Engineer within two weeks after successful installation of the tested tendon.

462-5.4 Payment for Testing: *Contractor* ~~T~~*t*esting ~~by the Contractor~~ will not be paid for separately but ~~shall~~*will* be incidental to the price paid for the post-tensioning.

462-5. 5 Application of Test Results: Reevaluate the theoretical elongations shown on the post-tensioning shop or working drawings using the results of the tests for Tendon Modulus of Elasticity and In Place Friction as appropriate and correct as necessary. Submit revisions to the theoretical elongations to the Engineer for approval.

462-6 Protection of Prestressing Steel.

462-6.1 Shipping, Handling and Storage: Protect all prestressing steel against physical damage and corrosion at all times, from manufacturer to final grouting or encasing in the concrete. The Engineer will reject prestressing steel that has *at any time,* sustained physical damage ~~at any time~~. Carefully inspect

any reel that is found to contain broken wires during use and remove and discard lengths of strand containing broken wires. The wire ~~shall~~*must* be bright and uniformly colored, having no foreign matter or pitting on its surface.

Prestressing steel ~~shall~~*must* be packaged in containers for protection of the steel against physical damage and corrosion during shipping and storage. A corrosion inhibitor, which prevents rust, ~~shall~~*must* be placed in the package, or ~~shall~~ be incorporated in a corrosion inhibitor carrier type packaging material. The corrosion inhibitor ~~shall~~*must* have no deleterious effect on the steel or the concrete or bond strength of steel to concrete. Inhibitor carrier type packaging material ~~shall~~*must* conform to the provisions of Federal Specification MIL-P-3420. Immediately replace or restore packaging damaged from any cause, to the original condition.

The shipping package ~~shall~~*must* be clearly marked with a statement that the package contains high-strength prestressing steel, the care to be used in handling, and the type, kind and amount of corrosion inhibitor used, including the date when placed, safety orders and instructions for use. Specifically designate low relaxation (stabilized) strand*s* per requirements of ASTM A 416. Strands not so designated will be rejected.

462-6.2 During Installation in the Structure: The time between the first installation of the prestressing steel in the duct and the completion of the stressing and grouting operations will not exceed seven calendar days. Any light surface corrosion forming during this period of time will not be cause for rejection of the prestressing steel.

If ducts require flushing, use flush water containing slack lime (calcium hydroxide) or quicklime (calcium oxide) in the amount of 0.17 lb/gal [0.2 kg/L].

Except when ~~approved~~ *waived* by the Engineer in writing, failure to grout tendons within the seven calendar days specified will result in stoppage of the ~~effected~~ *affected* work ~~as defined in subarticle~~ *in accordance with* 8-6.

462-7 Fabrication.

462-7.1 General: Accurately and securely fasten all post-tensioning anchorages, ducts, inlet and outlet pipes, miscellaneous hardware, reinforcing bars, and other embedments at the locations shown on the ~~P~~*p*lans or on the approved Shop or Working Drawings or as otherwise approved by the Engineer. Construct tendons using the minimum number of duct splices possible.

462-7.2 Ducts: Accurately align ducts and position at the locations shown on the ~~P~~*p*lans or according to the approved Shop or Working Drawings or as otherwise approved by the Engineer. Securely fasten all internal ducts in position at regular intervals not exceeding 30 inches [750 mm] for steel pipes, 24 inches [610 mm] for round plastic duct and 12 inches [300 mm] for flat ducts to prevent movement, displacement or damage from concrete placement and consolidation operations. Show the method and spacing of duct supports on appropriate Shop Drawings. Ensure that ducts for external tendons are straight between connections to internal ducts at anchorages, diaphragms and deviation saddles and are supported at intermediate locations according to the plans or approved shop drawings.

Ensure that all alignments, including curves and straight portions, are smooth and continuous with no lips, kinks or dents. This also applies to curves in pre-bent steel pipe.

Carefully check and repair all ducts as necessary before placing any concrete.

After installing the ducts and until grouting is complete, ensure that all ends of ducts, connections to anchorages, splices, inlets and outlets are sealed at all times. Provide an absolute seal of anchorage and duct termination locations by using plumber's plugs or equal. Grout inlets and outlets will be installed with plugs or valves in the closed position. Leave low point outlets open. The use of duct tape is not permitted.

462-7.3 Splices and Joints: All splices, joints, couplings, connections (inlet and outlet) and valves shall be part of the approved post-tensioning system. Approved shrink-sleeve material may be used to repair duct. The use of duct tape to repair or seal duct is not permitted.

462-7.4 Location of Grout Inlets and Outlets: Place grout inlets and outlets at locations as shown on the plans and shop drawings. Equip all grout inlets and outlets with positive shut-off devices. At a minimum, grout inlets and outlets will be placed in the following positions:

(a) Top of the tendon anchorage;

(b) Top of the grout cap;

(c) At the high points of the duct when the vertical distance between the highest and lowest point is more than 20 in*ches*. [0.5 m];

(d) At a location 3 f*ee*t. [1 m] past high points of the duct on the down stream side opposite the direction of grouting;

(e) At all low points;

(f) At major changes in the cross section of the duct;

(g) At other locations required by the Engineer.

Extend grout tubes a sufficient distance out of the concrete member to allow for proper closing of the valves.

462-7.5 Tolerances: Ensure that post-tensioning ducts in their final position are within the following tolerances:

Table of Duct Position Tolerances		
Tolerances	Vertical position Inches [mm]	Lateral position Inches [mm]
Horizontal tendons in slabs or in slab regions of larger members:	±1/4 [±6]	± 1/2 [±13]
Longitudinal draped super-Structure tendons in webs: Tendon over supports or in middle third of span	±1/4 [±6]	±1/4[±6]
Tendon in middle half of web depth	±1/2 [±13]	±1/4 [±6]
Longitudinal, generally horizontal, superstructure tendons usually in top or bottom of member:	±1/4[±6]	±1/4 [± 6]
Horizontal tendons in substructures and foundations:	± 1/2 [±13]	± 1/2 [±13]
Vertical tendons in webs	Longitudinal position ±1 [±25]	Transverse position ±1/4 [±6]
Vertical tendons in pier shafts	±1/2 [±13]	±1/4 [±6]

In all other cases, ensure that tendons are not out of position by more than ±1/4 inch [±6 mm] in any direction.

Ensure entrance and exit angles of tendon paths at anchorages and/or at faces of concrete are within ±3 degrees [±5%] of desired angle measured in any direction.

Angle changes at duct joints ~~shall~~*must* not be greater than ±3 degrees [±5%] in any direction.

Locate anchorages within ±1/4 inch [±6 mm] of desired position laterally and ±1 inch [±25 mm] along the tendon except that minimum cover requirements must be maintained.

Position anchorage confinement reinforcement in the form of spirals, multiple U shaped bars or links, to be properly centered around the duct and to start within 1/2 inch [13 mm] of the back of the main anchor plate.

If conflicts exist between the reinforcement and post-tensioning duct, the position of the post-tensioning duct shall prevail and the reinforcement shall be adjusted locally with the Engineer's approval.

462-7.6 Internal Duct Pressure Test: Pressure test all internal ducts, except longitudinal ducts in segmental box girders, ~~prior to~~*before* casting concrete. Seal the duct at the termini and test with compressed air to determine if the duct connections require repair. Pressurize the duct to 5 psi [34 kPa] and lock-off the outside air source. Record the pressure loss over five minutes. If the pressure loss exceeds 2 psi [14 kPa] repair the leaks in the duct using methods approved by the Engineer.

462-8 Placing Concrete.

462-8.1 Precautions: Use methods to place and consolidate concrete which will not displace or damage any of the post-tensioning ducts, anchorage assemblies, splices and connections, reinforcement or other embedments. Fabricate all duct splices to prevent duct kinks during concrete placement. Use mandrels as needed to maintain duct alignment and shape.

462-8.2 Proving of Post-Tensioning Ducts: Upon completion of concrete placement, prove that the post-tensioning ducts are free and clear of any obstructions or damage and are able to accept the intended post-tensioning tendons by passing a torpedo through the ducts. Use a torpedo having the same cross-sectional shape as the duct and that is a 1/4 inch [6 mm] smaller all around than the clear, nominal inside dimensions of the duct. Make no deductions to the torpedo section dimensions for tolerances allowed in the manufacture or fixing of the ducts. For straight ducts, use a torpedo at least 2 feet [0.6 m] long. For curved ducts, determine the length so that when both ends touch the outermost wall of the duct, the torpedo is 1/4 inch [6 mm] clear of the innermost wall. If the torpedo will not travel completely through the duct, the Engineer will reject the member, unless a workable repair can be made to clear the duct. The torpedo ~~shall~~*must* pass through the duct easily, by hand, without resorting to excessive effort or mechanical assistance.

462-8.3 Problems and Remedies: The Engineer will reject ducts or any part of the work found to be deficient. Perform no remedial or repair work without the Engineer's approval.

462-9 Installing Tendons.

For tendons subjected to contamination with chlorides (construction location in an aggressive environment), flush the duct ~~prior to~~*before* placing the prestressing strands, with lime treated potable water and test for presence of chlorides and oils. Chlorides in the water must be less than 600 ppm. If chloride levels are in excess of 600 ppm, continue to flush the duct until the chloride level is below 250 ppm. Blow oil-free compressed air through the duct to remove any excess water in the duct.

Push or pull post-tensioning strands through the ducts to make up a tendon using methods which will not snag on any lips or joints in the ducts. Strands which are pushed*,* should be rounded off the end of the strand or fitted with a smooth protective cap.

Alternatively, strands may be assembled to form the tendon and pulled through the duct using a special steel wire sock ("Chinese finger") or other device attached to the end. The ends of the strands may not be welded together for this purpose. Round the end of the ~~pre-assemblied~~ *pre-assembled* tendon for smooth passage through the duct. Cut strands using an abrasive saw or equal. Flame cutting is not allowed.

Do not install permanent tendons before the completion of testing as required by these Specifications or Plans. As a sole exception, the tendon to be tested in the "In Place Friction Test" may be installed for the test.

462-10 Post-Tensioning Operations.

462-10.1 General: Do not apply post-tensioning forces until the concrete has attained the specified compressive strength as determined by cylinder tests.

462-10.2 Stressing Tendons: Tension all post-tensioning steel with hydraulic jacks so that the post-tensioning force is not less than that required by the plans or approved shop drawings, or as otherwise approved by the Engineer. Do not utilize monostrand jacks to stress tendons with five or more strands.

462-10.2.1 Maximum Stress at Jacking: The maximum temporary stress (jacking stress) in the post-tensioning steel ~~shall~~*must* not exceed 80% of its specified minimum ultimate tensile strength. Do not overstress tendons to achieve the expected elongation.

462-10.2.2 Initial and Permanent Stresses: The post-tensioning steel ~~shall~~*must* be anchored at initial stresses that will result in the long term retention of permanent stresses or forces of no less than those shown on the ~~P~~*p*lans or the approved shop drawings. Unless otherwise approved by the Engineer, the initial stress after anchor set ~~shall~~*must* not exceed 70% of the specified ultimate tensile strength of the post-tensioning steel.

Permanent stress and permanent force are the stress and force remaining in the post-tensioning steel after all losses, including long term creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, losses in the post-tensioning steel from the sequence of stressing, friction and unintentional wobble of the ducts, anchor set, friction in the anchorages and all other losses peculiar to the post-tensioning system.

462-10.2.3 Stressing Sequence: Except as noted on the ~~P~~*p*lans, the approved shop drawings or ~~as approved by the Engineer,~~ permanent post-tensioning tendons*, as approved by the Engineer,* must be stressed from both ends. The required force may be applied at one end and subsequently at the other end or simultaneously at both ends.

Single end stressing is permitted when the following are satisfied:

(a) Space limitations prohibit double end stressing.

(b) The calculated elongation of the post-tensioning steel at the second end is 1/2 inch [13 mm] or less.

(c) Single end stressing applied at alternate ends of paired adjacent post-tensioning tendons is required to produce a symmetrical force distribution in agreement with the ~~P~~*p*lan design.

For construction in stages where some tendons are required to be stressed before others, install and stress in accordance with the ~~P~~*p*lans or approved ~~S~~*s*hop ~~D~~*d*rawings or as otherwise approved by the Engineer.

462-10.3 Stressing Equipment: Only use equipment furnished by the supplier of the post-tensioning system (tendons, hardware, anchorages, etc.).

462-10.3.1 Stressing Jacks and Gauges: Each jack ~~shall~~*must* be equipped with a pressure gauge for determining the jacking pressure. The pressure gauge ~~shall~~*must* have an accurate~~ly~~ reading gage with a dial at least 6 inches [150 mm] in diameter.

462-10.3.2 Calibration of Jacks and Gauges: Calibrate each jack and its gauge(s) as a unit. The calibration ~~shall~~*must* consist of three test cycles with the cylinder extension of the jack in various positions (i.e. 2", 4", 8" stroke). At each pressure increment, average the forces from each test cycle to obtain an average force. Perform the calibration with the equipment (jack, pump, hoses, etc.) setup in the same configuration that is intended to be used at the job site. The post-tensioning supplier or an independent laboratory shall perform initial calibration of jacks and gauge(s). Use load cells calibrated within the past 12 months to calibrate stressing equipment. For each jack and gauge unit used on the project, furnish certified calibration charts to the Engineer prior to stressing. Supply documentation denoting the load cell(s) calibration date and tractability to NIST (National Institute of Standards ~~&~~*and* Technology) along with the jack/gauge calibration.

Provide the Engineer with certified calibration curves prior to the start of the work and every six months thereafter, or as requested by the Engineer. Calibrations subsequent to the initial calibration with a load cell may be accomplished by the use of a master gauge. Supply the master gauge to the Engineer in a protective waterproof container capable of protecting the calibration of the master gauge during shipment to a laboratory. Provide a quick-attach hydraulic manifold to enable quick

and easy installation of the master gauge to verify the permanent gauge readings. The master gauge will be calibrated and provided to the Engineer. The master gauge will remain in the possession of the Engineer for the duration of the project.

Any jack repair, such as replacing seals or changing the length of the hydraulic lines, is cause for recalibration using a load cell.

No extra compensation will be allowed for the initial or subsequent calibrations or for the use and required calibrations of the master gauge.

462-10.4 Elongations and Agreement with Forces: Ensure that the forces being applied to the tendon and the elongation of the post-tensioning tendon can be measured at all times.

Elongations shall be measured to the nearest 1/16 inch [1.5 mm].

For the required tendon force, the observed elongation ~~shall~~*must* agree within 7% of the theoretical elongation or the entire operation ~~shall~~*must* be checked and the source of error determined and remedied to the satisfaction of the Engineer before proceeding further. Do not overstress the tendon to achieve the theoretical elongation.

In the event that agreement between the observed and theoretical elongations at the required force falls outside the acceptable tolerances, the Engineer may, at his discretion and without additional compensation to the Contractor, require additional tests for "Tendon Modulus of Elasticity" and/or "In-Place Friction" in accordance with 462-5.1 and 462-5.2.

462-10.5 Friction: The Contract Plans were prepared based on the assumed friction and wobble coefficients and anchor set noted on the ~~P~~*p*lans. Submit calculations and show a typical tendon force diagram, after friction, wobble and anchor set losses, on the ~~S~~*s*hop ~~D~~*d*rawings based upon the expected actual coefficients and values for the post-tensioning system to be used. Show these coefficients and values on the ~~S~~*s*hop ~~D~~*d*rawings.

If, in the opinion of the Engineer, the actual friction significantly varies from the expected friction, revise post-tensioning operations so the final tendon force is in agreement with the ~~P~~*p*lans.

When friction must be reduced, graphite may be used as a lubricant, subject to the approval of the Engineer. Flush lubricants from the duct as soon as possible after stressing is completed by use of lime treated potable water. After ducts are flushed, immediately blow dry with oil-free air.

462-10.6 Wire Failures in Post-Tensioning Tendons: Multi-strand post-tensioning tendons, having wires which fail, by breaking or slippage during stressing, may be accepted provided the following conditions are met:

(a) The completed structure must have a final post-tensioning force of at least 98% of the design total post-tensioning force.

(b) For precast or cast-in-place segmental construction and for any similar construction that has members post-tensioned together across a common joint face, at any stage of erection, the post-tensioning force across a mating joint must be at least 98% of the post-tensioning required for that mating joint for that stage of erection.

(c) Any single tendon must have no more than a 5% reduction in cross-sectional area of post-tensioning steel due to wire failure.

Any of the above conditions may be waived with approval of the Engineer, when conditions permit the Contractor to propose acceptable alternative means of restoring the post-tensioning force lost due to wire failure.

462-10.7 Cutting of Post-Tensioning Steel: Cut post-tensioning steel with an abrasive saw within 3/4 to 1 1/2 inches [20 to 40 mm] away from the anchoring device. Flame cutting of post-tensioning steel is not allowed.

462-10.8 Record of Stressing Operations: Keep a record of the following post-tensioning operations for each tendon installed:

(a) Project name, Financial Project ID;

(b) Contractor and/or subcontractor;

(c) Tendon location, size and type;

(d) Date tendon was first installed in ducts;
(e) Reel number for strands and heat number for bars
(f) Tendon cross-sectional area;
(g) Modulus of elasticity;
(h) Date Stressed;
(i) Jack and Gauge numbers per end of tendon;
(j) Required jacking force;
(k) Gauge pressures;
(l) Elongations (theoretical and actual);
(m) Anchor sets (anticipated and actual);
(n) Stressing sequence (i.e. tendons to be stressed before and after;
(o) Stressing mode (one end/ two ends/ simultaneous);
(p) Witnesses to stressing operation (Contractor and inspector);
(q) Date grouted

Record any other relevant information. Provide the Engineer with a complete copy of all stressing and grouting operations.

462-10.9 Duct Pressure Field Test: After stressing and ~~prior to~~*before* grouting internal or external tendons, install all grout caps, inlets and outlets and test the tendon with compressed air to determine if duct connections require repair. Pressurize the tendon to 100 psi [690 kPa] and lock-off the outside air source. Record pressure loss for five minutes. A pressure loss of 10 psi [69 kPa] is acceptable. If the pressure loss exceeds 10 psi [69 kPa], repair leaking connections using methods approved by the Engineer.

462-10.10 Tendon Protection: Within four hours after stressing, install grout caps and seal all other tendon openings. If tendon contamination occurs, remove and replace the tendon.

462-11 Grouting Operations.

462-11.1 Grouting Operations Plan: Submit a grouting operations plan for approval at least ~~6~~*six* weeks in advance of any scheduled grouting operations. Written approval of the grouting operations plan by the Engineer is required before any grouting of the permanent structure takes place.

At a minimum, the plan will address and provide procedures for the following items:

(a) ~~Provide n~~*N*ames and proof of training for the grouting crew and the crew supervisor in conformance with this specification;

(b) Type, quantity, and brand of materials used in grouting including all certifications required;

(c) Type of equipment furnished, including capacity in relation to demand and working condition, as well as back-up equipment and spare parts;

(d) General grouting procedure;
(e) Duct pressure test and repair procedures;
(f) Method to be used to control the rate of flow within ducts;
(g) Theoretical grout volume calculations;
(h) Mixing and pumping procedures;
(i) Direction of grouting;
(j) Sequence of use of the inlets and outlet pipes;
(k) Procedures for handling blockages;
(l) Procedures for possible post grouting repair.

Before grouting operations begin, a joint meeting of the ~~c~~*C*ontractor, subcontractors grouting crew and the Engineer will be conducted. At the meeting the grouting operation plan, required testing, corrective procedures and any other relevant issues will be discussed.

462-11.2 Grout Inlets and Outlets: Connections from the grout pump hose to inlets shall be free of dirt and be air- tight. Inspect valves to be sure that they can be opened and closed properly.

462-11.3 Supplies: Before grouting operations start, provide an adequate supply of water and compressed air for clearing and testing the ducts, mixing and pumping the grout. Where water is not supplied through the public water supply system, a water storage tank of sufficient capacity must be provided.

462-11.4 Equipment:

462-11.4.1 General: Provide grouting equipment consisting of measuring devices for water, a high-speed shear colloidal mixer, a storage hopper (holding reservoir) and a pump with all the necessary connecting hoses, valves, and pressure gauge. Provide pumping equipment with sufficient capacity to ensure that the post-tensioning ducts to be grouted can be filled and vented without interruption at the required rate of injection in not more than 30 minutes.

Provide an air compressor and hoses with sufficient output to perform the required functions.

Provide vacuum grouting equipment (volumetric measuring type) prior to the start of grouting operations and retain the equipment on the job during the duration of tendon grouting operations.

462-11.4.2 Mixer, Storage Hopper: Provide a high speed shear colloidal mixer capable of continuous mechanical mixing producing a homogeneous and stable grout free of lumps and undispersed cement. The colloidal grout machinery will have a charging tank for blending and a holding tank. The blending tank must be equipped with a high shear colloidal mixer. The holding tank must be kept agitated and at least partially full at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct.

Add water during the initial mixing by use of a flow meter or calibrated water reservoir with a measuring accuracy equal to one percent of the total water volume.

462-11.4.3 Grout Pumping Equipment: Provide pumping equipment capable of continuous operation which will include a system for circulating the grout when actual grouting is not in progress.

The equipment will be capable of maintaining pressure on completely grouted ducts and will be fitted with a valve that can be closed off without loss of pressure in the duct.

Grout pumps will be positive displacement type, will provide a continuous flow of grout and will be able to maintain a discharge pressure of at least 145 psi [1 MPa].

Pumps will be constructed to have seals adequate to prevent oil, air or other foreign substances entering the grout and to prevent loss of grout or water. The capacity will be such that an optimal rate of grouting can be achieved.

A pressure gauge having a full scale reading of no more than 300 psi [2 MPa] will be placed at the duct inlet. If long hoses (in excess of 100 ft [30 m]) are used, place ~~2~~*two* gauges, one at the pump and one at the inlet.

The diameter and rated pressure capacity of the grout hoses must be compatible with the pump output.

462-11.4.4 Vacuum Grouting Equipment: Provide vacuum grouting equipment at the job site concurrently with all pressure grouting operations. Projects containing only transverse tendons with a length of less than 100 feet [30 m] are exempt to this requirement. Vacuum grouting equipment ~~shall~~*must* be the volumetric measuring type with the ability to measure a void and supply a measured volume of grout to fill the void.

462-11.4.5 Stand-by Equipment: During grouting operations, provide a stand-by grout mixer and pump.

462-11.5 Grouting:

462-11.5.1 General: Grout tendons in accordance with the procedures set forth in the approved grouting operation plan. Grout all empty ducts.

462-11.5.2 Temperature Considerations: Maximum grout temperature will not exceed 90°F [32°C]. Use chilled water and/or pre-cooling of the bagged material to maintain mixed grout temperature below the maximum allowed temperature. Grouting operations are prohibited when the

ambient temperature is below 40°F [4°C] or is 40°F [4°C] and falling. Remove any standing water from ducts using compressed air, if freezing temperatures are forecast.

462-11.5.3 Mixing and Pumping: Mix the grout with a metered amount of water.

The materials will be mixed to produce a homogeneous grout. Continuously agitate the grout until grouting is complete.

462-11.5.4 Grout Production Test: During grouting operations the fluidity of the grout ~~shall~~*must* be strictly maintained within the limits established by the grout manufacturer. A target flow rate ~~shall~~*will* be established by the manufacturer's representative*,* based on ambient weather conditions. Determine grout fluidity by use of either test method found in Section 938. Perform fluidity test and maintain the correct water to cementitious ratio. Do not use grout which tests outside the allowable flow rates.

Condition the grout materials as required to limit the grout temperature at the end of the grout hose to 90°F [32°C]. Check the temperature of the grout at the end of the grout hose hourly.

At the beginning of each days grouting operation, perform a wick induced bleed test in accordance with Section 938. If zero bleed is not achieved at the end of the required time period, do not begin grouting of any further tendons until the grouting operations have been adjusted and further testing shows the grout meets the specified requirements.

462-11.5.5 Grout Operations: Open all grout outlets before starting the grouting operation. Grout tendons in accordance with the Grouting Operations Plan.

Unless approved otherwise by the Engineer, pump grout at a rate of 16 feet (5 m) to 50 feet [15 m] of duct per minute. Conduct normal grouting operations at a pressure range of 10 psi [69 kPa] to 50 psi [345 kPa] measured at the grout inlet. Do not exceed the maximum pumping pressure of 145 psi [1.0 MPa] at the grout inlet.

Use grout pumping methods which will ensure complete filling of the ducts and complete encasement of the steel. Grout must flow from the first and subsequent outlets until any residual water or entrapped air has been removed prior to closing the outlet.

Pump grout through the duct and continuously discharge it at the anchorage and grout cap outlets until all free water and air are discharged and the consistency of the grout is equivalent to that of the grout being pumped into the inlet. Close the anchorage outlet and discharge a minimum of 2 gallons [7.5 liters] of grout from the grout cap into a clean receptacle. Close the grout cap outlet.

For each tendon, immediately after uncontaminated uniform discharge begins, perform a fluidity test using the flow cone on the grout discharged from the anchorage outlet. The measured grout efflux time will not be less than the efflux time measured at the pump or minimum acceptable efflux time as established in Section 938. Alternately, check the grout fluidity using the Wet Density method contained in Section 938. The measured density must fall within the values established in Section 938. The density at the final outlet ~~shall~~*must* not be less than the grout density at the inlet. If the grout fluidity is not acceptable, discharge additional grout from the anchorage outlet and test the grout fluidity. Continue this cycle until an acceptable grout fluidity is achieved. Discard grout used for testing fluidity. After all outlets have been bled and sealed, elevate the grout pressure to ± 75 psi [520 kPa] seal the inlet valve and wait two minutes to determine if any leaks exist. If leaks are present, fix the leaks using methods approved by the Engineer. Repeat the above stated process until no leaks are present. If no leaks are present, bleed the pressure to 5 psi [34 kPa] and wait a minimum of ten minutes for any entrapped air to flow to the high points. After the minimum ten minutes~~.~~ period has expired, increase the pressure as needed and discharge grout at each high point outlet to eliminate any entrapped air or water. Complete the process by locking a pressure of 30 psi [207 kPa) into the tendon.

If the actual grouting pressure exceeds the maximum allowed, the inlet will be closed and the grout will be pumped at the next outlet, which has just been, or is ready to be closed as long as a one-way flow is maintained. Grout will not be pumped into a succeeding outlet from which grout has not yet flowed. If this procedure is used, the outlet/inlet*,* which is to be used for pumping will be fitted with a positive shut-off and pressure gage.

When complete grouting of the tendon cannot be achieved by the steps stated herein, stop the grouting operation. After waiting 48 hours, fill the tendon with grout in accordance with the procedure outlined in 462-11.5.7.

462-11.5.6 Vertical Grouting: Grouting of cable stays is not covered by this ~~s~~specification. For all vertical tendons, provide a standpipe at the upper end of the tendon to store bleed water and grout, maintain the grout level above the level of the prestressing plate and anchorage. This device will be designed and sized to maintain the level of the grout at an elevation which will assure that bleeding will at no time cause the level of the grout to drop below the highest point of the upper anchorage device. Design the standpipe to allow all bleed water to rise into the standpipe, not into the uppermost part of the tendon and anchorage device.

Discharge grout and check grout fluidity as described in 462-11.5.5. As grouting is completed, the standpipe will be filled with grout to a level which assures that, as settlement of the grout occurs, the level of the grout will not drop below the highest point in the upper anchorage device. If the level of the grout drops below the highest point in the anchorage device, immediately add grout to the standpipe. After the grout has hardened, the standpipe will be removed. In the presence of the Engineer, visually inspect for voids using an endoscope or probe. Fill all voids found in the duct using volumetric measuring vacuum grouting processes.

For vertical tendons in excess of 100 f*ee*t. [30 m] or if the grouting pressure exceeds the maximum recommended pumping pressure, then grout will be pumped at increasingly higher outlets which have been or are ready to be closed as long as a one-way flow of grout is maintained. Grout will be allowed to flow from each outlet until all air and water have been purged prior to using that outlet for pumping.

462-11.5.7 Post-Grouting Operations and Inspection: Do not remove or open inlets and outlets until the grout has cured for 24 to 48 hours and inspections are to be performed within one hour. After the grout has cured, remove all outlets located at anchorages and high points along the tendon to facilitate inspection. Depending on the geometry of the grout inlets, drilling may be required to penetrate to the inner surface of the trumpet or duct. Use drilling equipment that will automatically shut-off when steel is encountered. Unless grout caps are determined to have voids by sounding, do not drill into the cap. Perform inspections in the presence of the Engineer using endoscopes or probes. Fill all voids using the volumetric measuring vacuum grouting process. Within four hours of completion of the inspections, vacuum injection or removal of non-inspected inlet/outlets, seal the inlet/outlet and repair the remaining void in accordance with 462-12.2. Use an injection tube to extend to the bottom of the drilled holes for backfilling with epoxy or grout.

Post grouting inspection of tendons having a length of less than 150 feet [46 m] may utilize the following statistical frequency for inspection:

1. For the first 20 tendons, inspect all outlets located at anchors and tendon high points by drilling and probing with an endoscope or probe. If one or more of the inspection locations are found to contain a defect (void), continue testing all tendons until 20 consecutive tendons have been inspected and no voids have been found.

2. When no defects are detected as defined in No. 1 above, the frequency of inspection can be reduced to inspect every other tendon (50%). If a defect is located, inspect the last five tendons grouted. Return to step 1 above and renew the cycle of 100% tendon inspection.

If tendon grouting operations were prematurely terminated prior to completely filling the tendon, drill into the duct and explore the voided areas with an endoscope. Probing is not allowed. Determine the location and extent of all voided areas. Install grout inlets as needed and fill the voids using volumetric measuring vacuum grouting equipment.

462-11.5.8 Grouting Report: Provide a grouting report signed by the Contractor and/or the Subcontractor within 72 hours of each grouting operation for review by the Engineer.

Report the theoretical quantity of grout anticipated as compared to the actual quantity of grout used to fill the duct. Notify the Engineer immediately of shortages or overages.

Information to be noted in the records ~~shall~~*must* include but ~~shall~~ not necessarily be limited to the following: identification of the tendon; date grouted; number of days from stressing to grouting; type of grout; tendon(s) grouted; injection end and applied grouting pressure, ratio of actual to theoretical grout quantity; summary of any problems encountered and corrective action taken.

462-12 Forming and Repairs of Holes and Block-Outs.

462-12.1 Repair of Lifting and Access Holes: Repair all holes with Magnesium Ammonium Phosphate Concrete meeting the requirements of Section 930. Immediately before casting the concrete (within 24 hrs.), mechanically clean and roughen the mating concrete surfaces to remove any laitance and expose the small aggregate. Grit blasting or water blasting using a minimum 10,000 psi [69 MPa] nozzle pressure is required. Flush surface with water and blow dry. Mix, place and cure the material in strict compliance with the manufacture's recommendations.

Upon completion of the deck grooving, coat the repaired holes, block-outs and an area extending 6 inches [150 mm] outside the perimeter of the repair with Methyl Methacrylate. Apply and remove any excess material as per manufacturer's instructions.

Alternately, a Type Q Epoxy grout meeting the requirements of Section 926 may be used for the repair material.

462-12.2 Repair of Grout Inlets and Outlets: Place threaded plastic caps in all inlet/outlet locations required in the plans. Repair inlets/outlets as shown on the plans using an epoxy grout, Type E epoxy or Type F-1 epoxy meeting the requirements of Section 926. Prepare the surface to receive the epoxy material in strict compliance with the manufacture's recommendations.

462-13 Protection of Post-Tensioning Anchorages.

Within seven days upon completion of the grouting, protect the anchorage of post-tensioning bars and tendons as indicated in the plans. Use plastic threaded caps to plug all grout inlets/outlets. Use an epoxy grout, Type Q, meeting the requirements of Section 926 to construct all pourbacks located at anchorages.

Remove all laitance, grease, curing compounds, surface treatments, coatings and oils by grit blasting or water blasting using a minimum 10,000 psi [69 MPa] nozzle pressure. Flush surface with water and blow dry. Surfaces must be clean, sound and without any standing water. In case of dispute, use ACI 503 for substrate testing and develop a minimum of 175 psi. [1.2 MPa] tension (pull-off value).

Mix and apply epoxy as per manufacturer's current standard technical guidelines. *Construct* ~~A~~*a*ll pour-backs ~~shall be constructed~~ in leak proof forms creating neat lines. The epoxy grout may require pumping for proper installation. Construct forms to maintain a liquid head to insure intimate contact with the substructure. Use vents as needed to provide for the escape of air to insure complete filling of the forms.

Coat the exposed surfaces of pour-backs or grout caps, except on transverse tendons, with an elastomeric coating system meeting the requirements of Section 975 and having a thickness of 30 to 45 mils. Assure concrete, plastic or other substrates are structurally sound, clean and dry. Concrete must be a minimum of 28 days old. Remove all laitance, grease, curing compounds, surface treatments, coatings and oils by grit blasting or water blasting using a minimum 10,000 psi [69 MPa] nozzle pressure to establish the anchor pattern. Blow the surface with compressed air to remove the dust or water.

Construct a 2 x 4 ft [0.61 x 1.2 m] concrete test block with a similar surface texture to the surfaces to be coated and coat a vertical face with the elastomeric coating system chosen. Determine the number of coats required to achieve a coating thickness between 30 to 45 mils without runs and drips. Mix and apply elastomeric coating as per manufacturer's current standard technical specifications. Spray or roller application is permitted (spray application preferred). Apply coatings using approved and experienced personnel with a minimum of three years experience applying similar polyurethane systems. Submit the credentials of these persons to the Engineer for review and consideration for approval.

462-14 Method of Measurement.

The quantity of post-tensioning tendons to be paid for under this Section will be the computed weight, in pounds [kilograms], of permanent post-tensioning steel tendons entered into the completed structure and accepted. Measurement will be the theoretical plan length measured from anchorage to anchorage (measured from front face of the bearing plate) with no allowance made for waste or extension past the bearing faces. No measurement will be made for temporary post-tensioning which will be considered incidental to the item "Post-Tensioning Tendons".
For quantity determination, the following unit weights will be used:

Prestressing System	Weight per Unit Length lb/ft [kg/m]
1/2 inch [12.7 mm] diameter 7 wire strand	0.52 [0.77]
0.6 inch [15.2 mm] diameter 7 wire strand	0.74 [1.1]
1 inch [26 mm] high strength deformed bar	3.01 [4.48]
1 1/4 inch [32 mm] high strength deformed bar	4.39 [6.54]
1 3/8 inch [36 mm] high strength deformed bar	5.56 [8.28]
1 3/4 inch [46 mm] high strength deformed bar	9.23 [13.74]

462-15 Basis of Payment.

462-15.1 General: Post-tensioning tendons will be paid for at the Contract unit price per pound [kilogram] of steel tendon, completed and accepted. Payment will be full compensation for furnishing, installing, stressing and grouting all temporary and permanent post-tensioning tendons. Payment also includes anchorage assemblies and associated supplemental reinforcing steel required by the supplier, post-tensioning system hardware which is not embedded in concrete, ducts, grout and grouting, all testing, protection of post-tensioning anchorages, vents, inlets, outlets and all labor, materials, tools, equipment and incidentals necessary for completing the work in accordance with the Contract Documents. This payment also includes lubricants in the tendon ducts for friction control and flushing lubricants or contaminants from the ducts. Anchorage components, ducts and similar items of post-tensioning system hardware embedded within precast components or cast-in-place concrete will be deemed to be included in the cost of the precast components or cast-in-place concrete.

If the Contractor constructs the structure with an accepted alternate not detailed on the ~~P~~plans, payment will be based on the unit price bid extended by either the quantities shown in the Contract Documents or the actual quantities used and accepted, whichever is less.

Permanent post-tensioning strand or bar tendons which are an integral part of individual precast concrete segments or units will be measured and paid for under this item and will not be considered incidental to the cost of those precast concrete segments or units.

Payment for post-tensioning will be made following successful placement, stressing, grouting, inspection, protection and approval by the Engineer. Full payment for post-tensioning tendons, within precast segmental concrete structure units, may occur prior to erection of the segments into final position when ducts have been grouted and anchorage protection system applied and the segmental unit otherwise approved for placement by the Engineer.

462-15-2 Payment Items:

Payment will be made under:

Item No. 462-2 - Post-tensioning Tendons - per pound
Item No. 2462-2- Post-tensioning Tendons - per kilogram

~~If the Contractor constructs the structure with an accepted alternate not detailed on the Plans, payment will be based on the unit price bid extended by either the quantities shown in the Contract Documents or the actual quantities used and accepted, whichever is less.~~

~~Permanent post-tensioning strand or bar tendons which are an integral part of individual precast concrete segments or units will be measured and paid for under this item and will not be considered incidental to the cost of those precast concrete segments or units.~~

~~Payment for post-tensioning will be made following successful placement, stressing, grouting, inspection, protection and approval by the Engineer. Full payment for post-tensioning tendons, within precast segmental concrete structure units, may occur prior to erection of the segments into final position when ducts have been grouted and anchorage protection system applied and the segmental unit otherwise approved for placement by the Engineer.~~