

Section 509—Prestressing Concrete by Post Tensioning

509.1 General Description

This work consists of prestressing concrete by post-tensioning cast-in-place concrete. The work includes furnishing, placing, and tensioning prestressing steel according to the Plan details and these Specifications.

509.1.01 Definitions

Working Force and Working Stress: The force and stress remaining in the prestressing steel after the following losses:

- Creep and shrinkage of concrete
- Elastic compression of concrete
- Creep of steel
- Loss in post-tensioned prestressing steel from the sequence of stressing
- Friction and anchor set (see [Subsection 509.3.05.J](#), “Post-Tension the Tendons,” steps 18 to 19)
- Other losses peculiar to the method, technique, or system of prestressing (see [Subsection 509.3.05.J](#), “Post-Tension the Tendons,” step 21)

509.1.02 Related References

A. Standard Specifications

[Section 501—Steel Structures](#)

[Section 535—Painting Structures](#)

B. Referenced Documents

AASHTO Specifications for Highway Bridge, Article 9.16.1

AASHTO Specifications for Highway Bridge, Article 9.16.2

ASTM C 109

ASTM A 416

ASTM A 722

ASTM C 939

509.1.03 Submittals

A. Coupler Use and Location

The use and location of couplers in bars entering into the prestressing work is subject to the Engineer’s approval.

B. Alternate Stressing or Anchorage Block Drawings and Calculations

When using stressing or anchorage blocks not shown on the Plans, submit shop drawings and calculations for the blocks to Bridge and Structural Design when submitting the prestressing system calculations and shop drawings.

C. Design Calculations

Submit design calculations for the proposed post-tensioning system to Bridge and Structural Design for Department review and approval. Design calculations may be on letter size sheets.

Submit calculations for the size and spacing of the reinforcing around the ducts, as shown in [Figure 1 \(metric\)](#), to Bridge and Structural Design. Include the following in the calculations:

- Required jacking force and elongation of tendons during tensioning

Section 509—Prestressing Concrete by Post Tensioning

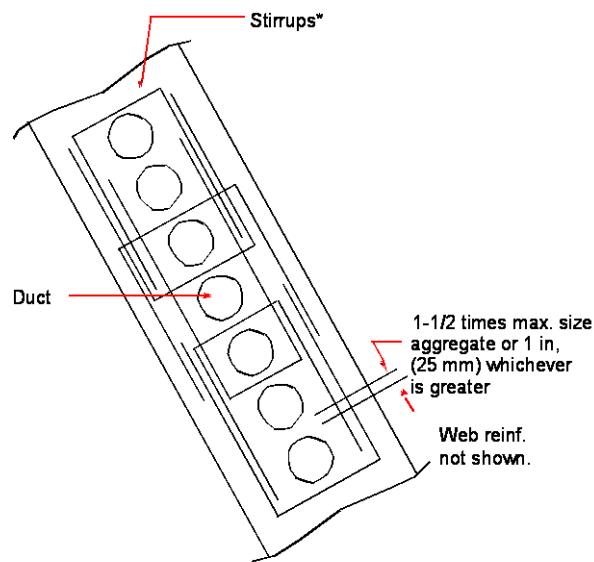
Using the initial jacking force, design the reinforcing to prevent ducts from pulling out because of the effects of web curvature and slope.

- Stresses in anchorages and distribution plates

Ensure that the calculations account for reinforcing to prevent the peeling of anchorages from the top and bottom slab. See [Figure 2 \(metric\)](#) for minimum reinforcing requirements for tying ducts to the deck reinforcing.

- Stress-strain curves typical of the prestressing steel to be furnished
- Seating losses
- Temporary overstresses
- Reinforcing in the concrete to resist tensioning loads

Determine bearing offsets and expansion joint gaps and adjust for construction sequence, prestress shortening, and temperature.



- * A stirrup group is one pair of overlapping "U" shaped bars.
 - Stirrups shall enclose vertical web reinforcement.
 - No more than 3 ducts shall be enclosed by a stirrup group.
 - Min. bar size: No. 4 (No. 13 M).
 - Max. longitudinal bar spacing: 24 in. (600 mm)

Figure 1 (metric)

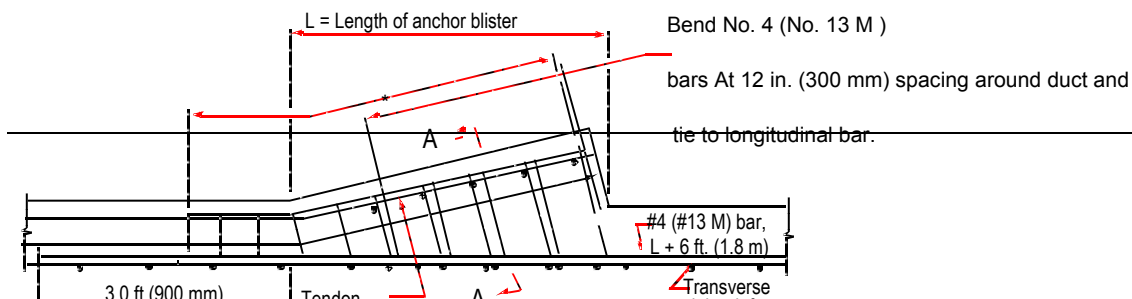


Figure 2 (metric)

D. Certificates of Compliance

The Department will accept certificates of compliance for cements to be used. The Department reserves the right, however, to sample and test the cement before its use and at any time during the progress of the work.

E. Certified Mill Test Reports

Submit certified mill test reports for high tensile prestressing steel to the Project Engineer.

F. Shop Drawings

Submit Shop Drawings for review and approval according to [Subsection 501.1.03.B](#), “Shop Drawings.” Place a title block in the lower right-hand corner of the drawings that includes the following:

- Project number
- Sheet numbering for the Shop Drawings
- Structure name
- Contractor and fabricator names

Submit Shop Drawings on 23 in by 36 in (575 mm by 900 mm) sheets with a 1-1/2 in (38 mm) left margin and a 1/2 in (13 mm) top, bottom, and right margins.

The Shop Drawings shall include the following:

1. Fully dimensional views showing all projections, recesses, notches, openings, blockouts, and pertinent design details
2. Details of mild steel reinforcing showing size, spacing, and location, including special reinforcing required as determined by the design calculations but not shown on the Plans
3. Details of ducts for post-tensioning tendons showing size, type, and horizontal and vertical profiles

Section 509—Prestressing Concrete by Post Tensioning

4. Details of duct supports, grout tubes, and vents showing size, type, and location
5. Details of the relative positions of reinforcing steel, ducts, and anchorages
6. Details of the anchorage systems for the proposed post-tensioning system
7. A table giving jacking sequence, jacking forces, and initial elongation of the tendons at each erection stage for post-tensioning
8. Details and a complete description of the post-tensioning system to be used for permanent tendons
9. Details of the prestressing, including:
 - Method, sequence, and procedure for prestressing and securing tendons
 - Procedure for releasing tendons
 - Equipment supplier and type
 - Tendon size and properties
 - Anchorage plates and assemblies
10. Information on grouting, including:
 - Grout mix design
 - Method of mixing and placing the grout
 - Type and capacity of grouting equipment
11. Working drawings and bar schedules for each prestressing system
12. Details of reinforcing or coil ties under anchorage plates
13. Details for usage of high-strength steel bar (furnished by the bar manufacturer)
14. Friction factors used in the prestressing system of deformed bars

G. Ram Calibration Charts

Before using rams in the work, furnish the Engineer with a certified chart from the calibration for each ram.

H. Designs and Details of Distribution Reinforcing Steel

The Department plans for anchorages show only a minimum amount of distribution reinforcing steel.

Design and detail the reinforcement needed to prevent bursting, peeling, and splitting. Submit the designs and details to the Engineer for review and approval.

I. Gauge Readings and Elongations

Keep a record of gauge pressures or readings and elongations at the end of each jacking operation and submit it to the Engineer for review and approval.

509.2 Materials

Ensure that materials meet the requirements of the following Specifications:

Material	Section
Steel Wire Strand	853
Structural Steel for Anchorage Devices, Distribution Plates, and Incidental Parts Required to Be of Steel	501
Grout	509.3.02.C
Cement	830

Section 509—Prestressing Concrete by Post Tensioning

Admixtures	831
Water	880

Do not use strands from more than one source within the same tensioning operation.

Strands that differ in size from ASTM A 416 are to be submitted for prior approval.

High strength steel bars shall meet ASTM A 722 Type II, and S1 through S3 supplemental requirements and have manufacturers details for their use.

Ensure all bars within any member are of same grade.

Bar couplers and locations are to be approved prior to use and shall have tensile strength not less than manufacturers minimum for strength of bar.

Allow the Department 60 calendar days before installing prestressing steel to test the steel and approve the materials furnished.

Use the anchor devices and distribution plates recommended by the manufacturer of the prestressing system.

Have the Engineer approve grout for filling recesses or encasing anchoring devices. Use a type recommended by the manufacturer for highly stressed steel.

509.2.01 Delivery, Storage, and Handling

A. Protect Prestressing Steel

Protect prestressing steel against physical damage, rust, and corrosion..

Reject all damaged, rusted, or corroded prestressing steel. See [Subsection 509.3.06](#), “Quality Acceptance.”

B. Package Prestressing Steel

Package prestressing wire or strand in containers or shipping forms to protect steel from physical damage and corrosion during shipping and storage. Comply with these packaging requirements:

1. Place a corrosion inhibitor to protect against rust and corrosion as follows:
 - a. Place the inhibitor in the package or form.
 - b. Incorporate the inhibitor in a carrier-type packaging material.
 - c. Apply the inhibitor directly to the steel.

Ensure that the corrosion inhibitor does not damage the steel, grout, or bond strength of the steel to the grout.

2. Immediately replace or restore to original condition damaged packaging or forms.
3. Clearly mark the shipping package or form with the following:
 - A statement that the package contains high-strength prestressing steel
 - Handling instructions
 - The type, kind, and amount, of corrosion inhibitor used, including the date placed, safety orders, and instructions for use

C. Ducts

1. Place all prestressing steel tendons in openings or ducts.
2. Unless otherwise approved by the Engineer, use only rigid, galvanized, ferrous metal that is mortar tight for all longitudinal prestressing steel ducts.
3. Fabricate the ducts with an inside area that is at least double the effective area of the prestressing steel in the duct.

Section 509—Prestressing Concrete by Post Tensioning

- a. Fabricate ducts that encase single high-strength prestressing steel bars with an inside diameter at least 3/8 in. (10 mm) larger than the diameter of the bar to be used.
 - b. Use a minimum wall thickness of 0.030 in (0.75 mm).
4. Rigid ducts may be fabricated with either welded or interlocked seams. There is no need to galvanize the welded seam or the transition couplings that connect the ducts to anchoring devices.
 5. Weld transition couplings to the anchor plate.
 6. Pre-bend all ducts that must be curved to match the roadway alignment and/or tendon profile. Shape the ducts without crimping or flattening them.

509.3 Construction Requirements

509.3.01 Personnel

A. Representative of the Post-Tensioning System Supplier

If the Engineer requires, provide a representative of the post-tensioning system supplier at no additional cost to the Department.

Provide a representative who:

- Is skilled in using post-tensioning systems
- Supervises or provides surveillance of the work
- Provides information about the post-tensioning system to the Engineer as needed

509.3.02 Equipment

A. Prestressing Equipment

Provide the following equipment for construction and prestressing:

1. Tensioning Jacks

Use tensioning jacks equipped with the following:

- Long enough stroke to perform stressing in a minimum number of strokes
Provide a positive means of marking each elongation increment where two or more strokes are required
- Ports or windows to exam and measure tendon movement
- Slow stress release capability to allow the jack to relax from overstress to the proper seating force

2. Tensioning Equipment

Use tension prestressing tendons equipped with the following:

- Equipment that allows direct elongation measurement
- Hydraulic ram that determines the tensioning force applied

Measure the tensioning force applied by the ram using either of the following gauges:

- a. Gauge that measures either the internal hydraulic pressure in the ram or the force exerted by the ram
- b. Spring-type dynamometer used with the tensioning force applied directly

Convert the readings from either of these gauges to actual tensioning forces using calibrated values from a calibration chart.

Use gauges with a diameter of at least 6 in (150 mm) that allow accurate readings of load increments of one percent of the total capacity of the ram used, not to exceed two percent of the tensioning force used.

3. Load Cell

Section 509—Prestressing Concrete by Post Tensioning

Ensure that the range of the load cell does not use the lower 10 percent of the manufacturer's rated capacity to determine the jacking stress.

B. Sampling and Inspecting Prestressing Steel

The Department will identify, sample, test, and approve all prestressing steel as follows:

1. Identification
 - a. Assign a lot number to all strand and all bars of each size from each mill heat shipped to the jobsite.
 - b. Tag the lots so that each such lot can be positively identified at the job site.
 - c. Assign and tag each lot of anchorage assemblies and bar couplers.
 - d. The Engineer or Department inspector will reject all unidentified prestressing steel, couplers, or anchorage assemblies received at the site, and any items without positive identification.
2. Sampling
 - a. Give to the Engineer samples from each size and each heat of prestressing bars and prestressing steel strand, and from each lot of anchorage assemblies and bar couplers.
 - b. Submit with each sample of prestressing strand or bar the manufacturer's certification stating the minimum guaranteed ultimate tensile strength of the sample furnished.
 - c. Submit enough samples to make up two assembled test units from each heat, complete with end fittings and anchoring devices. Test units shall be at least 8 ft. (2.4 m) long.
 - d. If the Engineer's tests indicate the necessity of retests, submit twice the number of previous specimens without cost to the Department. Identify the samples by heat number.
 - e. Submit samples to the Engineer in ample time to allow for testing, tabulating results, and, in case of unsatisfactory findings, to call for and test substitute samples.
 - f. The Department will not pay the Contractor additional compensation because of the delay while waiting for approval of the material furnished for testing.
3. Tendon Modulus of Elasticity
 - a. Submit to the Engineer for approval the apparatus and test methods you propose to use to determine the modulus of elasticity.
 - b. Run bench tests on two samples of each size and type of longitudinal strand and/or wire tendon prior to stressing the initial tendon.
 - c. Stress the tendon at an anchor assembly with the dead end consisting of a load cell.
 - d. Apply 80 percent of the ultimate tension to the test specimen in 10 increments and record the gage pressure, elongation and load cell force for each increment..
 - e. Detension the test specimens back to 0 in 10 increments, and record the gage pressure, elongation, and load cell force for each increment.
 - f. Submit the test data to the Engineer.
 - g. Re-evaluate and correct, as necessary, the theoretical elongations shown on the post-tensioning working drawings based on the results of the tests.
 - h. Submit any revisions to the theoretical elongations to the Engineer.
 - i. After the initial testing, the Engineer may require five more tests. Space these tests evenly throughout the duration of the contract.
4. In-Place Friction Test
 - a. Submit to the Engineer for approval the apparatus and test methods you propose to use to measure the in-place friction.

Section 509—Prestressing Concrete by Post Tensioning

- b. After receiving approval for the apparatus and method, test the first draped continuity strand and/or wire tendon in place of each size and type.
- c. Apply 80 percent of the ultimate tension to the test specimen in 10 increments and record gage pressure elongation and load cell force for each increment.
- d. Detension the tendon back to 0 in 10 increments, and record the gage pressure, elongation, and load cell force for each increment.

NOTE: You only need to run one friction test for each type and size of a tendon for the Project.

- e. Submit the results of the tests (loss due to friction and modulus of elasticity) to the Engineer.

C. Grouting Equipment

Use grouting equipment capable of the following:

- Continuously grouting the largest tendon on the Project in 20 minutes or less
- Pumping the mixed grout according to the requirements of this Specification

Provide the following grouting equipment:

- Mixer capable of continuous mechanical mixing and of producing a grout that is free of lumps and undispersed cement
- Accessory equipment that provides accurate solid and liquid measures to batch materials
- Positive displacement pump able to produce an outlet pressure of at least 150 psi (1 MPa) gauge
- Pump seals that do the following:
 - Keep oil, air, or other foreign substance out of the grout
 - Prevent loss of grout or water
- Pressure gauge with a maximum full scale reading of 300 psi (2 MPa) installed at some point in the grout line between the pump outlet and the duct inlet to establish grout pressure at the pump
- Standby flushing equipment capable of pumping at 300 psi (2 MPa) gauge and flushing out partially-grouted ducts
- A different power source for the flushing equipment than the grouting equipment
- Screen with 0.125 in (3 mm) maximum clear openings to screen the grout before it is introduced into the grout pump
- Hopper placed directly over the pump inlet
 - Attach the hopper to the pump inlet using a gravity feed.
 - Keep the hopper at least partially full of grout during the pumping operation to prevent air from being drawn into the post-tensioning duct.

D. Rams

Twenty days before using rams and their gauges or reading devices in the work, have them calibrated by an approved laboratory.

Recalibrate the equipment every three months during the work or when the Engineer observes erratic results. For each calibration, furnish a calibration chart, certified by the laboratory, to the Engineer.

The Engineer may extend the 3-month interval if there are no performance changes. However, recalibrate at least every 6 months.

509.3.03 Preparation

A. Test Tendon Modulus of Elasticity

To determine the tendon elongations while stressing, bench test two samples of each size and type of longitudinal strand and/or wire tendon using the following procedure:

1. Propose apparatus and methods used to perform these tests for approval by the Engineer.
2. Stress the tendon at an anchor assembly with the dead end consisting of a load cell.
3. Tension the specimen to 80% of ultimate in 10 increments.
4. Detension the specimen from 80% of ultimate to 0% in 10 increments.
5. Record the gage pressure, elongation, and load cell force for each increment. Provide this data for the Engineer.
6. Reevaluate the theoretical elongations shown on the post-tensioning working drawings using the results of the tests. Correct the results as necessary.
7. Submit revisions to the Engineer for approval.
8. Perform five more tests after the initial testing (if required by the Engineer). Space these tests evenly throughout the duration of the contract.

B. Test Friction

To accurately determine the friction loss in a strand and/or wire tendon, test, in place, the first draped continuity tendon of each size and type using the same procedure described for the modulus of elasticity test. Only one friction test for each type and size of a tendon is required for the project. Submit the results of the tests to the Engineer.

C. Test Anchorages

Before construction, test prestressing anchorage blocks of the type indicated in [Figure 2 \(metric\)](#) using the proposed jacking system as follows:

1. Construct and test anchorage test blocks for the following:
 - Each different radius of bend of the duct into the anchorage
 - Each different number of strands per duct arrangement
2. If anchorages (reinforcing, anchorage geometry, anchor plate, and duct bend radius) are the same within a Project or bridge, test only the anchorage with the largest jacking force.
3. Assemble a test block with these features:
 - Same concrete dimensions of the structure cross section at the points of anchorage in the proposed system
 - Tendon geometries, anchor plates, and anchorage reinforcing steel proposed for use in the structure
4. Place the tendons.
5. Stress the tendons to the full force required by the design using the proposed jacking system and stressing procedures.

Anchorages are acceptable to the Department if no concrete cracks wider than 1/100 in (0.25 mm) develop within 3 days under full force.

509.3.04 Fabrication

General Provisions 101 through 150.

509.3.05 Construction

A. Contractor Options

The Contractor may choose from these options when constructing the structure according to the Department plans:

1. Alternative Prestressing Systems

Section 509—Prestressing Concrete by Post Tensioning

The Contractor may use post-tensioning systems other than those shown on the Plans. The alternative system may use wires, bars, or strands anchored with friction grips or bearings.

Unless the Plans allow, do not use prestressing systems that incorporate dead-end anchorages.

Choose alternative systems that can be stressed from either end unless the construction staging does not allow room to stress tendons from both ends. In this case, use anchorage systems with compression plates or fittings to seat anchor wedges.

2. Alternative Stressing or Anchorage Blocks

Stressing or anchorage blocks for the structure may deviate from those shown on the Plans.

Alternate stressing or anchorage blocks must be located inside the box. Place the blocks in any of the following locations:

- At the juncture of the bottom of the top slab
- At the juncture of the top of the bottom slab and the web walls
- Within fillet areas in reinforced stressing blocks
- In partial depth diaphragms

Permanent or temporary stressing blockouts are allowed in the top of the top slab when post-tensioning ducts do not have a moisture-retaining low point.

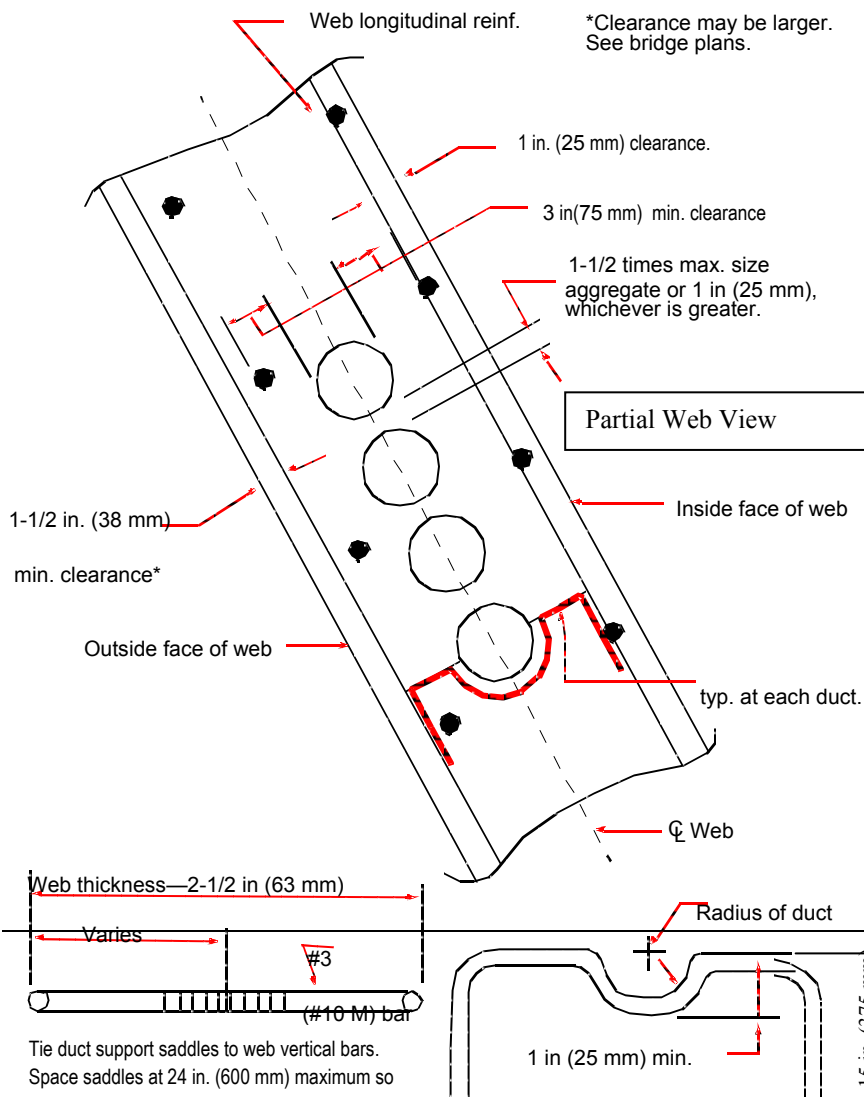
B. Install the Ducts

Install ducts for prestressing steel as follows:

1. Support ducts at intervals of no more than 2 ft (600 mm).
The horizontal tolerance for longitudinal ducts in the top or bottom slab is plus or minus 1 in (25 mm). The vertical tolerance for longitudinal ducts is plus or minus 1/4 in (6 mm).
2. Join rigid duct sections using positive metallic connections. Connect the sections carefully to prevent misaligning the ducts at the joints.
3. Use waterproof tape at the connections.
4. Make duct splices so that the nose of the tendon being pushed into the duct goes from a male end into a female end. This prevents tendons from catching on a duct end.
5. Stagger splices in ducts to prevent splices in the same location in a row of ducts. Stagger the splices to give a 3 ft (900 mm) longitudinal spacing from row to row.
6. Carefully cut and deburr the ends of ducts.
7. Use ducts or anchorage assemblies with pipes or other connections as grout ports for injecting grout after the prestressing. Ports are required at each tendon anchorage.
8. Place continuous-draped longitudinal ducts in the web in one vertical row at the center of the web.
9. Tie the ducts securely to the saddles, which shall hold the duct in position during concrete placement and hardening.
10. Ensure that the clear distance between the ducts is 1-1/2 times the maximum size aggregate in the concrete mix or 1 in (25 mm) whichever is greater.
11. Do not bundle ducts.
12. See [Figure 3 \(metric\)](#) below for an illustration of how to tie duct support saddles.
13. If needed, place ducts in the top or bottom slab in one of these ways:
 - Horizontally at the variable spacings
 - In closely and uniformly spaced groupsThe minimum horizontal clear spacing between ducts must be 3 in (75 mm).

Section 509—Prestressing Concrete by Post Tensioning

14. Install at least one more continuity duct than needed in each web throughout the length of the structure. This duct will be used during blockage and excessive prestress losses during construction.
15. Position the ends of the additional ducts to use anchorage blocks if necessary.
16. Vent continuity ducts over each intermediate support.
Provide vents with a diameter of at least 1/2 in (13 mm) and made of either steel or polyethylene.
17. Provide vents at the low point of every duct to drain off water in the duct.
18. Connect vents to ducts using approved metallic structural fasteners.
19. Ensure that the vents are:
 - Mortar tight
 - Taped as necessary
 - Sealable
 - Capable of allowing grout to be injected through them
20. Immediately before installing the prestressing steel, demonstrate to the Engineer that ducts are unobstructed and free of water and debris.
21. After installing ducts in the forms, keep the duct ends sealed to keep out water and debris.
22. After post-tensioning the steel, fill ducts with or without strands full of grout.
23. After the grout has set, remove the ends of the vents flush with the concrete surface.



C. Install Reinforcing Steel

Fabricate reinforcing steel and place it according to the Plans and Shop Drawings.

Do not cut and remove reinforcing steel to align stressing ducts properly. Replace bars that cannot be fabricated to clear the ducts with bars with an adequate lap length.

Where bars are extended by the use of couplers, the assembled units shall have a tensile strength of not less than the manufacturer's minimum guaranteed ultimate tensile strength of the bar.

Submit revised drawings indicating the proposed bar to the Engineer for review and approval.

D. Install Anchorages

Secure post-tensioned prestressing steel at the ends using permanent anchoring devices recommended by the prestressing steel manufacturer and meeting the requirements herein..

Use anchoring devices that hold the prestressing steel at a load producing a stress of at least 95 percent of the guaranteed minimum tensile strength of the prestressing steel.

E. Install Distribution Devices

Distribute the load from the anchoring device to the concrete using devices that conform to the following:

- The final unit compressive stress on the concrete directly underneath the plate or assembly does not exceed 3,000 psi (20 MPa) or 0.9 (f'ci), whichever is less.
- Bending stresses in the plates or assemblies induced by the pull of the prestressing steel do not exceed the yield point of the material or distort the anchorage plate as determined by the Engineer when 100 percent of the load is applied.

The Contractor may omit steel distribution plates or assemblies when furnishing large anchoring devices used with a steel grill embedded in concrete to distribute the compressive stresses to the concrete.

Install distribution devices as follows:

1. Place steel distribution plates, if used, inside the end surface of the member.
2. Recess anchoring devices so that the ends of the prestressing steel and all of the anchoring devices are embedded in concrete.

Section 509—Prestressing Concrete by Post Tensioning

3. After post-tensioning and grouting the duct, clean foreign and loose material off the surfaces of the concrete.
Do not clean the concrete until the duct grouting operations are complete.
4. Fill anchoring device recesses with an approved, non-shrink grout.
5. Cover the anchoring devices and ends of the prestressing steel with at least 2 in (50 mm) of grout, unless the Plans specify more.

F. Have the Engineer Inspect

Have the Engineer inspect and approve the placement of reinforcement, ducts, and anchorages before pouring concrete into the forms.

G. Pour the Concrete

Pour concrete according to [Section 500](#).

H. Install the Tendons

Install tendons in the ducts after pouring the top deck or when the Engineer approves.

Before installing the tendons, demonstrate to the Engineer that the ducts are unobstructed and free of water.

Install the tendon in the duct as approved by the Engineer.

I. Follow Weld Restrictions

The Engineer will not allow welds or welding equipment grounds on the forms or near the prestressing steel after the steel has been installed.

J. Post-Tension the Tendons

Post-tension the tendons as follows:

1. Before post-tensioning tendons, ensure that the deck slab thickness and deck reinforcement cover comply with the Plan requirements.
2. Unless otherwise noted on the Plans or approved by the Engineer, wait to prestress cast-in-place concrete until the compressive strength of all the concrete placed reaches the required 28-day strength and the concrete is at least 14 days old.
If the Engineer approves, the Contractor may apply a portion of the prestressing force to a member with a concrete strength less than the value shown on the Plans.
Even with this partial prestressing, the Contractor must successfully construct the members.
3. Conduct the tensioning process so that the applied tension and the elongation can be measured.
4. Tension the prestressing steel using hydraulic jacks.
5. Tension the prestressing tendons in continuous post-tensioned members by jacking at each end of the tendon.
Jacking of both ends does not need to be done simultaneously.
6. When approved by the Engineer and if shown on the Plans, tension bent cap tendons by jacking from one end only.
7. Tension the prestressing tendons in simple span post-tensioned members by jacking from one end only.
8. When tensioning from one end of the tendon only, tension half of the prestressing steel in each member from one end and the other half from the opposite end of the span unless otherwise shown on the Plans.
9. Unless allowed on the Plans, do not use prestressing systems that incorporate dead-end anchorages.
10. Where construction staging does not allow room to stress tendons from both sides, use anchorage systems with compression plates or fittings to seat anchor wedges.
11. Ensure that the prestressing steel force does not drop below the value shown on the Plans.

Section 509—Prestressing Concrete by Post Tensioning

12. Ensure that the tendon force measured by gauge pressure is within 5 percent of the force calculated by elongation movement.
13. If the measured elongation at the jacking stress varies more than 5 percent from the theoretical elongation, or if the unbalanced force about the section center line exceeds 3 percent:
 - a. Check the entire operation and determine the error.
 - b. Correct the error to the Engineer's satisfaction before proceeding with the work.
14. Do not allow the total force at each section to drop below the total prestressing force specified. However, the prestressing force may vary plus or minus 5 percent per tendon.
15. Unless otherwise specified on the Plans, ensure that the average working stress in the prestressing steel does not exceed 80 percent of the yield point stress of the prestressing steel.
16. To determine the amount of steel required, ensure that the maximum temporary tensile (jacking) stress in prestressing steel does not exceed 80 percent of its specified minimum ultimate tensile strength unless the Plans indicate a lower jacking stress.
17. Anchor the prestressing steel at stresses (initial stress) that will retain working forces at or higher than the minimum values shown on the Plans or approved by the Engineer.

Do not allow the initial stress to exceed 70 percent of the specified minimum ultimate tensile strength of the prestressing steel.
18. Check that the loss of elongation from anchor set agrees with the anticipated value used in the stress calculations.
 - a. Adjust measured Elongation to account for the actual measured anchor set.
 - b. Maintain 5 percent agreement between the elongation and the stressing force.
19. To compute the prestress losses from friction, use the formula in the AASHTO Specifications for Highway Bridge, Article 9.16.1. The total friction losses at any section will be the sum of the effects for each tendon, depending on its anchorage location for each tendon.
20. To compute other prestress losses, use the AASHTO Specifications for Highway Bridge, Article 9.16.2.
21. After stressing and anchoring tendons and after the Engineer approves, trim projecting tendons by sawing as shown in the approved working drawings.

K. Mix the Grout

Grout for Prestressing Concrete Bridge Members: Grout for use with prestressing concrete bridge members includes a mixture of Portland cement, water, and an approved expansive admixture, as follows:

- Water—Use potable water or other water that meets the requirements of [Subsection 880.2.01](#).
- Portland cement—Use Portland cement that meets the requirements of [Subsection 830.2.01](#). Standard usage is Type II Portland cement, but the Engineer may allow Type I or III. The Engineer may require Type III for cold weather grouting.

Submit to the Department certificates of compliance for the cements used. However, the Department reserves the right to sample and test the cement before its use and at any time during the work.

- Admixture—Use admixtures that meets the requirements of [Subsection 831.2.02.A](#).

NOTE: Do not use sand in grout used for prestressing concrete bridge members.

1. Before grouting, select the material proportions based on the following:
 - Tests made on the grout
 - Documented experience with similar materials, equipment, and field conditions (weather, temperature, etc.).
2. Select admixtures used in Grout for Prestressing Concrete Members. If used and approved by the Engineer, use admixtures that demonstrates low water content, good flowability, and minimum bleed.

You may use the following:

- Either liquid or solid admixtures
- Enough fine, aluminum powder to obtain 5 to 10 percent unrestrained expansion of the grout

Do not use the following:

- Thixotropic additives without prior approval from the Engineer
 - Admixtures that have ingredients corrosive to steel or chemicals in quantities that may have a harmful effect on cement
 - Admixtures with chloride ions in excess of 0.50 percent by weight of the admixture (assuming 1 lb (0.45 kg) of admixture per 94 lbs (42.6 kg) each of cement), florides, sulphites, and nitrates
- a. At least 30 days before using the admixture, submit to the Engineer at least 2 1/2 lbs (1 kg) of a proposed dry-type admixture, or 1 quart (1 L) of a proposed liquid-type admixture.
 - b. Send with the sample a description of the content, recommended proportions to be used, and the manner and sequence of adding to the mix.
3. Ensure that the water content is the minimum necessary for proper placement and does not exceed a water-cement ratio of 0.45 (approximately 5 gal (19 L) of water per bag of cement).
 4. Add the grout components to the mixer in the order listed or as required by the admixture manufacturer and mix the dry materials in a mixer or clean, tight box until the mixture is a uniform consistency:
 - Water
 - Portland cement
 - Admixture
 5. Mix the grout long enough to thoroughly blend it without excessively increasing the temperature or losing admixture expansion properties.
 6. Agitate the grout continuously until it is pumped.
 7. Do not add water to increase grout flowability that has decreased because grout use is delayed.

The Engineer may determine grout pumpability according to the ASTM C 939. When using this method, efflux time for the grout sample immediately after mixing must be at least 11 seconds.

L. Prepare Ducts for Grouting

Prepare the ducts for grouting by flushing the metal ducts as determined by the Engineer.

1. Use water to flush ducts that contains at least 0.1 lb/gal (10 g/L) of slaked lime (calcium hydroxide) or quicklime (calcium oxide).
2. Use oil-free compressed air to blow out ducts.

M. Grout the Duct

Bond prestressing steel to the concrete by filling the space between the duct and the tendon with grout.

Grout the duct as follows:

1. Open the grout and vent openings.
2. Ensure that the pumping pressure at the tendon inlet does not exceed 250 psi (2 MPa) gauge.
3. Allow grout to flow from the first vent after the inlet pipe to remove residual flushing water or entrapped air.
4. Once water or air is removed, cap or otherwise close the vent. Close the remaining vents in sequence in the same manner.
5. If the grouting pressure exceeds 250 psi (2 MPa) gauge, inject grout at a vent that has been or is ready to be capped.

Section 509—Prestressing Concrete by Post Tensioning

- a. Maintain a one-way grout flow while injecting.
 - b. Fit the vent used for injection with a positive shutoff.
 - c. If a one-way flow of grout cannot be maintained, immediately flush the grout out of the duct with water.
6. Pump grout through the duct and waste it continuously at the outlet pipe until the following happens:
 - No visible slugs of water or air are ejected.
 - The efflux time of the ejected grout is at least 11 seconds.
 7. To ensure that the duct remains filled with grout:
 - a. Close the outlet.
 - b. Hold pumping pressure for an additional 15 seconds and then close the inlet.
 - c. Do not remove or open plugs, caps, or valves used to close off the outlet or inlet until the grout has set.

N. Place Rust Inhibitor

If prestressing and grouting are not completed within 10 consecutive days after installing steel strands in the ducts (or within 30 days in the case of bars), use rust inhibitor in the ducts.

Prestressing steel installed but not grouted within the specified number of consecutive days is subject to the limits in [Subsection 509.3.06.C](#), “Rust Limits.” If the Engineer directs, remove rejected tendons at no cost to the Department.

Do not reuse prestressing steel that has been detensioned. Replace detensioned prestressing steel.

O. Paint Steel Parts

Paint steel parts exposed in the completed structure as follows:

1. Field clean the parts according to [Subsection 535.3.03.A](#), “Clean New Steel Structures.”
2. Field paint the parts according to System IV of [Section 535](#).
3. Paint the ends of strands according to System IV of [Section 535](#).

509.3.06 Quality Acceptance

A. For Prestressing Concrete Bridge Members

Use grout that has a minimum compressive strength of 3,000 psi (20 MPa) at 28 days, as determined by ASTM C 109.

B. Tendon Standards

Individual wires in a 7-wire strand or wires in a parallel wire tendon may fail if the total area of wire failure is not more than 2 percent of the total cross-sectional area of tendons in any member.

Failure of an entire strand will be subject to structural review.

C. Rust Limits

Prestressing steel will be rejected when:

- The opened package (pak) of prestressing steel has an even coating of rust or rust film over the entire pak.
- One or more wires in a strand are rusted throughout their length.
- A length of strand or bar contains clinging rust, pits, or other faults.

Prestressing steel will be accepted when:

- Rust film can be removed by light rubbing, leaving light streaks or spots but no pitting.
- Rust forms during the 10 consecutive days (or 30 consecutive days for bars) between the installation of steel in the ducts and the prestressing and grouting.

Section 509—Prestressing Concrete by Post Tensioning

509.3.07 Contractor Warranty and Maintenance

General Provisions 101 through 150.

509.4 Measurement

Prestressing cast-in-place concrete is measured as an accepted lump quantity, complete in place.

The Contract Lump Sum price paid for prestressing cast-in-place concrete will be full compensation for the following:

- Furnishing labor, materials, tools, equipment, and incidentals
- Doing Work to furnish, place, and tension the prestressing steel in cast-in-place concrete structures complete in place and as specified on the Plans and in these Specifications

509.4.01 Limits

A. Tests

Tests performed by the Contractor will not be paid for separately but will be considered incidental to the project.

No additional payment will be made for testing prestressing anchorage blocks. Costs associated with performing the test, including materials, equipment, and labor, will be included in the bid price for prestressing.

B. Additional Compensation

No additional compensation will be made for the following:

- Furnishing and placing additional deformed bar reinforcing steel, ducts, anchoring devices, saddles, distribution plates or assemblies, and incidental parts
- Furnishing samples for testing
- Performing testing
- Grouting recesses
- Pressure grouting ducts

Full compensation will be included in the Contract Lump Sum price paid for prestressing cast-in-place concrete.

509.5 Payment

Payment will be made under:

Item No. 509	Prestressing cast-in-place concrete, Bridge No. _____	Per lump sum
--------------	---	--------------

509.5.01 Adjustments

General Provisions 101 through 150.