CONSTRUCTION SPECIFICATION FOR STRESSING SYSTEMS FOR POST-TENSIONING

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910.01 SCOPE

This specification covers the construction requirements for internal bonded post-tensioning and grouting of tendons in prestressed concrete.

910.02 REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specification, Construction

OPSS 904 Concrete Structures
OPSS 905 Steel Reinforcement for Concrete

Ontario Provincial Standard Specification, Material

OPSS 1302 Water
OPSS 1440 Steel Reinforcement for Concrete

Ontario Ministry of Transportation Publications

Structural Manual:
Division 1 - Exceptions to the Canadian Highway Bridge Design Code CAN/CSA S6 for Ontario

MTO Forms:

PH-CC-701	Request to Proceed
PH-CC-702	Notice to Proceed
PH-CC-822	Certificate of Conformance

Canadian Standards Association

A23.2-1B	Viscosity, Bleeding, Expansion and Compressive Strength of Flowable Grout [Part of CSA A23.1-19/A23.2-19, Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete]
A283-19	Qualification Code for Concrete Testing Laboratories
A3004-2C	Test Method for Determination of Compressive Strengths* *[Part of CSA A3000-18, Cementitious Materials Compendium]
S6-19	Canadian Highway Bridge Design Code

ASTM International

A53/A53M-22	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless
A123/A123M-17	Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A370-22	Test Methods and Definitions for Mechanical Testing of Steel Products
C109/C109M-20b	Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50 mm] Cube Specimens)
C1152/C1152M-20	Test Method for Acid-Soluble Chloride in Mortar and Concrete
D2239-22	Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
D3350-21	Specification for Polyethylene Plastics Pipe and Fitting Materials
D4285-83(2018)	Test Method Indicating Oil or Water in Compressed Air
E328-21	Test Methods for Stress Relaxation for Materials and Structures

International Organizations for Standardization/International Electrotechnical Commission

ISO/IEC DIS Guide 17025

Post Tensioning Institute

PTI/ASBI M50.3-19	Multistrand and Grouted Post-Tensioning
PTI M55.1-19	Grouting of Post-Tensioned Structures

International Federation for Structural Concrete (fib)

FIBBUL 75	Polymer-duct systems for internal bonded post-tensioning

European Organisation for Technical Assessment

ETAG 013	Guideline for European Technical Approval of Post-Tensioning Kits for Prestressing of Structures

910.03 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Anchorage Zone means the end portion of the post-tensioning element consisting of local zone and general zone.

Calibration means the process of determining experimentally the absolute values corresponding to the gradation on a scale subject to error.

Coupler means a device for the joining of two post-tensioning tendons or prestressing steel bars by means of a mechanical connector.

General Zone means the anchorage zone region of post-tensioned component which extends from anchorage device along the axis of the component according to CSA S6.

Local zone means the zone behind the anchorage device where the prestressing force is transferred to the post-tensioned structural component.

Post-Tensioning means a method of prestressing in which tendons are tensioned after the concrete has reached a predetermined strength.

Prestressing Steel means as defined in OPSS 905.

Prestressing Steel Bar means as defined in OPSS 1440.

Primary Tendon Anchorages means the anchorage on longitudinal tendons.

Tendon means a high-strength steel element used to impart prestress to concrete.

Tensile Strength means the breaking load of the tendon per unit area established by tensile testing.

Vent means an inlet to permit the injection of grout into the duct or an outlet to provide for the escape of air, grout, and to bleed or drain water.

Yield Strength means the stress at which the tendon exhibits a specified deviation of proportionality of stress and strain.

910.04 DESIGN AND SUBMISSION REQUIREMENTS

910.04.01 Design Requirements

910.04.01.01 General

All proposed post-tensioning systems shall meet the induced slip requirements specified in the Contract Documents.

910.04.01.02 Design of Anchorage Zone

Design shall be according to the CSA S6 and the Structural Manual, Division 1. The supplier of the post-tensioning system shall be responsible for the design of the local zone according to CSA S6. Design of the general zone shall be as specified in the Contract Documents.

910.04.02 Submission Requirements

910.04.02.01 General

All Working Drawings, post-tensioning details, and calculations shall bear the seal and signature of an Engineer.

All submissions shall be according to the appropriate clause; however, when other authorities are involved in the approval of the design or construction of a Highway structure, submissions shall be made at least 5 weeks prior to commencement of work and one additional copy of the submission shall be provided for each authority.

910.04.02.02 Post-Tensioning Working Drawings

At least 3 weeks prior to commencement of post-tensioning work, one electronic copy of all Working Drawings in pdf format shall be submitted to the Contract Administrator. The drawings shall include the following:

a) Design details.

b) Slip.

c) Calculation data.

d) Post-tensioning sequence.

e) Details of the:

i. Ducts.
ii. Supports.
iii. Vents.
iv. Anchorages.

Details of anchorages for post-tensioning tendons shall be according to the requirements of the manufacturer of post-tensioning system.

Where post-tensioning tendons are anchored internally in concrete, anchorages shall be by means of bulbs crimped onto the ends of individual strands. When anchorages of this type are used, the Working Drawings shall also include the following:

a) Anchorage bulb dimensions.

b) Spacing of bulbs.

c) Length of strand embedded in concrete.

d) Ultimate load capacity of the anchorage.

910.04.02.03 Post-tensioning Details

At least 2 weeks prior to commencement of the post-tensioning operations, one electronic copy in pdf format of the following information shall be submitted to the Contract Administrator:

a) Elongation calculations that take into account all relevant losses.

b) The type of jacks.

c) Friction of jacks.

d) Jacking pressure.

e) Method of attaining the required slip (e.g. wedge or nut seating procedure).

f) Two copies of the prestressing steel manufacturer's stress-strain curves test reports.

910.04.02.04 Couplers

910.04.02.04.01 General

At least 3 weeks prior to the commencement of the work, a copy of the post-tensioning system manufacturer's catalogue giving complete data on the coupler material, installation procedures, and test reports from the manufacturer certifying that the strength and fatigue requirements have been satisfied shall be submitted to the Contract Administrator.

910.04.02.04.02 Testing

Dynamic tests are not required on bonded tendons, unless the anchorage is located or used in such a manner that repeated load applications could be expected on the anchorage.

A dynamic test for tendons shall be performed on a representative anchorage and coupler specimen and the results submitted to the Contract Administrator. The tendon shall withstand, without failure, 500,000 cycles from 60 to 66% of its minimum specified ultimate strength and also 50 cycles from 40 to 80% of its minimum specified ultimate strength. The period of each cycle shall be the change from the lower stress level to the upper stress level and back to the lower. The specimen used for the second dynamic test may be the same one used for the first dynamic test. Systems using multiple strands, wires, or prestressing steel bars may be tested using a test tendon of smaller capacity than the full-sized tendon. The test tendon shall duplicate the behaviour of the full-sized tendon and generally shall not have less than 10% of the capacity of the full-sized tendon.

910.04.02.05 Prestressing Steel Mill Test Certificates and Stress-Strain Curves for Prestressing Steel

Submission of mill test certificates and stress strain curves shall be according to Mill Certificates and Stress-Strain Curves for Prestressing Steel subsection in OPSS 1440

One copy of mill test certificates for all material to be used in the fabrication of the prestressing steel shall be available for review at the fabricating plant during fabrication. The mill test certificates shall show that the material is according to the Contract Documents.

Mill test certificates for prestressing steel bars shall demonstrate that tensile testing has been carried out on full-section specimens according to ASTM A370.

Test results shall be provided for relaxation testing of prestressing steel bars for the same heat number as the material supplied for the work. The testing shall be carried out according to the test procedure described in the Material section.

910.04.02.06 Prestressing Personnel

At least 12 weeks prior to commencing the post-tensioning operation, experience records shall be submitted to the Contract Administrator for prestressing personnel employed or licensed by the manufacturer of the post-tensioning system as described herein.

910.04.02.07 Grouting Plan

At least 4 weeks prior to the work, written procedures for grouting operations shall be submitted to the Contract Administrator. The grouting plan shall include the following:

a) Pre-packaged grout product name, manufacturer, and quantity to be used in grouting.

b) Manufacturer's specified limits for efflux time measurement for the fluidity of the grout.

c) 28-Day compressive strength test results for the grout from the manufacturer within the last 12 months.

d) Type of grouting equipment including provision for spare parts and details of a backup mixer.

e) Mixing and pumping procedures.

f) Direction of grouting and sequence of use of the inlets and outlets.

g) Procedures for handling blockages, and procedures for possible regrouting.

h) Temperature control measures for grouting operation.

i) Details of vacuum-assisted grouting procedures, if applicable.

910.04.02.08 Corrosion Inhibitor

At least 3 weeks prior to the commencement of the work, the name of the corrosion inhibitor applied to the prefabricated cables and verification it is approved by the post-tensioning system supplier shall be submitted to the Contract Administrator.

910.05 MATERIALS

910.05.01 Anchorages and Couplers

910.05.01.01 General

When anchorages and couplers for post-tensioning are tested in an unbonded condition, they shall develop at least 95% of the ultimate tensile strength of the tendons. After tensioning and the initial slip required to seat the strands has occurred, anchorages shall be capable of sustaining the applied loads without additional slippage, distortion, or other changes that could result in unaccounted loss of prestress.

910.05.01.02 Anchorages

The manufacturer of the post-tensioning system shall establish the dimensions and details of anchorages within the local zone, which are dependent on the jacking force and the concrete strength at transfer specified in the Contract Documents. Additional steel reinforcement required to resist tensile, bursting, spalling, or longitudinal edge tension forces within the general zone shall be as specified in the Contract Documents.

Primary tendon anchorages shall be multi-plane bearing type. Primary and transverse tendon anchorages shall be provided with end caps that cover the strand ends and wedges according to PTI/ASBI M50.3. Steel and plastic end caps are permitted. The end caps shall have a 3 mm minimum wall thickness and shall have attachments and gaskets that allow the cap to withstand full grouting pressures. End caps shall be vented to ensure that they are completely filled with grout. Steel end caps shall be galvanized according to ASTM A123 or equivalent.

Anchorages for unbonded tendons shall not cause a reduction in the total elongation of the tendon, under ultimate load, greater than 2% measured in a minimum gauge length of 3 m.

910.05.01.03 Couplers

Couplers shall be according to the submitted manufacturer’s data accepted by the Contract Administrator.

910.05.02 Ducts

910.05.02.01 General

Ducts for internal post-tensioning shall be corrugated plastic. The ducts, including joints, shall be watertight, vapour-tight and nonreactive with concrete, tendons, or grout. The ducts and components shall meet the requirements of Post-Tensioning System Tendon Protection Level 2 (PL-2) according to PTI/ASBI M50.3.

Ducts for external post-tensioning shall be made from smooth, and rigid polyethylene.

All ducts shall be provided with suitable devices for the injection and discharge of grout after prestressing. Air vents shall be provided at all high points on the ducts that are continuous over more than one span. Air and drainage vents shall be provided at other locations as specified in the Contract Documents.

Ducts shall be capable of withstanding concrete pressures without excessive deformations and shall not permit the entrance of cement paste during the placement of concrete. The ducts shall have sufficient rigidity to maintain the required profile between points of support.

For single strand of prestressing steel tendons, the inside diameter of the ducts shall be at least 6 mm larger than the nominal diameter of the strand or prestressing steel bar. For multiple strand tendons, the inside cross-sectional area of the duct shall be at least twice the cross-sectional area of the tendon.

The diameter of a duct, or an equivalent diameter of a non-circular duct, shall not exceed 40% of the least gross concrete section thickness at the location of the duct.

910.05.02.02 Plastic Ducts

Plastic ducts, including their splices, shall be made of polyethylene or polypropylene according to PTI/ASBI M50.3 and shall be vapour-tight and remain so after tendon installation and stressing.

Plastic for the external post tensioning ducts shall be code letter D or E for colour and ultraviolet (UV) stabilizer according to ASTM D3350. The plastic duct shall be manufactured according to ASTM D2239 from virgin material.

Plastic ducts shall not be used when the specified radius of curvature of the tendon is less than 10 m. The ducts shall be capable of being curved to the specified radius without damage. The duct wall thickness shall not be less than 1 mm for the specified minimum radius of curvature, after a tendon movement of 750 mm under a tendon stress of 80% of the specified strength. For curved ducts, the radial force, as exerted on the duct wall by a single strand, shall not exceed 40 kN/m.

The plastic ducts shall meet the following requirements:

a) For ducts with an inside diameter of 50 mm or less, a 3 m length supported at the ends shall not deflect under its own weight by more than 75 mm at a temperature of not less than 20 °C.

b) For ducts with an inside diameter of more than 50 mm, a 6 m length supported at the ends shall not deflect under its own weight by more than 75 mm at a temperature of not less than 20 °C.

c) The duct shall not deform more than 3 mm under a point load of 445 N applied through a No. 10 reinforcing steel bar located between the corrugation ribs at a temperature of not less than 20 °C.

d) Material thickness shall be as follows:

    i. Corrugated, internal duct shall have a minimum of 2.0 mm wall thickness or meet the requirements of FIBBUL 75 Table 8.1, with ETAG 013 approval. Corrugated duct shall have at least 2 longitudinal flow channel ribs throughout the cross section.
    ii. External ducts shall have an external diameter to wall thickness ratio of 17 or less.

910.05.02.03 Ducts at Deviators

Ducts within a deviator for post-tensioning tendons shall be galvanized steel pipe according to ASTM A53, Type E, Grade B, with a wall thickness of not less than 3 mm. The duct shall be formed to conform to the alignment of the tendon.

910.05.02.04 Vents

Vents shall be a 20 mm minimum diameter flexible tubing material capable of withstanding the applied grouting pressures. Vents shall be temporarily equipped with an airtight shut-off valve to isolate the duct system from the environment.

910.05.03 Grout

910.05.03.01 Pre-Packaged Grout

The grout used shall be one of the pre-packaged grout products listed in Table 1 and shall meet the requirements of a Class C grout according to PTI M55.1.

The pre-packaged dry grout mixture shall be supplied on skids and covered with polyethylene sheeting. The pre-packaged dry grout mixture shall be stored in a dry condition up to the time of its use and suitably protected against the weather during delivery and storage on site. The pre-packaged dry grout mixtures shall be used within 6 months of packaging and shall be stored on site for a maximum of 1 month.

The dry ingredients of the grout shall be thoroughly mixed and packaged in bags, with a maximum bag size of 30 kg. The bag shall be of sufficient strength and waterproof to withstand handling and to protect the grout from moisture and contamination. The bags shall have the following information printed on the outside: Name of manufacturer, maximum amount of water to be used per bag of dry grout mixture, date packaged, and expiry date.

910.05.03.02 Grout Properties

The grout shall have the following physical properties:

a) The minimum 28-Day compressive strength shall be 55 MPa, when tested according to CSA A3004-2C.

b) No bleeding or segregation when allowed to stand for 3 hours according to clause 4.4.8.1, Wick-induced bleed test of PTI M55.1

c) The efflux time measurement for the fluidity of the grout shall be within the limits specified by the manufacturer.

d) The chloride content shall be according to PTI M55.1 when tested according to ASTM C1152

910.05.04 Hardware

Only hardware, including spacers and support devices for the ducts, that are capable of withstanding the loads placed on it and that is approved by the Owner shall be used. All embedded hardware within 100 mm of exposed faces shall be coated with an acceptable material or be of an acceptable non-metallic material.

910.05.05 Prestressing Steel

910.05.05.01 General

Prestressing steel shall be low alloy prestressing steel bar or uncoated, low relaxation 7-wire strand according to OPSS 1440.

Prestressing steel bar shall be low relaxation and shall meet the requirements of relaxation testing as specified herein when furnished in its final condition after all processing. Relaxation loss shall be less than 3.0% when tested at an initial stress of 70% of minimum specified ultimate tensile strength of the bar for 1000 hours according to ASTM E328 Method A, except a gauged bar is not required if the specimen length is at least 60 bar diameters. Relaxation testing shall be completed at a temperature of 20 °C ± 2 °C. Quenched and tempered bars are not permitted.

910.05.05.02 Corrosion Inhibiting Coating

A corrosion inhibitor, approved by the post-tensioning system supplier, shall be applied to the prefabricated cables to prevent the pitting of the prestressing steel as described herein.

910.05.06 Steel Reinforcement

Steel reinforcement shall be according to OPSS 1440.

910.05.07 Water

Water shall be according to OPSS 1302.

910.06 EQUIPMENT

910.06.01 Air Compressor

The air compressor used for air blasting shall have a minimum capacity of 3.5 m^3/min. The compressed air shall be free of oil according to ASTM D4285.

910.06.02 Grouting Equipment

The grouting equipment shall consist of a mixer, a separate holding tank, and a pump.

The mixer shall be a high-shear mechanical or colloidal type with a speed of 1200 to 2000 rpm.

The mixer shall be:

a) A high-shear mechanical or colloidal type with a speed of 1200 to 2000 rpm.

b) Equipped with a calibrated measuring device for determining the quantity of mixing water. The total quantity of water used in each batch of grout shall be measured to an accuracy of ± 2%.

c) Equipped with a visible timing device suitable for controlling the mixing time.

d) Calibrated within a 6 month period preceding the work. The device shall be accompanied by a certified calibration curve that bears the seal and signature of an Engineer.

The holding tank shall be capable of keeping the mixed grout continuously in motion until it is used. The outlet to the pump shall have a 5 mm screen.

The grout pump shall be capable of grouting to a pressure of at least 1 MPa and shall be equipped with a pressure gauge and a pressure valve set to release at a pressure of 1 MPa. The pressure gauge shall have an accuracy of ± 2%, shall be accompanied by a certified calibration curve that bears the seal and signature of an Engineer, and shall be calibrated at least once a year.

The grouting equipment shall be of sufficient capacity to ensure that the grouting of the longest duct can be completed within 30 minutes after mixing. The velocity of grout in the duct shall be between 6 and 12 m/min and the pressure shall be compatible with the length and size of the duct.

The grout hoses and their rated pressure capacity shall be compatible with the pump output and the maximum grouting pressure. All connections from the grout pump to the duct shall be airtight so that air cannot be drawn into the duct.

The configuration of the equipment shall be such that the grout can be recirculated to the holding tank, if stoppage occurs in the grouting.

A backup mixer in good working condition shall be available at the site before commencement of grouting in case of breakdown of the grouting equipment during grouting. Suitable equipment to grout a number of ducts simultaneously shall be readily available.

910.06.03 Malfunction of Gauges

Malfunctioning gauges shall be replaced immediately upon discovery of the malfunction.

910.06.04 Measuring Devices for Post-tensioning

Pressure gauges, dynamometers, tension meters, load cells, or other suitable devices shall be used for controlling and measuring the tendon forces and shall be according to the following:

a) The device shall be capable of measuring the forces to an accuracy of ± 2%.

b) Each gauge shall be capable of indicating forces directly in Newtons or be accompanied by a conversion chart so that the imperial readings can be converted into Newtons.

c) The indicating dials of the gauges shall be at least 150 mm in diameter.

d) Each gauge shall be accompanied by a certified calibration curve that bears the seal and signature of an Engineer.

e) The graduated capacity of the gauge shall be such that the forces to be measured fall within 25 and 75% of the minimum and maximum measurement levels respectively, unless calibration data clearly establishes that the gauge is accurate over a wider range.

f) Pressure gauges shall not fluctuate excessively and shall remain steady until the jacking load is released.

g) Gauges shall be mounted near eye level and within 2 m of the operator and positioned so readings can be obtained without parallax.

h) Two gauges shall be used at each jack and pump combination.

i) The gauges shall be recalibrated any time a gauging system indicates erratic results and at intervals not greater than 6 months.

910.07 CONSTRUCTION

910.07.01 Prestressing Personnel

Personnel employed or licensed by the manufacturer of the post-tensioning system shall carry out the work.

Personnel employed to supervise the work of tensioning and grouting shall have a working knowledge of the post-tensioning system used and shall be capable of evaluating the forces, gauge pressures, elongations, and method by which the post-tensioning system transfers the forces to the structure. They shall have a minimum of 5 years experience in carrying out this type of work within the last 10 years, shall be present during the post-tensioning and grouting, and shall also be present during concreting operations to ensure that the post-tensioning components of the work are not adversely affected.

910.07.02 Welding

Shop welding of the prestressing tendons shall only be permitted to facilitate pulling the tendon through the duct. Where the ends of strands are welded together to facilitate pulling the tendon through the duct, the length of the tendon used as an electrical ground or 1 m, whichever is greater, shall be cut off from the welded end prior to stressing. Care shall be exercised at all times to prevent the possibility of heat destroying the tensile properties of the steel. No other welding of post-tensioning tendons and ducts is permitted.

Field welding within 3 m of the post-tensioning steel is not permitted on site. Field welding equipment shall not use any components of the post-tensioning system as an electrical ground.

910.07.03 Surface Condition

All material shall be clean and free of oil, dirt, scale, and pitting. A light rust coating on steel components is acceptable. Prestressing steel shall be free of rust or pitting prior to grouting. Strand condition shall be evaluated according to Figure 11.1 of PTI/ASBI M50.3 and the condition shall be similar to Photo 2 or better. A quality process shall be established to maintain the corrosion inhibitor on the prestressing steel until the time of grouting. Vapour phase corrosion inhibitor or dry hot air shall be blown into the ducts and sealed to maintain the prestressing steel condition if the time between stressing and grouting is to exceed 14 Days.

910.07.04 Installation

910.07.04.01 Post-Tensioning System

The post-tensioning system shall meet a protection level of PL-2, according to PTI/ASBI M50.3 and as described herein.

Prestressing steel, ducts, anchorages, couplers, and local steel reinforcement at anchorages shall be placed in the position specified in the Contract Documents and shall be held in the correct location during the operations of placing and consolidating of concrete. The ducts shall be supported and secured at intervals not exceeding 0.6 m and a smooth profile shall be maintained. Flat ducts shall be supported and secured at intervals not exceeding 0.5 m. All joints between ducts and other associated hardware shall be protected against the ingress of laitance during concreting and against the entry of any deleterious material before, during, and after placement of concrete. Ducts and anchorages shall be installed at the locations specified in the Contract Documents and within the following tolerances:

a) Longitudinal sheath ± 15 mm.

b) Transverse sheath ± 10 mm.

c) Anchorage ± 10 mm.

Couplers for strand or prestressing steel bar are not permitted in the work unless specified in the Contract Documents. When couplers are specified in the Contract Documents, they shall be installed according to the recommendations of the manufacturer of the post-tensioning system used.

Bearing plates at anchorage components shall be within 2 degrees of their design orientation and trumpets shall be perpendicular to the faces of the bearing plates and securely fastened in place.

Duct alignment and transition to anchorage components shall be free of kinks and shall provide smooth continuous transitions between elements. Slitting of ducts to facilitate bending is not permitted. Pushing or pulling of strands through ducts shall be done with methods that will maintain parallelism and not snag or cut ducts.

Joints in ducts shall be by means of proprietary couplers. Fusion welding of ducts in not permitted. Heat shrink sleeves, if applicable, shall be as per PTI/ASBI M50.3. Proprietary couplers shall be according to the PL-2 leak-tightness requirements of FIBBUL 75. Joint tape is not permitted in lieu of couplers.

Half-shell duct supports shall be used to support the inside radius of curvature for bonded rounded ducts when the radius of curvature is less than 20 m.

Monostrand jacks shall not be used to stress tendons with six or more strands.

MTO form PH-CC-701, Request to Proceed, shall be submitted to the Contract Administrator after the installation of the post-tensioning system is complete and prior to placing the concrete.

The next operation shall not proceed until MTO form PH-CC-702, Notice to Proceed, has been received from the Contract Administrator.

910.07.04.02 Vents

Vents shall be installed as follows:

a) At the anchorages of the tendon.

b) At the high points of the duct.

c) At the lowest point of a tendon having a small radius such as a vertical loop.

d) At major changes in the cross-section of the duct such as trumpets of couplers and anchorages.

e) For all tendons other than top slab transverse tendons, place drains at low points of all duct profiles, or as close as practical to the geometric low points of all duct profiles, except where an inlet, outlet, or anchorage that can service as a drain is located at the low point.

Vents at anchorages and high points shall extend at least 500 mm above the highest point on the profile of the duct in which the vent is placed. Duct holes at vent locations shall be of the same size as the inside diameter of the vent tube. Direct inlets, outlets or drains existing on vertical or predominantly vertical surfaces of box girders towards the interior of the box.

Vents shall be sealed when not in use for grouting operations.

910.07.04.03 Placing of Steel Reinforcement

The placing of steel reinforcement as duct support spirals, tensioning rings, and reinforcing grids at anchorages shall be according to OPSS 905.

910.07.04.04 Duct Proving

When strands are installed after concreting, a torpedo shall be passed through the longitudinal ducts prior to closing the forms to check for obstructions and after initial set of the concrete to confirm the ducts are free of any obstructions according to PTI/ASBI M50.3.

910.07.05 Post-Tensioning

910.07.05.01 Material Sampling

The Contract Administrator shall be notified when the post-tensioning steel is available for sampling at least 1 week in advance of stressing.

Prestressing steel samples selected by the Contract Administrator for testing and inspection shall be labelled by the Contractor with the following information:

a) Manufacturers identification number.

b) Reel number.

c) Heat number.

d) Location of sampled area.

Samples of post-tensioning materials and the dry grout mixture shall be submitted to the Contract Administrator as follows:

a) For strand, 1 sample 1.0 m long from each reel.

b) For prestressing steel bar, 1 sample 1.0 m long from each heat number.

c) For anchorages and couplers, samples shall be selected by the Contract Administrator on a random basis.

d) For dry grout mixture, representative samples of the packaged material shall be submitted to the Contract Administrator when requested.

910.07.05.02 Post-tensioning of Prestressing Steel

Post-tensioning shall not commence until the concrete has reached the strength specified in the Contract Documents.

Post-tensioning shall be carried out according to the Contract Documents.

After post-tensioning, all openings and vents along the post-tensioning system shall be temporarily plugged or sealed until grouting commences.

MTO form PH-CC-701, Request to Proceed, shall be submitted to the Contract Administrator upon completion of the post-tensioning and prior to cutting of tendons and grouting.

Cutting of tendons and grouting shall not proceed until MTO form PH-CC-702, Notice to Proceed has been received from the Contract Administrator.

910.07.05.03 Measurement of Tensioning and Variation in the Post-Tensioning Force

Friction losses in jacks, hoses, and connections shall be determined and recorded. The force in the tendons shall be determined by means of the pressure gauge and shall be continually verified by measuring the tendon elongation. The pressure gauge readings and the elongations shall be recorded at intervals of 25% of the maximum force and shall include the final reading.

The measured elongations of individual tendons, at the specified jacking force and based on the gauge pressures, shall be within - 3 to + 9% of the calculated values. If the actual elongation is outside this tolerance, jacking of that tendon shall stop and the Contractor shall prepare and submit a report rationalizing the observed difference.

The variation from the specified total post-tensioning force over the entire component cross-section, including any broken strands, shall not exceed ± 5%. The distribution of the variation of the total post-tensioning force across the component cross-section shall be subject to the approval of the Contract Administrator.

910.07.05.04 Prestressing Steel Friction Test

Where the theoretical and actual elongations are significantly different, the Contractor's Engineer may request the Contractor to carry out a friction test on one or more tendons to verify the theoretical value of friction used in the design and elongation calculation.

910.07.05.05 Maximum Tension

In no case shall the low relaxation steel be tensioned above 85% of its tensile strength and in no case shall any steel be tensioned above 94% of its yield strength.

910.07.05.06 Post-Tensioning Records

Upon completion of all post-tensioning operations, the Contractor shall submit to the Contract Administrator, records of elongation, calibrated jacking pressure readings, slippages, and strand breakages.

910.07.05.07 Cutting of Tendons

Care shall be exercised at all times in the cutting of tendons to avoid the possibility of adversely affecting the pre-stressing steel.

Cutting of the tendons shall be by mechanical means.

910.07.06 Grouting

910.07.06.01 General

Grouting shall be carried out as soon as possible, but in no case shall any post-tensioning ducts be left un-grouted for more than 7 Days from the date of the Contract Administrator's completed MTO form PH-CC-702, Notice to Proceed, or more than 14 Days from the time of first installation of prestressing within ducts.

The temperature of the concrete and the ducts shall not be less than 5 °C or higher than 30 °C before grouting commences and for at least 72 hours after grouting has been completed.

When the ambient air temperature is expected to exceed 28 °C or fall below 2 °C at the time of placement or in the 48 hour period following placement, grouting shall not proceed.

The preparation, mixing and grouting procedures shall follow manufacturer's instructions unless otherwise specified in this specification.

910.07.06.02 Preparation for Grouting

Dry, oil free compressed air shall be blown through each duct. Each vent shall be tested in turn to ensure that the ducts, vents, inlets, and outlets are capable of accepting the injection of grout.

All ducts shall be free of all deleterious material that may impair bonding of the grout to the ducts and tendons. The use of steam or flushing with water is not permitted.

910.07.06.02.01 Duct Air Test

An air test shall be carried out on all ducts prior to grouting according to PTI/ASBI M50.3.

910.07.06.03 Grout Mixing

Grout mixture showing evidence of dampness, lumps, hardened pieces, or contamination shall not be incorporated in the work.

A standard batch size shall be established and the size of the batch to be used shall be reported to the Contract Administrator prior to commencement of grouting. The standard batch size shall be used throughout the grouting operation.

The time interval between the addition of the dry grout to the mixer and pumping of the grout shall not exceed 15 minutes. Water shall not be added to the grout after initial mixing.

The holding tank shall be kept partially full at all times during the pumping operation to prevent air from being drawn into the duct.

910.07.06.04 Temperature of Grout

When the ambient air temperature exceeds 15 °C, the grout shall be stored and protected in a shaded area.

The temperature of the grout in the holding tank at the time of injection shall meet the manufacturer's instructions, but shall not exceed 35 °C. Temperature shall be measured hourly.

910.07.06.05 Grouting Procedures

All grout vents of each duct shall be open when grouting starts. The elevation of the end of the injection vent, at the free end, shall be higher than the high point vents along the duct.

Grouting shall commence as soon as possible after mixing is complete. The grout shall be continuously pumped from the lowest grout inlet without any interruptions. The one-way flow of grout shall be maintained throughout the grouting operation. The pumping pressure at the injection vent shall not exceed 1 MPa.

The method of injection shall ensure that the ducts are completely filled with grout and the tendons or prestressing steel bars encapsulated with grout.

The consistency of grout flowing from a vent shall be examined to determine whether or not the grout is of the same consistency as that being pumped into the injection vent. When the grout is of the same consistency, an additional 5 litres of grout shall be allowed to flow out prior to closing that vent. An additional 20 litres of grout, minimum, shall be pumped out the final outlet until consistency is achieved and no visible signs of air is being ejected. The outlet at the end of the tendon shall not be permanently closed until the wet density consistently meets the established acceptable range.

As grout of original consistency flows from the vents, the vents shall be successively closed as the filling of the duct progresses. When grout of original consistency flows from the ejection vent at the free end, that vent shall be closed. The injection tubes shall be sealed off under pressure when the duct is completely filled with grout. A pressure of approximately 500 kPa shall be maintained for at least 1 minute after sealing. Grout vents shall not be reinjected to burp the ducts.

The grout tubes shall be topped up with grout if subsidence of grout occurs when disconnecting the pump or pressure apparatus so that grout completely fills the ducts and openings. After the grout has hardened, the grout tubes shall be cut off flush with the surface of the deck and any tubes not completely full of grout shall be topped up with grout flush with the surface of the concrete.

After grouting is completed, any residue of grout remaining on concrete surfaces adjacent to the vents shall be removed.

After grouting, loads shall not be applied to or removed from the structure until the grout has reached a minimum compressive strength of 20 MPa. For the purposes of this clause, removal of falsework and formwork shall not constitute a load on the structure.

910.07.07 Material Sampling and Testing

910.07.07.01 Grout Mixture

910.07.07.01.01 General

Field trial batch testing shall be carried out on site using the same equipment, materials, and personnel to be used in grouting production.

Production testing shall be carried out at the time of grouting.

Field sampling and testing shall be performed by a person certified according to the Testing of Plastic Concrete clause of OPSS 1350. Additionally, test cubes for compressive strength testing shall be prepared by personnel from a testing laboratory certified by an organization accredited by the Standards Council of Canada according to CSA A283 for Additional Tests according to CSA A3004-2C.

910.07.07.01.02 Field Trial Batch Testing

At least 7 Days prior to the grouting operation, a trial batch shall be carried out to ensure that the grout meets the specified requirements. The Contractor shall notify the Contract Administrator of the date and location of the trial batch at least 7 Days prior.

The trial batch shall consist of the following tests, at minimum:

a) Pumpability and fluidity test according to clause 4.4.7 of PTI M55.1.

b) Wick-induced bleed test according to clause 4.4.8.1 of PTI M55.1 or, alternatively, Schupack pressure bleed test according to clause 4.4.8.2 of PTI M55.1.

c) Chloride ion content according to clause 3.3.4 of PTI M55.1 from a sample of the grout with the same water source to be used for the operation. Testing shall be completed by an independent testing laboratory.

910.07.07.01.03 Testing of Plastic Grout

Prior to grouting, the fluid grout shall be sampled from the mixer or holding tank of the mixer immediately following completion of mixing in the presence of the Contract Administrator. The sample batch of grout shall be tested for the following:

a) A pumpability and fluidity test shall be carried out according to clause 4.4.7 of PTI M55.1. The efflux time shall be within 5 seconds of the previously measured trial batch values. Measurements shall be performed immediately after the grout is removed from the mixer and 30 minutes after mixing, when the grout shall be remixed for 30 seconds. Subsequent fluidity tests shall be carried out at the mixer and the end outlet every 2 hours during grouting operations.

    i. The grout used for the first set of fluidity measurements shall be discarded after testing and shall not be used for the 30 minute measurement. The grout used for the 30 minute measurement shall be left undisturbed in a clean container covered with a lid until the measurement is performed.

b) One wick-induced bleed test shall be initiated prior to the start of grouting according to clause 4.4.8.1 of PTI M55.1.

c) A wet density (mud balance) test shall be performed for the initial batch of grout and every 2 hours at the mixer and the outlet to establish batch consistency, according to PTI M55.1. The permitted density range shall be specified by the grout manufacturer. The density at the outlet should be equal to or greater than the value measured at the mixer. If the density at the outlet is lower, then additional grout shall be pumped until consistency is achieved.

The results of the fluidity, wick-bleed, and wet density tests shall be submitted to the Contract Administrator. Any test result that indicates the grout is not meeting the requirements specified herein shall be immediately reported to the Contract Administrator with proposed corrective measures.

910.07.07.01.04 Sampling for 28-day Compressive Strength Acceptance Testing

Cubes for determination of the compressive strength of the grout shall be cast and cured according to CSA A3004-C2 for testing of 28-Day compressive strength by the Owner. Two sets of six cubes shall be cast per lot, one set for acceptance testing and one set for referee testing, if invoked. The Contract Administrator shall randomly select the batch from the Day's production from which the acceptance and referee samples are taken.

Stainless steel moulds provided by the Contract Administrator shall be used for preparing cubes for compressive strength tests.

The specimens shall be stored at a temperature between 15 °C and 25 °C and shall not be moved prior to demoulding. The specimens shall be demoulded and transported to the designated laboratory within 24 hours ± 4 hours. The samples shall be transported in a sealed white opaque plastic bag containing at least 250 ml of water and maintained at a temperature between 15 °C and 25 °C.

910.07.07.01.05 Early Compressive Strength Tests

Prior to early loading, it shall be demonstrated that the grout has attained a compressive strength of 20 MPa. Grout cubes for compressive strength testing shall be prepared, stored, demoulded and tested according to CSA A3004-2C.

The laboratory conducting the early compressive strength tests shall be CSA certified as specified herein.

910.07.07.01.06 Access for Quality Assurance

Unhindered access for inspection and testing of all the work shall be provided to the Contract Administrator or the Owner's representative. Any debris and obstructions shall be removed to allow access for the purposes of dimensional measurements and/or inspection.

910.07.08 Test Reports

910.07.08.01 Post Grout Inspection

A post-grout inspection shall be carried out 24 hours after grouting by the prestressing personnel. The prestressing personnel shall be according to the Prestressing Personnel subsection. An inspection report shall be submitted to the Contract Administrator within 7 Days of grouting. The report shall describe, with photos, any leaks, cracks, voids or other deficiencies found and shall note locations of deficiencies, if present.

910.07.09 Inspection after Cutting Tendons and after Grouting

Placement, stressing, and grouting of the post-tensioning system shall be carried out as specified in the Contract Documents.

A MTO form PH-CC-822, Certificate of Conformance shall be submitted to the Contract Administrator upon completion of cutting tendons and after grouting.

910.07.10 Management of Excess Material

Management of excess material shall be as specified in the Contract Documents.

910.08 QUALITY ASSURANCE

910.08.01 General

The acceptance of post-tensioning system shall be according to the requirements of this specification, including satisfactory completion of any repairs. Repairs shall not be carried out without the prior written acceptance by the Contract Administrator.

910.08.02 Acceptance of Post-tensioning System

Acceptance shall be based on:

a) Acceptable 28-Day Compressive strength of the grout.

b) The post-tensioning system being free of voids, contamination, or defects.

c) No damage to prestressing steel, anchorages, ducts, vents, and other system components

d) Damage to prestressing steel including but not limited to yielding, pitting, nicks, heat damage shall be cause for rejection.

e) Damaged or blocked ducts or incompletely filled tendons shall be rejectable and shall be repaired to the satisfaction of the Contract Administrator.

910.08.03 Acceptance 28-Day Compressive Strength of Grout

910.08.03.01 Lot Size

A lot shall consist of all the grout from one Day's placement of grout.

910.08.03.02 Acceptance Testing

One set of six cubes shall be tested for 28-Day compressive strength per lot to determine the acceptance of the lot. The compressive strength of a lot shall be the average of the set of the six cubes.

Compressive strength shall be determined according to CSA A3004-C2.

Compressive strength shall be considered acceptable when the lot strength is greater than or equal to the specified 28-Day compressive strength.

Unacceptable grout shall be subject to removal and replacement.

910.08.03.04 Referee Testing

The referee testing process for 28-Day compressive strength of grout is based on duplicate cubes cast at the same time as the acceptance cubes.

Referee testing of compressive strength for a lot may only be invoked by the Contractor within 3 Business Days of receiving the test results for that lot.

The referee laboratory shall be designated by the Owner. Referee test results shall be forwarded to the Contractor as they become available.

If the difference between the referee test result and the acceptance test result is less than or equal to the confirmation value, then the acceptance test result is confirmed, and the acceptance test result shall be used in the determination of acceptance for the grout. If the difference between the referee test result and the acceptance test result is greater than the confirmation value, the acceptance test result is not confirmed, and the acceptance test result shall be disregarded and the referee results shall be used in the determination of acceptance. The confirmation value for confirming the acceptance test result shall be the greater of 10% of the specified strength or 10% of the strength of the acceptance cubes, expressed to one decimal place.

910.08.03.04.01 Referee Testing Cost

The cost of compressive strength referee testing shall be as specified in the Contract Documents.

When the referee result confirms the acceptance test result, the Contractor shall be charged the cost of compressive strength referee testing. When the referee result does not confirm the acceptance test result, the Owner shall bear the cost.

910.08.04 Acceptance of Prestressing Steel

Acceptance of prestressing steel shall be according to OPSS 1440.

910.10 BASIS OF PAYMENT

910.10.01 Longitudinal Stressing System - Item
Transverse Stressing System - Item
Vertical Stressing System - Item

Payment at the Contract price for the above tender items shall be full compensation for all labour, Equipment, and Materials to do the work.

TABLE 1
Pre-Packaged Grouts

Manufacturer	Product Name
Target Products Ltd.	Target® 1121 Cable Duct Grout
BASF Master Builders Solutions	MasterFlow® 1205
Sika Canada Inc.	SikaGrout®-300 PT