SECTION 1108—POST-TENSIONING OPERATIONS

1108.01 GENERAL REQUIREMENTS—

(a) Description. This work is prestressing, grouting, and other work related to post-tensioning operations.

(b) General. Perform post-tensioning operations in the presence of an authorized representative of the Department, either in a prestressing plant or on the project site.

Retain a Professional Engineer registered in the State, experienced in post-tensioning operations, to be present and in charge of tensioning and grouting operations. Two weeks before the start of the post-tensioning operations, submit, in writing, to the District Bridge Engineer, the Engineer's name and the date and place of post-tensioning. A Professional Engineer registered in the State is not necessary for post-tensioning box culverts or transversely post-tensioning adjacent box beam bridges.

(c) Shop Drawings. Section 105.02 and as follows:

Show the proposed method, material, and equipment including any changes to reinforcing steel. Show the method and sequence of stressing including complete specifications and details of the prestressing steel and anchoring devices, bearing devices, location of splices or couplings, working stresses, anchoring stresses, type of ducts, steel corrosion protection, proposed arrangement of the prestressing steel in the members, pressure-grouting material and equipment, and vent details including size, type, spacing, and location and direction of grouting.

Provide a detailed stressing force diagram showing the following:

- deviations from design forces;
- sequence of loading stages;
- friction coefficients for the duct and tendon combinations;
- friction and jacking forces;
- jacking techniques, e.g., overjacking;
- friction loss diagram, superimposed on the force diagram; and
- elongation computations.

Provide shop drawings that are signed, dated, and sealed by a Professional Engineer registered in the State.

Unless indicated, or specified, do not use a working stress greater than 0.6 f_u, a temporary stress greater than 0.75 f_u, or an anchoring stress greater than 0.7 f_u. (f_u = specified minimum ultimate tensile strength of prestressing steel.)

Working force and working stress are the force and stress remaining in the prestressing steel after losses, including concrete creep and shrinkage, elastic concrete compression, steel losses due to stressing sequence, steel relaxation, friction and take up at anchorages, and other losses peculiar to the prestressing system.

1108.02 MATERIAL—

(a) Prestressing Steel. Use wire, strand, or bar, conforming to the requirements specified in Section 1107.02(n).

(b) Corrosion Inhibitor. Obtain from a manufacturer listed in Bulletin 15. Submit the grout mixture to the District Materials Engineer/District Materials Manager for review and approval before use.

Certify as specified in Section 106.03(b)3.

(c) Anchorages, Bearing Devices, Fittings, and Couplings. Design anchorages to develop 0.95 f_u. Design couplings to develop 1.0 f_u. Use bearing devices designed to transmit the anchor force to the concrete, at bearing stress no greater than 21 MPa (3,000 pounds per square inch). Limit bearing device stress to 80% of its yield strength when the prestressing steel is stressed to 0.95 f_u.

Certify as specified in Section 106.03(b)3.

(d) Duct Sheathing. Unless otherwise indicated, use corrugated, rigid or semi-rigid type, galvanized steel sheathing.

Certify as specified in Section 106.03(b)3.

Minimum duct thickness for metal ducts shall be as follows:

- Strand tendons—0.4 mm (26 gauge) diameter for ducts less than or equal to 66.7 mm (2.625 inches) in diameter and 0.5 mm (24 gauge) diameter for ducts greater than 66.7 mm (2.625 inches) in diameter

- Bar tendons—0.2 mm (31 gauge) diameter

(e) Epoxy Resin. Section 1019.2(b)

(f) Water. Section 720.1

(g) Unbonded Prestressing Steel for Precast Box Culverts and Adjacent Box Beams. Encased, corrosion protected, prestressing strand for unbonded post-tensioning, comprised of the following components:

1. Special Grade, 7-Wire, Uncoated, Low-Relaxation Strand. Section 1107.02(n)3.d

2. Polymer Sheathing.

2.a Material. Polypropylene, cell classification PP 210 B55542, conforming to ASTM D 4101, or polyethylene, High Density Type II, conforming to ASTM D 3350 and ASTM D 1248.

2.b Thickness and Diameter. Provide a minimum sheathing wall thickness of 1.25 mm (0.05 inch) and an inside diameter of 0.75 mm (0.03 inch) greater than the maximum diameter of the strand.

2.c Application. Apply around prestressing strand in a seamless hot-melt extrusion process. Provide a smooth, circular outside with no visible reveal of the lay of the strand.

3. Corrosion Inhibitor Compound.

3.a Material Properties. Provides corrosion protection to the strand; lubrication between the strand and sheathing; continuous non-brittle coating if exposed to a temperature of -23 °C (-10F); resists flow within temperature range of -23 °C to 43 °C (-10F to 110F); and chemically stable and nonreactive with prestressing strand, reinforcing steel, sheathing material, and concrete.

3.b Quantity. Not less than 1.14 kg (2.5 pounds) per 30.5 m (100 feet) for 12.7 mm (0.5-inch) diameter strand and 1.36 kg (3.0 pounds) per 30.5 m (100 feet) for 15.25 mm (0.6-inch) diameter strand. Completely fill the annular space between the strand and sheathing along the entire length of strand.

3.c Performance Criteria. Table A.

TABLE A
Performance Specification for Corrosion Inhibitor Compound

Test Description	Test Method	Acceptance Criteria
Dropping Point	ASTM D 566 or ASTM D 2265	Minimum 149 °C (300F)
Oil Separation at 71 °C (160F)	FTMS (Federal Test Method Standard) 791B Method 321.2	0.5% max by weight (mass)
Water Content	ASTM D 95	0.1% maximum
Flash Point (refers to oil content)	ASTM D 92	Minimum 149 °C (300F)
Corrosion test (5% salt fog at 38 °C (100F) 127 µm (5 mils))	ASTM B 117	Rest Grade 7 or better after 1000 hours of exposure according to ASTM D 610
Water-soluble ions * a. Chlorides b. Nitrates c. Sulfides	 ASTM D 512 ASTM D 3867 APHA (American Public Health Association) 4500-S^2E	 10 ppm maximum 10 ppm maximum 10 ppm maximum
Soak test (5% salt fog at 38 °C (100F) 127 µm (5 mils) coating, Q Panel Type S. Immerse panels 50% in a 5% salt solution and expose to salt fog)	ASTM B 117 (modified)	No emulsification of the coating after 720 hours of exposure.
Compatibility with sheathing a. Hardness and volume after exposure of polymer to grease, 40 days at 66 °C (150F) b. Tensile strength change of polymer after exposure to grease, 40 days at 66 °C (150F)	 ASTM D 4289 (ASTM D 792 for density) ASTM D 638	 Permissible change in hardness 15%, volume 10%. Permissible change in tensile strength 30%.

* Procedure: The inside (bottom and sides) of a 1 L Pyrex beaker (approximate outside diameter 105 mm, 145 mm height) is thoroughly coated with 100 ± 10 g of corrosion inhibitor compound. The coated beaker is filled with approximately 900 cc of distilled water and heated in an oven at a controlled temperature of 38 °C ± 1° for 4 hours. The water extraction is tested by the noted test procedures for the appropriate water-soluble ions. Results are reported as ppm in the extracted water.

1108.03 CONSTRUCTION—

(a) Post-Tensioning Systems. Include anchorages, fittings, sheathing, tendons, and grout.

(b) Corrosion Protection. Protect prestressing steel against physical damage, rust, and corrosion. Do not use prestressing steel that has sustained physical damage, pitting, or that has rust that cannot be removed by wiping with a dry cloth. Do not retain prestressing steel in an ungrouted duct for more than 10 days without special acceptable corrosion protection. Pack prestressing steel in containers or other shipping forms for protection against physical damage and corrosion during shipping and storage. Place a corrosion inhibitor that prevents rust or other corrosion in the package or form or, when allowed, apply it directly to the steel or to the tendon.

Mark on the shipping package or form that the package contains high-strength, prestressing steel and the care to be used in handling. State the type, kind, and amount of corrosion inhibitor used, including placement date, safety orders, and instructions for use.

When stressing and grouting are completed within 10 calendar days after the prestressing steel installation, rust that may form will not be cause for rejection. In this case, use of a corrosion inhibitor is not necessary.

Before use submit the coating system for tendon corrosion protection in a bonded system for approval.

Protect bar tendons from corrosion at the job site by spraying with a rust preventative and by use of an approved protective covering over the bars.

(c) Anchorages and Bearing Devices. Use permanent-type anchorages to secure prestressing steel at the ends. Steel distribution plates or assemblies may be omitted if large enough anchorages are used in conjunction with a steel grill embedded in the concrete to effectively distribute the compressive stresses to the concrete.

For all systems of post-tensioning, set each anchorage device in all directions perpendicular to the prestressing steel axis. At both tendon ends, make accurate measurements of anchorage loss, due to slippage or other causes. Compare these losses with the assumed losses shown in the post-tensioning schedule on the shop drawings. When necessary, make adjustments or corrections in the operation.

For special anchorage devices, test according to AASHTO Standard Specification Division II, Section 10.3.2.3.

(d) Installation of Sheathing Ducts. Form and place sheathing and secure it to prevent movement when concrete is placed. Make splices grout-tight.

After installation, blow the ducts clear using oil-free compressed air, for at least 5 seconds each. Plug the duct ends to prevent the entry of water or debris.

Furnish sheathing ducts with interlocked seams. Make joints with positive metallic connections, which do not result in angle changes at the joints. Use waterproof tape at the connections to seal seams.

Provide ducts or anchorage assemblies with pipes or connections for grout injection. Install pipe vents that are 13 mm (1/2 inch) or larger in size near the high points of each duct. Use metallic structural fasteners to make connections to ducts. Make vents grout-tight, tape as necessary, and provide means for grout injection. Remove vent ends 25 mm (1 inch) below the member surface, after grouting has been completed.

For tendons made up of single prestressing bar or strand, make the inside diameter at least 6 mm (1/4 inch) greater than the diameter of the prestressing bar or strand. For tendons made up of a number of prestressing bars or strands, make the duct's cross-sectional area at least twice the net area of prestressing steel.

Locate ducts within the specified tolerances. For curved members, place the ducts on, or symmetrically about, the member axis parallel to the curvature direction.

Provide concrete cover a minimum of 38 mm (1 1/2 inches) for sheathing up to 51 mm (2 inches) O.D., and a minimum of 51 mm (2 inches) of cover for larger sheathing. Provide a minimum of 38 mm (1 ½-inch) clear spacing between the sheathing at the beam ends, or provide 1 1/2 times the maximum aggregate size, whichever is greater.

After the prestressing steel has been installed, do not weld or ground for welding equipment on steel in the member. Do not flame cut, unless the ducts and tendons are effectively shielded.

(e) Prestressing. Tension prestressing steel, using hydraulic jacks, so the force in the prestressing steel is not less than the value indicated or on the accepted shop drawings with appropriate allowance for all losses.

Within 20 days before stressing, calibrate all jacks and pressure gauge system and furnish certified copies of the load calibration curves to the Engineer except jack calibration for post tensioning of box culverts and adjacent box beams. For post tensioning of box culverts and adjacent box beams accompany jack gages with a current, certified calibration chart, not older than 6 months. Equip each jack with a pressure gage having an accurate reading dial at least 150 mm (6 inches) in diameter. Calibrate each jack and its gage as a unit, with the cylinder extension in the approximate position it will be in at final jacking force. Recalibrate stressing equipment at 6-month intervals and at other times when required. Do not interchange jacks and gauges without recalibration. Check the certified calibration chart for hydraulic jacks and pressure gages used for tensioning prestressing steel, both before and during tensioning operations.

Do not stress tendons until the concrete has attained its 28-day strength, unless partial stressing is allowed at a lower strength.

Apply to the tendon, an initial load of 10% of the full load to take up slack and to provide a starting point for measurement of elongations. Apply the final load, including any overload. Apply the load at a rate consistent with procedures recommended by the manufacturer of the system.

Unless otherwise indicated, in simple span members, stress by jacking from one end only, with one-half of the prestressing steel in each member tensioned from one end and the other one-half tensioned from the opposite end.

When the same tendons are jacked from two ends, both jacking operations may be done simultaneously, provided uniform tensioning forces are applied at each end. The stressing forces, measured by jacking pressures and elongation, are required to agree within 5%. If the measurements cannot be reconciled within this range, halt the stressing, examine the procedure, and determine the sources of error so the measured force can be verified within this limit. If sources of error cannot be determined or verified by the Professional Engineer in charge of post-tensioning operations, to the satisfaction of the Engineer, the post-tensioning of the member will be stopped and the member rejected.

In continuous members, tension by jacking at each tendon end, unless otherwise indicated. Jacking of both ends need not be done simultaneously, unless otherwise indicated.

(f) Bonding and Grouting. Start grouting promptly after tensioning.

1. Grout. Use grout consisting of Portland cement, water, and admixtures. Use Type I, II, or III Portland cement. Use nonshrink admixture and anti-bleed admixture of the type recommended by the manufacturer of an accepted tendon. Do not use admixtures containing chlorides or nitrates, or that release free hydrogen.

Use enough grout plastic to pump and completely fill the ducts. No grout shrinkage is allowed while in the plastic state. Before post-tensioning, design the mix and verify that it has a strength of 17 MPa (2,500 pounds per square inch) at 7 days and has 4% to 10% expansion. Verify strength by testing according to ASTM C 109. Limit the water content of the grout to the minimum volume necessary to produce a mix that can be pumped, with a maximum of 19 L (5 gallons) per bag of cement.

Prepare test cylinders from each day's grouting.

Visually determine the grout's ability to be pumped.

Place water in the mixer, then add cement and admixture.

Strength testing of grout for precast box culverts is not required.

2. Grouting Equipment. Use equipment capable of grouting at a pressure of at least 700 kPa (100 pounds per square inch). Furnish equipment with a pressure gage that has a full-scale reading of not more than 2 MPa (300 pounds per square inch). Provide standby flushing equipment and compressed air equipment capable of developing a pumping pressure at 1.7 MPa (250 pounds per square inch) and large enough to flush out partially grouted ducts. Provide working pressure meters on the group pumps, meters that show the grout pressure at the injector nozzle discharge end.

3. Grouting. Clear ducts of deleterious materials that would impair grout bonding or interfere with grouting procedures.

After curing, blow ducts free of water and keep them dry until grouting. Immediately before grouting, flush the ducts with clean water, then remove excess water by blowing out with oil-free compressed air.

Mix the grout in mechanical mixing equipment that produces uniform and thoroughly mixed grout. Do not retemper grout. Agitate the grout continuously until it is pumped. Before entry into the pump, screen grout through 2 mm (0.07-inch) maximum, clear opening screen.

Grout the ducts on the day of completion of the tensioning operation of each unit, unless otherwise directed.

Equip grout injection pipes with positive, mechanical shutoff valves. Fit vents and ejection pipes with valves, caps, or other devices capable of withstanding the pumping pressures. Do not remove or open valves and caps until directed, generally after the grout has set.

Apply grout by pumping toward open vents. Pump continuously, using moderate pressure at the entry point in the duct, until entrapped air is forced out the open vent or vents and until visible slugs of water or air are ejected. Close the outlet pipe. With the entire duct filled and discharge vents closed, raise the pressure to a minimum of 345 kPa (50 pounds per square inch) and hold for a minimum of 1 minute, then plug the injection point to prevent any grout loss. Close the valve at the inlet while maintaining this pressure.

Using an abrasive, blast clean the concrete surfaces at anchorage assemblies, until clean aggregate is exposed, to ensure concrete bonding or grout encasement of assemblies.

Where the end of a post-tensioned assembly is not embedded in concrete, recess the anchorages so the prestressing steel ends and parts of the anchorages will be at least 50 mm (2 inches) inside of the member end surface, unless a greater embedment is indicated. Following post-tensioning, clean the recesses, fill with nonshrinking mortar, and finish flush. After curing, paint surfaces with two coats of epoxy resin.