

## SECTION 502

### PRESTRESSING CONCRETE

**502-1.01 DESCRIPTION.** Prestress precast or cast-in-place concrete by furnishing, placing, tensioning, and bonding prestressing steel by using either pretensioning or post-tensioning methods or a combination of the two methods ~~Furnish, place, and tension prestressing steel for pretensioning precast concrete or post-tensioning cast-in-place concrete~~ in accordance with the Contract.

For pretensioning, this work also includes furnishing and installing all materials and equipment necessary to prestress concrete as designated in the Contract.

For post-tensioning, this work includes furnishing and installing all post-tensioning systems and all other pertinent items necessary for the particular prestressing system used, including but not limited to ducts, anchorage assemblies, supplementary reinforcement, and grout used for pressure grouting ducts.

#### **502-1.02 DEFINITIONS.**

**ANCHORAGE.** An assembly of various hardware components that secure a tendon at its ends after it has been stressed imparting the tendon force into the concrete.

**ANTICIPATED SET.** The set that was assumed to occur in the design calculation of the post-tensioning forces immediately after load transfer.

**BEARING PLATE.** Hardware that transfers the tendon force directly into concrete.

**BLEED.** The autogenous flow of mixing water within or its emergence from newly placed grout caused by the settlement of the solid materials within the mass and filtering action of strands.

**DUCT.** Material forming a conduit to accommodate prestressing steel installation and provide an annular space for the grout that protects the prestressing steel.

**FLUIDITY.** 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 that contains the grout and forms a protective cover sealing the post-tensioning steel at the anchorage.

**POST-TENSIONING.** A method of prestressing in which the tendons are tensioned after the concrete has reached a specified strength.

**PRESTRESSING STEEL.** The steel 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.

**POST-TENSIONING SYSTEM.** An assembly of proprietary post-tensioning hardware, including but not limited to anchorage assembly, local zone reinforcement, wedge plate, wedges, bearing

plate, prestressing steel, duct, duct connections, vents and grout cap, used to construct a tendon of a particular size and type.

**SET (Also Anchor Set or Wedge Set).** The total movement of a point on the strand outside 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.

**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.

**STRAND COUPLER.** An assembly by which the prestressing force may be transmitted from one partial length prestressing tendon to another. (Strand couplers are not permitted.)

**TENDON.** A single or group of prestressing steel elements and their anchorage assemblies that imparts prestress to a structural member. 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.

**THIXOTROPIC.** The material property exhibited by certain grouts that enable material to stiffen, achieve a higher viscosity, in a short time while at rest, but to become liquid, acquire a lower viscosity, when mechanically agitated.

**VENT.** Tubing or pipe used for injection of grout into the duct and to allow escape of air, water, grout and bleed water from the duct.

**WEDGE.** A conically shaped device that anchors the strand in the wedge plate.

**WEDGE PLATE.** The hardware that holds the wedges of a multi-strand tendon and transfers the tendon force to the anchorage assembly.

**502-2.01 MATERIALS.** Use materials that conform to the following:

Concrete	Section 501
<u>Water</u>	<u>Subsection 712-2.01</u>
Reinforcing steel	<u>Subsection 709-2.01</u> <del>Section 503</del>
<u>Epoxy-Coated Reinforcing Steel</u>	<u>Subsection 709-2.01</u>
<del>Portland Cement</del>	<del>Section 701</del>
<del>Grout</del>	<del>Section 701</del>
Prestressing Steel and Fittings	Section 721
<u>Post-tension Grout</u>	<u>Subsection 701-2.05</u>
<del>Corrosion inhibitor</del>	<del>Federal Specification MIL-P-3420F-87</del>
<del>Approved Ducts</del>	<del>AASHTO LRFD Bridge Design Specifications</del>

~~Expanded polyethylene material: Closed-cell expanded polyethylene planks with a density of 2.2 ( $\pm 0.2$ ) lb/ft<sup>3</sup> as determined by ASTM C 271. Use planks that have a maximum compressive deflection of 50% at 15 ( $\pm 3$ ) psi, and that do not retain a compression set of more than 15% of the plank thickness after maintaining 50% compression deflection for 22 hours with a following 24-hour recovery period, as determined by ASTM D 1056. Use planks that have a maximum water absorption by weight of 10% as determined by ASTM C 272.~~

## CONSTRUCTION REQUIREMENTS

**502-3.01 ~~PRESTRESSING~~ PRETENSIONING METHODS.** Select a ~~prestressing~~ pretensioning method that provides the magnitude and distribution of prestressing force and ultimate strength ~~without exceeding allowable temporary stresses~~, subject to the requirements in this specification.

~~Perform the prestressing by either pretensioning or post-tensioning methods, or a combination of the two methods.~~

1. Submittals.

~~a.~~ Working Drawings. Before casting members to be prestressed, submit for approval working drawings including complete details and substantiating calculations of the method, materials, and equipment proposed for use in the prestressing operations, any additions or rearrangement of reinforcing steel, and any revision in concrete dimensions.

Include an outline of the method and sequence of stressing, complete specifications and details of the prestressing steel and anchoring devices to be used, anchoring stresses, strand release sequence, ~~type of enclosures~~, and other data pertaining to the prestressing operations, including the proposed arrangement of the prestressing units in the members. ~~Include conformance test data for the post tensioning system, conforming with Subsection 721-2.05.~~

Compute the anticipated camber at the time of prestressing force transfer and at other significant times. Show the values on the shop drawings as a time/deflection curve, subject to approval.

Include on working drawings embedded items such as ~~the post-tensioning ducts, vents, anchorage reinforcement and hardware~~, reinforcing steel, lifting devices, coil anchors, anchor bolts, ~~earthquake restrainers, deck joint seal assemblies~~, drainage systems, utility conduits and other such items. Ensure there will be no conflict between the planned positions of any embedded items and that concrete cover will be adequate.

~~b2.~~ Quality Control Program. Submit for approval a quality control program that verifies that all materials and workmanship incorporated into the ~~precast~~ prestressed concrete members conform ~~with~~ to the requirements.

Perform all pretensioning operations under the direct supervision of a qualified pretensioning technician. Provide a pretensioning technician, skilled in the prestressing method, to aid and instruct in using the prestressing equipment and in installing the materials to obtain required results.

The pretensioning technician shall be present at all times during prestressing steel installation and tensioning and shall provide close observation and control of all pretensioning operations, as necessary for compliance with the Contract.

3. Protection of Prestressing Steel. Protect prestressing steel and anchor assemblies against physical damage and corrosion at all times from manufacture to grouting. Keep prestressing steel and anchor assemblies clean and free of deleterious material such as grease, oil, wax, paint, or other foreign materials. The Engineer will reject prestressing steel that has sustained physical damage at any time. The Engineer will reject prestressing steel that has developed visible rust pitting or other results of corrosion, other than rust stain.

Package prestressing steel and anchorage assemblies in containers or shipping forms for the protection of the steel against physical damage and corrosion during shipping and storage. Protect the prestressing steel from corrosion during shipping and storage by placing a corrosion inhibitor in the package or form, incorporating a corrosion inhibitor carrier-type packaging material, or applying a corrosion inhibitor directly to the steel. Do not use corrosion

inhibitors that have deleterious effect on the steel or concrete or bond strength of steel to concrete. Immediately replace packaging or forms damaged from any cause or restore packaging to original condition.

Clearly mark the shipping package or form with a statement that the package contains high-strength prestressing steel, and the type of corrosion inhibitor used, including the date packaged.

4. Prestressing Equipment. Use hydraulic jacks to tension prestressing steel so that the force in the prestressing steel will not be less than the value shown on the Plans or as approved by the Engineer. Do not use monostrand jacks to stress multi-strand tendons.

Equip each jack used to stress tendons with either:

- a. two pressure gages
- b. one pressure gage and one load cell

In the event that any uncertainty exists regarding jack calibration, pressure gage usage, strand elongation or any other prestressing strand tensioning issue, provide and use a calibrated load cell when prestressing steel tendons.

Permanently mark the jack body with the ram area. Ensure each pressure gage is fully functional, calibrated and has an accurately reading dial at least 6 inches in diameter.

Calibrate the jack and each gage used to stress tendons as a unit within 6 months prior to use and after each repair. If used, provide a load cell calibrated within the past 12 months with an indicator that may be used to determine the prestressing force in the tendon. The range of the load cell shall be such that the lower 10 percent of the manufacturer's rated capacity will not be used in determining the jacking stress.

Use the following calibration procedure; Perform three calibration test cycles with the cylinder extension of the jack in various positions (i.e. 2 inch, 4 inch, 8 inch stroke). At each pressure increment, average the forces from each test cycle to obtain an average force. Perform the calibration with the equipment setup in the same configuration that will be used at the job site. Use load cells calibrated within the past 12 months to calibrate stressing equipment.

For each jack and gauge unit used on the project, provide the Engineer with certified calibration curves prior to the start of the work and every 6 months thereafter, or as requested by the Engineer. If used, supply documentation denoting the load cell calibration date prior to the start of the work and every 6 months thereafter. Furnish certified calibration charts to the Engineer prior to stressing.

Recalibrate jacks requiring repair, such as replacing seals or changing the length of the hydraulic lines. No extra compensation will be allowed for the initial or subsequent calibrations.

5. Placing Reinforcing Steel and Prestressing Steel. Place reinforcing steel according to the requirements of Section 503, except as modified by this section.

Place prestressing steel in the position as designated in the Contract or on the approved working drawings.

6. Pretensioning. Do not begin tensioning operations until concrete cylinders test, manufactured of the same concrete and curing conditions outlined in AASHTO T 23 and tested using AASHTO T 22, indicate that the concrete has attained the minimum initial compressive

strength (release strength) as indicated in the Contract. Do not tension the prestressing steel until all concrete in the member has been placed.

Ensure that the tension load indicated by the gauge(s) is within 5% of the calculated tension load based on elongation measurements for each tendon.

Limit the strand stress in pretensioned members before seating (jacking stress) to 70 percent of the minimum ultimate tensile strength ( $0.70 f'_s$ ) of the prestressing steel.

Stress strands by either single strand stressing or multiple strand stressing.

Bring all strands to be stressed in a group (multiple strand stressing) to a uniform initial tension, prior to being given their full pretensioning, that is within the range specified and sufficient to eliminate all slack and equalize the stresses in the strands.

Use approved low-friction devices at all points of change in slope of tendon trajectory when tensioning harped strands.

Tension harped strands from both ends of the bed if the load, as determined by elongation measurements, is more than 5 percent less than that indicated by the jack gauges. Ensure the computed load from the sum of elongation at both ends is within 5 percent of that indicated by the jack gauges.

Permit only one splice per strand when using single strand jacking. Splice all strands or splice no more than 10 percent of the strands when multistrand jacking is used. Splice strands with similar physical properties, from the same source, and with the same "twist" or "lay." Locate all splices outside of the prestressed units.

Keep the temperature of the strands during tensioning and concrete placement within 25 °F of the concrete temperature. During the interval between tensioning and concrete placement, do not let a temperature drop increase the stress level in the strands more than 0.05 GUTS (guaranteed ultimate tensile strength), nor cause the stress in the strand to exceed 0.75 GUTS. Unless noted otherwise, cut all pretensioned-prestressing strands flush with the end of the member. Cut or release the elements in an order that minimizes the lateral eccentricity of the pre-stress. Clean and paint the exposed ends of the strand and a 1-inch strip of adjoining concrete.

7. Placing Concrete. Produce and place concrete according to the requirements of Section 501, except as modified by this section.

Before depositing concrete in the forms, obtain an inspection and approval of the placement of reinforcing, enclosures, anchorages, and prestressing steel. Vibrate the concrete internally, externally, or both, as directed by the Engineer. Vibrate carefully to avoid displacing the reinforcing steel or other items embedded in the concrete.

8. Girder Inserts. Provide threaded inserts, coil anchors, or approved equal in the girder as indicated on the plans.

The Contractor may provide additional inserts in the girder to accommodate diaphragm forms or other construction related requirements.

Provide holes in the girder web as indicated on the plans to accommodate reinforcing steel. Verify that the hole size provided will accommodate reinforcement placement procedures.

**502-3.02 POST-TENSIONING METHODS.** Select a post-tensioning system that provides the magnitude and distribution of prestressing force and ultimate strength without exceeding allowable temporary stresses, subject to the requirements in this specification.

For box girders, distribute the prestressing steel so that the force in each girder stem does not vary more than five percent from the required force per girder stem provided the required total force in the superstructure is obtained and the force is distributed symmetrically about the centerline of the typical section.

Do not exceed 75 percent of the specified guaranteed ultimate tensile strength of the prestressing steel for maximum temporary tensile stresses (jacking stresses) in prestressing steel. Do not exceed 70 percent of the specified guaranteed ultimate tensile strength of the prestressing steel at anchorages after anchor set.

Working force and working stress will be considered as the force and stress remaining in the prestressing steel after all losses (e.g., creep and shrinkage of concrete, elastic compression of concrete, creep of steel, losses in post-tensioned prestressing steel due to sequence of stressing, friction and take up of anchorages and all other losses peculiar to the method or system of prestressing) have taken place or have been accommodated. Calculate loss of prestress using industry recognized methods. The calculation and analysis methods are subject to approval by the Engineer.

1. Working Drawings and Calculations. Before casting members to be prestressed, submit working drawings and supporting calculations of the prestressing system to the Engineer for approval no less than forty-five days prior to the placement of bridge concrete. Submit four sets of the drawings for initial review. After the initial review has been reviewed and you have received and implemented all comments from the Engineer, submit drawings to the Engineer for approval and for use during construction in accordance with Subsection 105-1.02, Plans and Working Drawings.

Show complete details on the working drawings of the prestressing system and all substantiating calculations of the method, materials, and equipment to be used in the prestressing operations, including any additions or rearrangement of reinforcing steel and any revision in concrete dimensions from that shown on the Plans. Outline in sufficient detail the method and sequence of stressing. Include complete specifications and details of the prestressing steel and anchoring assemblies, working stresses, anchoring stresses, type of ducts, initial prestress losses, final prestress losses and all other data pertaining to the prestressing operation. Show tendon geometry and locations complying with the plans and the limitations of the selected post-tensioning system. Show all vent locations, high point outlet inspection details, anchorage inspection details and grout caps, protection system materials and application limits. Include on the working drawing the location of the anchorages, vents, and duct enclosures at 2-foot (maximum) intervals along the length of the girder.

Submit calculations for the anticipated camber at the time of prestressing force transfer and at other significant times. Show the values on the shop drawings as a time/deflection curve.

Submit calculations for the anticipated tendon elongation. Utilize the modulus of elasticity, based on nominal area, as furnished by the prestressing steel manufacturer for the lot of steel being tensioned. Show a typical tendon force diagram, after friction, wobble and anchor set losses, on the shop drawings based upon the expected friction curvature and wobble coefficients and values for the post-tensioning system used. Show the coefficients and values on the shop drawings.

Produce all shop drawings related to post-tensioning by an engineer specializing in post-tensioning concrete. Bear the signature and seal of the engineer who specializes in post-tensioning construction on all calculations, drawings, and procedures.

Include post-tensioning system certification(s) conforming to Subsection 721-2.04, Certification of Post-tensioning Systems.

2. Post-tensioning Technician. Perform all post-tensioning field operations under the direct supervision of a qualified post-tensioning technician. Provide a post-tensioning technician with at least five (5) years of experience in construction of post-tensioned prestressed concrete structures. Provide a technician, skilled in the prestressing method, to aid and instruct in using the prestressing equipment and in installing the materials to obtain required results.

Perform all grouting under the direct supervision of a certified grouting technician. Provide a technician skilled in various aspects of grouting whom the American Segmental Bridge Institute certifies as an "ASBI Certified Grouting Technician".

The post-tensioning technician shall be present at all times during duct installation, tendon tensioning, and grouting operations and shall provide close observation and control of all post-tensioning and grouting operations, as necessary for compliance with the Contract. Submit the name of the post-tensioning technician and proof of certification to the Engineer no less than thirty days before the start of bridge concrete placement operations.

Do not substitute post-tensioning technicians unless the Contractor receives prior written approval from the Engineer. Provide documentation required in this specification demonstrating that the proposed substitute individual meets the qualifications at the time that the request for substitution is made. All post-tensioning operations will be suspended if the Engineer has not approved the proposed substitution in writing. If work is suspended due to unapproved substitutions of special qualification personnel, you shall be liable for all additional costs resulting from the suspension of work and no claim for damages or additional compensation or adjustment in contract time resulting from the suspension of work will be made or permitted.

3. Protection of Prestressing Steel and Anchorages. Protect prestressing steel and anchor assemblies against physical damage and corrosion at all times from manufacture to grouting. Keep prestressing steel and anchor assemblies clean and free of deleterious material such as grease, oil, wax, paint, or other foreign materials. The Engineer will reject prestressing steel that has sustained physical damage at any time. The Engineer will reject prestressing steel that has developed visible rust pitting or other results of corrosion, other than rust stain.

Package prestressing steel and anchorage assemblies in containers or shipping forms for the protection of the steel against physical damage and corrosion during shipping and storage. Protect the prestressing steel from corrosion during shipping and storage by placing a corrosion inhibitor in the package or form, incorporating a corrosion inhibitor carrier-type packaging material, or applying a corrosion inhibitor directly to the steel. Do not use corrosion inhibitors that have deleterious effect on the steel or concrete or bond strength of steel to concrete. Immediately replace packaging or forms damaged from any cause or restore packaging to original condition.

Clearly mark the shipping package or form with a statement that the package contains high-strength prestressing steel, and the type of corrosion inhibitor used, including the date packaged.

If prestressing steel is installed in ducts but not tensioned and grouted within the seven days, perform Nondestructive Examination (NDE) by visually inspecting the entire length of the

prestressing steel for corrosion. Perform additional visual NDE inspection at least once every seven days until the prestressing steel is tensioned and grouted by either videoscoping the entire length of the prestressing steel inside the ducts or visually inspecting the prestressing steel upon removing the prestressing steel from the duct. Perform NDE inspection to the satisfaction of the Engineer. Provide a report of the tendon condition to the Engineer following each NDE inspection tendon installation.

If corrosion is not found on the prestressing steel upon completion of NDE inspection, the Engineer may require protecting prestressing steel corrosion by means of a corrosion inhibitor placed in the ducts. Do not place a corrosion inhibitor inside the duct if prestressing steel installation, tensioning, and grouting is performed within seven days. Do not use corrosion inhibitors that have deleterious effect on the steel or concrete or bond strength of steel to concrete. Submit for approval the name, manufacturer, and type of corrosion inhibitor to be used in the ducts at least seven days before installation of any prestressing steel. Prior to grouting, flush the corrosion inhibitor from the ducts using a solution of quick lime (calcium oxide) or slaked lime (calcium hydroxide) in the amount of 0.1 lbs/gal. Use compressed air that is oil free to blow out ducts and remove flush water.

Cover and protect the anchorages against corrosion at all times from installation of the prestressing steel to placement of the concrete pour-backs.

Do not weld on or near prestressing steel, ducts, anchorages, or other assemblages. Protect prestressing steel and hardware from weld spatter or other damage. Once the prestressing steel has been installed, do not make welds or grounds for welders on the forms or on the steel members.

4. Prestressing Equipment. Use hydraulic jacks to tension prestressing steel so that the force in the prestressing steel will not be less than the value shown on the Plans or as approved by the Engineer. Do not use monostrand jacks to stress multi-strand tendons.

Equip each jack used to stress tendons with either:

- a. two pressure gages
- b. one pressure gage and one load cell

In the event that any uncertainty exists regarding jack calibration, pressure gage usage, strand elongation or any other prestressing strand tensioning issue, provide and use a calibrated load cell when prestressing steel tendons.

Permanently mark the jack body with the ram area. Ensure each pressure gage is fully functional, calibrated and has an accurately reading dial at least 6 inches in diameter.

Calibrate the jack and each gage used to stress tendons as a unit within 6 months prior to use and after each repair. If used, provide a load cell calibrated with in the past 12 months with an indicator that may be used to determine the prestressing force in the tendon. The range of the load cell shall be such that the lower 10 percent of the manufacturer's rated capacity will not be used in determining the jacking stress.

Use the following calibration procedure; Perform three calibration test cycles with the cylinder extension of the jack in various positions (i.e. 2 inch, 4 inch, 8 inch stroke). At each pressure increment, average the forces from each test cycle to obtain an average force. Perform the calibration with the equipment setup in the same configuration that will be used at the job site. Use load cells calibrated within the past 12 months to calibrate stressing equipment.

For each jack and gauge unit used on the project, provide the Engineer with certified calibration curves prior to the start of the work and every 6 months thereafter, or as requested

by the Engineer. If used, supply documentation denoting the load cell calibration date prior to the start of the work and every 6 months thereafter. Furnish certified calibration charts to the Engineer prior to stressing.

Recalibrate jacks requiring repair, such as replacing seals or changing the length of the hydraulic lines. No extra compensation will be allowed for the initial or subsequent calibrations.

5. Enclosures for Post-Tensioning. Accurately place enclosures (anchorage, ducts, and vents) for prestressing reinforcing according to the Plans or approved working drawings.

Set and hold the anchorage assemblies and block-out templates for anchorages so that their axis coincides with the axis of the tendon and the wedge plates are normal in all directions to the tendon. Securely fasten anchorages and block-outs to prevent displacement during concrete placement.

Securely fasten ducts at the proper locations in the forms by ties to reinforcing steel that are adequate to prevent displacement during concrete placement. Use supplementary support bars where needed to maintain proper alignment of the duct. Use hold-down ties to prevent displacement due to duct buoyancy in the fluid concrete. Fasten ducts at 2-foot maximum intervals along the girder.

Do not damage the ducts during installation. Do not crimp, flatten, or dent the ducts. Do not perforate the ducts or provide openings in the ducts except at locations designated in the Contract or working drawings. After duct installation, inspect all ducts for damage. The Engineer will reject ducts with unintentional holes or openings and ducts that are dented, crimped, or flattened. Repair duct sections to the satisfaction of the Engineer at no additional cost to the Department and no adjustment in contract time.

After installation in the forms, cover the ends of the ducts and anchorages at all times to prevent the entry of water or debris.

Prior to placing forms for closing slabs of box girder cells, demonstrate to the satisfaction of the Engineer that all ducts are unobstructed.

6. Location of Grout Vents. Place grout vents at locations designated in the Contract and shop drawings. Equip all grout vents with positive shut-off devices. Extend grout tubes with sufficient distance out of the concrete member to allow for proper closing of the valves.

7. Placing Reinforcing Steel and Prestressing Steel. Place reinforcing steel according to the requirements of Section 503 and as modified by this section.

Place prestressing steel in the position as designated in the Contract or on the approved working drawings. Install the prestressing steel in the enclosures by pushing or pulling the total number of strands in a tendon individually or as a unit.

For strands that are pushed, round off the end of the strand and fit the end of the strand with a smooth protective cap.

For strands that are pulled, use a special steel wire sock or other device attached to the end strands to pull the assembled tendon through the duct. Do not weld the ends of the strands together for this purpose. Round the end of the pre-assembled tendon for smooth passage through the duct. Cut strands using an abrasive saw or equal. Do not flame cut strands.

Immediately prior to installing the prestressing steel, demonstrate to the satisfaction of the Engineer that the ducts are free of water, debris, and other obstructions by passing a torpedo

through the ducts. Use a torpedo having the same cross-sectional shape as the duct and that is 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 long. For curved ducts, determine the length so that when both ends touch the outermost wall of the duct, the torpedo is 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 must pass through the duct easily, by hand, without resorting to excessive effort or mechanical assistance.

If the strands do not easily pass through the duct or an obstruction is encountered, do not force strands through the duct.

Do not install the prestressing steel in the duct prior to placing and curing of the concrete.

Straighten prestressing steel strands that are to be stressed simultaneously or when necessary to ensure proper positioning in the ducts.

8. Placing Concrete. Produce and place concrete according to the requirements of Section 501 and as modified by this section.

Before depositing concrete in the forms, obtain an inspection and approval of the placement of reinforcing, enclosures, anchorages, and prestressing steel. Vibrate the concrete internally, externally, or both, as directed by the Engineer. Vibrate carefully to avoid displacing the reinforcing steel, anchorages, ducts, grout vents, or other items embedded in the concrete.

9. Post-tensioning. Do not begin tensioning operations until concrete cylinders test, manufactured of the same concrete and curing conditions outlined in AASHTO T 23 and tested using AASHTO T 22, indicate that the concrete has attained the minimum initial compressive strength indicated (release strength) in the Contract. Do not begin tensioning operations until after the Engineer approved patches or repairs have been satisfactorily completed. Do not tension the prestressing steel until all concrete in the member has been placed.

Perform stressing of tendons in conformance with the sequence shown on the approved shop drawings and to the satisfaction of the Engineer. Stress tendons in such a sequence that lateral eccentricity of prestress and loss of prestress will be a minimum. Stress tendons symmetrically about the center of the typical section so no more than one tendon is eccentric about the centerline at any one time. Sequence the stressing of the tendons so the individual tendon force does not exceed the tendon force in all other tendons by more than 50 percent of the final jacking force of the tendon at any one time.

Stress all strands in each tendon simultaneously. Stress tendons by jacking from only one end of the member unless otherwise approved by the Engineer.

Conduct the tensioning process so that tension being applied and the elongation of the prestressing steel may be measured at all times. Measure elongation to the nearest 1/16 inch. Tension all tendons to a preliminary force between 5 and 25 percent of the final jacking force to eliminate any wedge slip or take-up in the tensioning system before elongation measurements are started. Record the preliminary force so that it can be used in the elongation measurement. Mark at least 25 percent of the strands in each tendon prior to final stressing to permit measurement of elongation and to ensure that all anchor wedges set properly.

For the required tendon force, the observed elongation must agree within five (5) percent of the theoretical tendon elongation. In the event the observed elongation is not within

acceptable tolerances, determine the source of error and revise the post-tensioning operation to the satisfaction of the Engineer before proceeding. Do not overstress the tendon to achieve the theoretical elongation. No claim for damages or additional compensation or adjustment in contract time resulting from revisions to the post-tensioning operation will be made or allowed.

Multi-strand post-tensioning tendons having wires that fail, by breaking or slippage during stressing, will be rejected.

Cut post-tensioning steel with an abrasive saw within 25 to 50 mm from the anchoring device. Do not flame cut prestressing steel.

Provide a record of the post-tensioning operation to the Engineer following each tendon installation including, but not limited to, the following:

- a. Project name and bridge number;
- b. Contractor and / or subcontractor name;
- c. Tendon location, size, type;
- d. Date and time tendon was first installed in the duct;
- e. Reel number for strands;
- f. Tendon cross-sectional area;
- g. Modulus of elasticity;
- h. Date and time tendon was stressed;
- i. Jack and gage numbers per end of tendon;
- j. Required jacking force;
- k. Gauge pressure;
- l. Elongation (theoretical and actual);
- m. Anchor set; (anticipated and actual);
- n. Stressing sequence (i.e. tendons stressed before and after);
- o. Stressing mode (one end/ two ends/ simultaneous);
- p. Witnesses to stressing operation (Contractor's and inspector's signature); and
- q. Date grouted.

Cover ends of tendons and anchorages immediately after stressing in accordance with Subsection 502-3.02 item 3.

### **502-3.02 FABRICATION.**

- ~~1.—General. Place reinforcing steel according to the requirements of Section 503. Produce and place concrete for prestressed concrete structural members according to the requirements of Section 501. Both are subject to the modifications and amendments contained in this specification.~~

~~Before depositing concrete in the forms, obtain an inspection and approval of the placement of the reinforcing, enclosures, anchorages, and prestressing steel.~~

~~Provide a technician, skilled in the prestressing method, to aid and instruct in using the prestressing equipment and in installing the materials to obtain required results.~~

- ~~2.—Placing Ducts, Prestressing Steel, and Anchorage Hardware. Rigidly support ducts in the forms by ties, supplementary support bars, and hold-down ties to prevent displacement during concrete placement and to maintain proper alignment of the duct.~~

~~Couple joints between sections of duct with positive connections that do not result in angle changes at the joints and that will prevent the intrusion of cement paste.~~

Vent all ducts for continuous structures at the high points of the duct profile, except where the curvature is small. Install drains at low point in ducts.

Remove the ends of vents and drains 1 inch below the surface of the concrete after grouting is completed. Fill the void with mortar.

Install prestressing steel accurately in the forms and hold in place by the stressing jack or temporary anchors and, when tendons are to be draped, by hold-down devices.

Set and hold anchorage devices or block-out templates for anchorages with their axes parallel to the axis of the tendon, and anchor plates perpendicular to the tendon.

Ensure prestressing steel installed in members or ducts, but not grouted within 10 days, is continuously protected against rust or other corrosion by means of a corrosion inhibitor placed in the ducts or directly applied to the steel. Protect the prestressing steel until grouted or encased in concrete.

Seal the openings at the ends of the ducts to prevent entry of moisture after tendons are placed in ducts. Install steel for post-tensioning until after steam curing is completed.

3. ~~Tensioning. Tension prestressing steel using hydraulic jacks to produce the forces on the approved working drawing with appropriate allowances for all losses. For post-tensioned work, the losses must also include the anchor set loss appropriate for the anchorage system employed.~~

You may use the following formula to estimate the stress losses due to friction between the duct and prestressing steel:

$$T_0 = T_x e^{(KL+ua)}$$

Where:  $T_0$  = Steel stress at jacking end

$T_x$  = Steel stress at any point x

e = Base of Napierian logarithms

u = Friction curvature coefficient

a = Total angular change of prestressing steel profile in radians from jacking end to point x

L = Length of prestressing steel element from jacking end to point x

K = Friction wobble coefficient per foot of prestressing steel

Values of K and u to be applied in the preceding formula are listed in Table 502-1.

**TABLE 502-1**

Type of Steel	Type of Duct	K	u
Wire cables	Bright metal sheathing	0.0020	0.30
	Galvanized metal sheathing	0.0015	0.25
	Greased or asphalt-coated and wrapped	0.0020	0.30
	Direct contact with concrete	0.0015	0.45
High-strength bars	Bright metal sheathing	0.0003	0.20
	Galvanized metal sheathing	0.0002	0.15
	Direct contact with concrete	0.0005	0.40
	Bright metal sheathing	0.0015	0.25

Galvanized strand	Galvanized metal sheathing	0.0010	0.20
	Direct contact with concrete	0.0015	0.50

~~Use jacks equipped with pressure gauges or other devices for measuring jacking force. Calibrate all devices, whether hydraulic jack gauges or otherwise. If necessary, recalibrate the devices to permit the stress in the prestressing steel to be computed at all times. Include a certified calibration curve with each device.~~

~~Ensure that the tension load indicated by the gauge(s) is within 5% of the calculated tension load based on elongation measurements for each tendon.~~

~~Limit the strand stress in pretensioned members before seating (jacking stress) to 80 percent of the minimum ultimate tensile strength ( $0.80 f'_s$ ) of the prestressing steel.~~

~~Limit the standard stress in post-tensioned members prior to seating (jacking stress) and the stress in the steel immediately after seating to the values allowed in AASHTO LRFD Bridge Design Specifications.~~

~~Apply or transfer prestressing forces to the concrete after the concrete has attained the strength specified for initial stressing.~~

~~Provide a record of gauge pressures and tendon elongations for each tendon for review.~~

~~Determine the stress in tendons during tensioning by the gauge or load cell readings and verify with the measured elongations using the modulus of elasticity, based on nominal area, as furnished by the manufacturer for the lot of steel being tensioned, or as determined by a bench test of strands used in the work.~~

~~Use a dynamometer or other approved method to measure the initial force so that its amount can be used as a check against elongation computed and measured. Mark each strand prior to final stressing to permit measurement of elongation and to ensure all anchor wedges set properly.~~

~~a. Pretensioning. Stress strands by either single strand stressing or multiple strand stressing.~~

~~Bring all strands to be stressed in a group (multiple strand stressing) to a uniform initial tension, prior to being given their full pretensioning, that is within the range specified and sufficient to eliminate all slack and equalize the stresses in the tendons.~~

~~Use approved low friction devices at all points of change in slope of tendon trajectory when tensioning draped pretensioned strands, regardless of the tensioning method used.~~

~~Tension draped strand from both ends of the bed if the load, as determined by elongation measurements, is more than 5 percent less than that indicated by the jack gages. Ensure the computed load from the sum of elongation at both ends is within 5 percent of that indicated by the jack gages.~~

~~Permit only one splice per strand when using single strand jacking. Splice all strands or splice no more than 10 percent of the strands when multistrand jacking is used. Splice strands with similar physical properties, from the same source, and with the same "twist" or "lay." Locate all splices outside of the prestressed units.~~

~~Keep the temperature of the strands during tensioning and concrete placement within 25 °F of the concrete temperature. During the interval between tensioning and concrete placement, do not let a temperature drop increase the stress level in the strands more than 0.05 GUTS~~

~~(guaranteed ultimate tensile strength), nor cause the stress in the strand to exceed 0.75 GUTS.~~

~~Cut all pretensioned prestressing strands flush with the end of the member. Cut or release the elements in an order that minimizes the lateral eccentricity of the pre-stress. Clean and paint the exposed ends of the strand and a 1-inch strip of adjoining concrete.~~

~~b. Post-Tensioning. Stress all strands in each tendon simultaneously with a multi-strand jack, except for those in flat ducts with not more than four strands. Tension tendons in continuous post-tensioned members by jacking at each end of the tendon. Provide the prestressing steel with permanent protection and bond to the concrete by completely filling the void space between the duct and the tendon with grout.~~

~~4. Grouting. Flush ducts with concrete walls (cored ducts) to ensure that the concrete is thoroughly wetted. Remove water from ducts with oil-free compressed air.~~

~~Add water to the mixer first, followed by portland cement and admixture, or as required by the admixture manufacturer. Mix to obtain a uniform, thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixture. Agitate grout continuously until it is pumped. Limit the water content to the minimum necessary for proper placement, and when Type I or II cement is used, to a water-cement ratio of 0.45.~~

~~Open all grout and high point vent openings when grouting starts. Allow grout to flow from the vent nearest the inlet pipe until any residual flushing water or entrapped air has been removed. Cap or otherwise close the vent.~~

~~Inject grout at any vent that has been, or is ready to be, capped if the grouting pressure exceeds the maximum recommended pumping pressure to maintain a one-way flow of grout.~~

~~Pump grout through the duct and continuously waste at the outlet pipe until no visible slugs of water or air are ejected and the efflux time of the ejected grout, as measured by a flow cone test, if used, is not less than that of the injected grout. Close the outlet and build the pumping pressure to a minimum of 75 psi before the inlet vent is closed.~~

~~Ensure the temperature of the concrete is 35 °F or higher from the time of grouting until job-cured 2-inch cubes of grout reach a minimum compressive strength of 800 psi. Ensure the temperature of the grout is below 90 °F during mixing or pumping.~~

~~5. **Camber**~~**502-3.03 CAMBER.** Camber is the upward deflection ~~which~~that occurs in prestressed concrete flexural members due to the combination of stressing forces and dead load. It does not include dimensional inaccuracies from manufacturing errors.

Form girders so the roadway surface conforms to the indicated grade line with an allowance for 1/2 inch of positive camber at midspan. Form girders to adjust for the predicted long-term camber from loss of prestress and from dead load deflection. When estimating this adjustment, assume that future paving will be applied 3 years after erection.

Control the concrete properties and the placing, curing, curing times, tensioning procedures, and the storage of precast prestressed beam sections. Control these elements so that the shape and amplitude of the deflection curves for all girders will be within specified tolerances and as nearly alike as possible.

Measure camber with the girder supported at bearing points only. When it is impractical to support the girder on its bearing points, you may use alternative support points. Obtain approval of the alternative supports and submit calculations of the effects of the supports on girder camber.

Measure actual camber during prestressing force transfer and compare it with computed values and tolerance.

**502-3.03-04 TOLERANCES.** Produce ~~Precast~~ prestressed concrete members ~~must~~ conforming to the following dimensional tolerances:

~~1. Length:  $\pm 3/4$  inch ( $\pm 1$  inch for girders longer than 100 feet).~~

~~2. Girder Width (overall):  $\pm 1/4$  inch, subject to item 11 below.~~

~~3. Depth:  $\pm 1/4$  inch.~~

~~4. Width of Webs, Stems, and Bottom Flanges:  $-1/8$  inch to  $+3/8$  inch.~~

~~5. Flange Thickness:  $+1/4$  inch,  $-1/8$  inch.~~

~~6. Horizontal Alignment (deviation from straight line parallel to centerline of member):  $1/2$  inch, subject to item 11 below.~~

~~7.1. Camber:~~ Do not vary from approved camber more than  $\pm 1/8$  inch per 10 feet of length with a maximum of 1 inch. In addition, the camber of any girder may not differ from that of any other girder by more than 1 inch.

~~8.2. Position of Tendons~~ Strands:  $\pm 1/4$  inch ( $\pm 1/2$  inch where harped strands exit the member).

~~9.3. Longitudinal Position of Deflection Point for~~ Deflected Harped Strands:  $\pm 12$  inches.

~~4. Position of Ducts and Anchorages:~~  $\pm 1/4$  inch

~~5. Position of Local Zone Reinforcement: Center reinforcement on the duct and start within  $1/2$  inch of the back of the bearing plate.~~

~~10.6. Position of Weld Plates:~~  $\pm 1$  inch measured along joint.  $\pm 1/8$  inch transverse to joint.

~~11. Deck Width (measured out to out of all girders in the span):  $+2$  inches, except not more than  $+1/2$  inch where more precision is dictated by substructure details such as anchor bolts, parallel wing walls, etc.~~

~~12. Parallelism of Top and Bottom Flanges: Do not vary the depth of any deck type girder at any transverse cross section more than  $1/4$  inch, when measured perpendicular from a line coincident with the surface of the bottom flange(s) to the deck surface at the edges of the girder.~~

**502-3.05 BONDING AND GROUTING.** Conform to the following:

1. General. Bond post-tensioned prestressing steel to the concrete by completely filling the entire void space between the duct and the tendon with grout. Grout tendons in accordance with the procedures set forth in the approved grouting operation plan. Grout all empty ducts.

2. Personnel Qualifications. Carry out all grouting operations by workers trained for and experienced in the tasks required. Perform grouting under the immediate control of the post-tensioning technician as described in Subsection 502-3.02.

3. Grouting Operation Plan. No less than 30 days prior to the initiation of production grouting, submit a grouting operation plan to the Engineer for approval. Devise the grouting

procedures to ensure that the ducts will be properly filled by grout. As a minimum, address and provide procedures for the following items in the grouting operation plan:

- a. Type, quantity, and brand of materials used in the grouting including all material certifications;
- b. Type of equipment furnished, including capacity in relation to demand and working condition, as well as back-up equipment and spare parts;
- c. Types and locations of vents;
- d. Types and sizes of grout hoses and connections;
- e. Theoretical grout volume calculations;
- f. General grouting procedure;
- g. Duct cleaning method prior to grouting;
- h. Mixing and pumping procedures;
- i. Type and frequency of quality control production tests;
- j. Direction of grouting;
- k. Sequence of use of the vents;
- l. Method to be used to control the rate of flow and pressure within the ducts;
- m. Procedures for handling blockages, including flushing of ducts;
- n. Procedures for possible post grouting repair; and
- o. Names of the persons in charge and the other personnel who will perform the grouting operation, including their relevant certification, experience, and skill.

Do not commence production grouting until the Engineer provides written approval of the grouting operation plan.

Before initiation of production grouting, conduct a joint meeting with the grouting technician, subcontractors, grouting crew, and the Engineer to discuss the grouting operation plan, required testing, corrective procedures, and other relevant issues.

4. Grout Storage. Store all grout materials in a dry enclosure or building that is convenient to the work site. Limit on site storage of grout to a maximum period of one month.

5. Grout Production Tests. Carry out the minimum number of production grout tests as follows:

- a. Grout Strength Test. Prepare grout cube specimens in accordance with ASTM C 942, "Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory." Perform a minimum of one strength test per day during grouting operations.
- b. Fluidity test. Perform a minimum of two modified version of ASTM C 939 "Standard Tests Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)." tests. Take one sample at the mixer and one sample at an anchorage outlet vent. Repeat testing every two hours of grouting operations. Submit test results to the Engineer within 24 hours of testing.

6. Field Trial Test. Demonstrate to the satisfaction of the Engineer that the grouting equipment, methods, and procedures are appropriate. Conduct field trial tests at least seven days prior to initiation of production grouting or as specified by the Engineer. Perform batching and testing with the same materials, personnel, and equipment used in production grouting. Furnish all materials and labor for testing at no cost to the Department.

7. Preparation of Enclosures. If a corrosion inhibitor, or any other material other than prestressing steel is inside the duct, flush the ducts using a solution of quick lime (calcium oxide) or slaked lime (calcium hydroxide) in the amount of 0.1 lbs/gal.

Blow duct with oil free compressed air to remove water and debris blockages that may interfere with the injection of grout.

Inspect valves to be sure that they can be opened and closed properly. Check that the grout hose connections and inlets are free of dirt.

8. Equipment. 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 grouting 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 20 minutes.

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

At the direction of the Engineer, provide vacuum grouting equipment (volumetric measuring type) in the event that voids are encountered after the grouting operation is complete. No additional compensation will be made in the event that vacuum grouting equipment is required.

Provide the following equipment:

- a. Mixing Equipment. Provide a high speed shear colloidal mixer capable of continuous mechanical mixing producing a homogeneous and stable grout free of lumps and undispersed cement. Use only colloidal grout machinery that has separate charging and storage tanks. Equip the charging tank with a high shear colloidal mixer and fit the storage tank with an agitator to keep the grout moving continuously before it is pumped into the duct. Use grouting equipment with a gravity feed to the pump inlet from the storage tank.

Include a screen having clear openings of 3 mm maximum size to screen the grout prior to its introduction into the grout pump or storage hopper. Locate the screen between the charging tank and the storage tank so that the screen is easily accessible for inspection and cleaning.

Keep the holding tank agitated and at least partially full at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct.

Periodically inspect the screen during grouting operations. Do not use grout if lumps of cement remain on the screen.

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. Where water is not supplied through the public water supply system, provide a water storage tank of sufficient capacity.

- b. Grout Injecting Equipment. Provide pumping equipment capable of continuous operation with little variation of pressure that includes a system for circulating the grout when actual grouting is not in progress.

Use positive displacement type grout pumps that provide a continuous flow of grout and will be able to maintain a discharge pressure of at least 145 psi. Use grout pumps with adequate capacity so that an optimal rate of grouting can be achieved. Ensure pumps are constructed to have seals adequate to prevent oil, air or other foreign substances entering the grout and to prevent loss of grout or water.

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

Install a pressure gauge having a full-scale reading of no more than 290 psi at the duct inlet. If hoses in excess of 100 feet total length are used, place and use two gauges, one at the pump and one at the inlet.

Use grout hoses with sufficient diameter, rated pressure capacity and that are compatible with the pump output. Install a sampling tee with stopcock that minimizes the number of bends, valves, and changes in diameter. Firmly connect grout hoses to pump outlets, pipes, and duct inlets.

Do not use compressed air to aid the pumping of grout.

c. Air Compression. Provide equipment to supply oil-free and water-free compressed air to blow out excess water and to check the free passage of the ducts.

d. Flushing Equipment. Provide standby flushing equipment using a potable water supply to facilitate complete removal of grout from the duct if difficult grouting conditions exist. This equipment is in addition to the grouting equipment. Utilize a different power source than the grouting equipment. Furnish equipment to flush out any partially grouted enclosure due to blockage or breakdown of the grouting equipment that is capable of delivering a pressure of at least 290 psi.

e. Vacuum Grouting Equipment. At the direction of the Engineer, provide vacuum grouting equipment. Use volumetric measuring type vacuum grouting equipment with the ability to measure a void and supply a measured volume of grout to fill the void.

f. Standby Equipment. During grouting operations, provide a standby grout mixer and pump.

9. Mixing of Grout. Mix grout using the entire contents of each bag in accordance with the manufacturer's recommendations and using a metered amount of water. Mix the materials thoroughly to produce a homogeneous grout without excessive temperature increase or loss of properties. Do not mix grout longer than the manufacturer's recommended duration. Continuously agitate the grout until grouting is complete.

For quality control, check the fluidity of the grout in accordance with Subsection 701-2.05, Post-tension Grout. Do not commence grout pumping until fluidity requirements are satisfied.

Do not add water to increase fluidity that has decreased by delayed use of the grout.

10. Injection of Grout. Use a method of injecting grout that will ensure complete filling of the ducts and complete encasement of the prestressing steel.

Open all grout vents before commencing grouting operations, unless otherwise approved by the Engineer.

Perform grouting in one operation, maintaining a continuous, one-way flow of grout at all times within a grouting stage. Grout tendons from the lowest vent in an uphill direction. Unless approved otherwise by the Engineer, pump grout at a rate of 15 feet to 50 feet of duct per minute to avoid air entrapment, segregation of the grout, and to ensure complete filling of the duct. Conduct normal grouting operations at a pressure range of 10 psi to 75 psi measured at the grout inlet. Do not exceed the maximum pumping pressure of 145 psi at the grout inlet.

Pump grout through the duct and continuously discharge grout from the first and subsequent outlets until any residual water and entrapped air has been removed and the consistency of

the grout is equivalent to that of the grout being pumped into the inlet. Discharge at least 3 liters of grout from each outlet prior to closing the vent. Close all outlet vents in a similar manner one after another in the direction of flow except that at intermediate crests, close outlet vents placed a short distance downstream of the crest before closing their associated high point vent. Discarded grout does not represent additional cost to the Department.

Pump grout through the duct and continuously discharge grout, to the satisfaction of the Engineer, 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 vent and discharge a minimum of 1 gallon 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 vent. If the measured grout efflux time is less than the efflux time measured at the pump or minimum acceptable efflux time as established in Subsection 701-2.05, Post-tension Grout, discharge additional grout from the anchorage outlet and test the grout fluidity. Continue this cycle until acceptable grout fluidity is achieved. Discard grout used for testing fluidity. After all outlets have been bled and sealed, bleed the grout pressure to 5 psi and wait a minimum of ten minutes for any entrapped air to flow to the high points. After ten minutes, 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 into the tendon prior to closing the inlet vent.

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

11. Temperature Considerations. Do not grout if the ambient air temperature exceeds 100° F. Do not grout if the ambient air temperature is expected to be less than 40° F within 48 hours. Ensure grout temperature upon mixing is between 50° F and 90° C.

If the ambient air temperature is below 32° F, keep ducts free of water to avoid damage due to freezing. Do not warm ducts with steam. Blow dry air (60% humidity or less) through the ducts to extract trapped water. Ensure ducts are free of frost and ice before commencing grouting operations.

12. Post-Grouting Inspection. Do not remove or open vents until the grout has cured for at least 24 hours.

Check the level of grout in the vents and grout caps. Fill vents, as necessary, with freshly mixed grout. After the grout has cured, remove all outlets located at anchorages and high points along the tendon to facilitate inspection.

13. Repairing and Filling Voids. Repair and fill all voids that occur in the ducts after the grouting operation is complete. Submit a grouting repair plan to the Engineer for review and approval immediately after voids have been detected. Vacuum grouting equipment may be required to repair and fill voids in the ducts.

Depending upon 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. Perform inspections in the presence of the Engineer using endoscopes or probes. Fill all voids using the volumetric measuring vacuum grouting process or as approved by the Engineer. 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. Use an injection tube to extend to the bottom of the drilled holes for backfilling with epoxy or grout.

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 or as approved by the Engineer.

14. Finishing. Do not remove or open vents until the grout as set for at least 24 hours. Remove all valves, caps and pipes for each vent at least 1 inch below the surface of the concrete. Permanently seal the recessed areas and fill flush with the surface of the concrete. Remove all miscellaneous materials used for sealing grout cap connections prior to carrying out further work to protect the anchorages including placing the concrete pour-backs.

15. Protection of End Anchorages. Within seven days upon completion of the grouting, permanently protect the anchorage of post-tensioning tendons to prevent access of water or other aggressive agents.

Immediately before casting the concrete pour-backs (within 24 hrs.), mechanically clean and roughen the mating concrete surfaces to remove any laitance and expose the small aggregate. Use grit blasting or water blasting with at least 10,000 psi nozzle pressure. Flush surface with water and blow dry. Ensure surfaces are clean, sound and without standing water.

Recess the anchoring assemblies so that the ends of the prestressing steel and all parts of the anchoring assemblies will be at least 3 inches inside of the end surface of the members, unless shown otherwise on the plans. Following post-tensioning, fill the recesses with concrete conforming to the provisions for the structure and finished flush. Construct all pour-backs in leak proof forms creating neat lines.

16. Record of Grouting Operation. Submit a written report to the Engineer within 72 hours after grouting. Include in this report:

- a. the date of grouting;
- b. the number of days from tensioning to grouting;
- c. the tendons grouted;
- d. the quantities and types of materials used;
- e. the volume of grout pumped into the duct
- f. a summary of problems encountered during grouting and steps taken to resolve them;
- g. the maximum pumping pressure at the inlet;
- h. the temperature measurement of the air, water, prepackaged material, mix grout, and concrete member in the duct.
- i. the results of quality control testing.

#### **502-4.01 METHOD OF MEASUREMENT.** Section 109.

**502-5.01 BASIS OF PAYMENT.** The lump sum payment is full compensation for furnishing, ~~placing~~installing, stressing, grouting, repairing, and ~~tensioning~~inspecting the all prestressing steel in post-tensioned ~~cast-in-place concrete structures,~~tendons accepted ~~complete~~ in place.

All items of the post-tensioning system embedded within the concrete including but not limited to prestressing steel, enclosures for prestressing steel, wedges, wedge plates, anchorage assemblies and associated supplemental reinforcing steel required by the supplier, grout vents, and grout gaps are subsidiary to post-tensioned concrete structural members.

All post-tensioning system hardware that is not embedded in concrete including but not limited to jacks, gauges, wire socks, and torpedoes are subsidiary to post-tensioned concrete structural members.

All items and equipment to fill the ducts with grout including but not limited to mixers, gauges, flushing equipment, and production tests are subsidiary to post-tensioned concrete structural members.

All materials for protecting the post-tensioning steel and anchorages including but not limited to corrosion inhibitors, flushing equipment, and equipment to prepare the concrete pour-backs are subsidiary to post-tensioned concrete structural members.

All labor, materials, tools, equipment and incidentals necessary for completing the work are subsidiary to post-tensioned concrete structural members.

Payment for prestressing precast concrete members is included in the Contract price paid for the precast members, as provided for Section 501.

~~Payment for furnishing and placing additional concrete and deformed bar reinforcing steel required by the particular system used, ducts, anchoring devices, distribution plates or assemblies and incidental parts, for furnishing samples for testing, working drawings, and for pressure grouting ducts is included in the Contract lump sum price paid for post-tensioning cast-in-place concrete or in the contract price for furnishing precast members. No additional compensation is allowed.~~

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit</b>
502(1) Post-Tensioning (Type)	Lump Sum