CONSTRUCTION SPECIFICATION FOR STRESSING SYSTEMS FOR POST-TENSIONING

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910.01 SCOPE

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

910.01.01 Specification Significance and Use

This specification is written as a provincial-oriented specification. Provincial-oriented specifications are developed to reflect the administration, testing, and payment policies, procedures, and practices of the Ontario Ministry of Transportation.

Use of this specification or any other specification shall be according to the Contract Documents.

910.01.02 Appendices Significance and Use

Appendices are not for use in provincial contracts as they are developed for municipal use, and then, only when invoked by the Owner.

Appendices are developed for the Owner's use only.

Inclusion of an appendix as part of the Contract Documents is solely at the discretion of the Owner. Appendices are not a mandatory part of this specification and only become part of the Contract Documents as the Owner invokes them.

Invoking a particular appendix does not obligate an Owner to use all available appendices. Only invoked appendices form part of the Contract Documents.

The decision to use any appendix is determined by an Owner after considering their contract requirements and their administrative, payment, and testing procedures, policies, and practices. Depending on these considerations, an Owner may not wish to invoke some or any of the available appendices.

910.02 REFERENCES

When the Contract Documents indicate that provincial-oriented specifications are to be used and there is a provincial-oriented specification of the same number as those listed below, references within this specification to an OPSS shall be deemed to mean OPSS.PROV, unless use of a municipal-oriented specification is specified in the Contract Documents. When there is not a corresponding provincial-oriented specification, the references below shall be considered to be to the OPSS listed, unless use of a municipal-oriented specification is specified in the Contract Documents.

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

Ontario Provincial Standard Specification, Construction

OPSS 905 Steel Reinforcement for Concrete

Ontario Provincial Standard Specification, Material

OPSS 1302 Water
OPSS 1304 Packaged Silica Fume Dry Grout Mixture for Post-Tensioning
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

Laboratory Testing Manual:
LS-100 Method for Rounding-off of test data and other numbers

Canadian Standards Association

A23.2-1B Viscosity, Bleeding, Expansion and Compressive Strength of Flowable Grout [Part of CSA A23.1-04/A23.2-04, Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete]
A283-00 (2003) Qualification Code for Concrete Testing Laboratories
S6-06 Canadian Highway Bridge Design Code

ASTM International

A 53/A 53M-04a	Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless
D 2239-03	Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
D 3350-04	Polyethylene Plastics Pipe and Fitting Materials
D 4285-83 (1999)	Indicating Oil or Water in Compressed Air

International Organizations for Standardization/International Electrotechnical Commission

ISO/IEC	DIS Guide 17025

910.03 DEFINITIONS

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

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

Cementing Materials means as defined in OPSS 1304.

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

Grout means an initially fluid mixture of cementing materials, aluminium powder water, and approved admixtures.

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

Primary Tendon Anchorages means the anchorage on longitudinal tendons.

Proposal means a Contractor's submission of changes, when engineering design is required, affecting the original design.

Splice-Prestressing Tendon means a connection of one prestressing tendon to another by means of a mechanical connector.

Tendon means a high strength steel element consisting of one or more wires, strands, or bars and used to impart prestress to the 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 and 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

Design shall be according to the CAN/CSA-S6 and the Structural Manual, Division 1.

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.

At least 5 weeks prior to the commencement of the work, 5 copies of any proposal by the Contractor shall be submitted to the Contract Administrator for acceptance. Proposals shall bear the seals and signatures of a design Engineer and a design checking Engineer. The Contractor shall not proceed with the changes until the Contract Administrator has accepted the proposal.

The Contract Administrator shall respond to the Contractor within 10 Business Days of receiving the proposal.

910.04.02.02 Post-Tensioning Working Drawings

At least 3 weeks before commencement of the placing of post-tensioning materials, 5 sets of all Working Drawings shall be submitted to the Contract Administrator. These 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 supplier's requirements.

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

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 Stressing Details

At least 2 weeks prior to commencement of stressing operations, 3 copies 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

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

910.04.02.04 Couplers

At least 3 weeks prior to the commencement of the work, a copy of the 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.

910.04.02.05 Post-Tensioning Steel Test Certificates

Mill test certificates and stress strain curve test reports shall be according to 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.

Where mill test certificates originate from a mill outside Canada or the United States of America, the Contractor shall have the information on the mill test certificate verified by testing by a Canadian laboratory. This laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian laboratory and appropriate wording stating that the material is in conformance with the specified Contract requirements. The stamp shall include the appropriate material specification number, testing date, and signature of an authorized officer of the Canadian laboratory.

Two copies of the mill test certificates shall be submitted to the Contract Administrator at the time the material is shipped from the fabrication plant.

910.04.02.06 Certificate of Compliance

The Certificate of compliance, as prepared according to OPSS 1304 and supplied with the packaged dry grout mixture, shall be submitted to the Contract Administrator prior to commencement of grouting.

910.05 MATERIALS

910.05.01 Ducts

910.05.01.01 General

Ducts for internal post-tensioning shall be formed from bright steel, galvanized steel, or plastic. The ducts, including joints, shall be watertight under an internal pressure of 350 kPa, corrugated, and non-reactive with concrete, tendons, or grout.

Ducts for external post-tensioning shall be made from smooth, 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 bar tendons, the inside diameter of the ducts shall be at least 6 mm larger than the nominal diameter of the strand or 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.

910.05.01.02 Steel Ducts

Rigid steel ducts shall have a wall thickness of at least 0.60 mm and shall be capable of being curved to an inside radius of 9 m without distress. Semi-rigid steel ducts shall have a wall thickness of at least 0.25 mm and shall be capable of being curved to an inside radius of 3.5 m without distress.

910.05.01.03 Plastic Ducts

Plastic ducts, including their splices, shall be made of high-density polyethylene according to ASTM D 3350, Cell Classification 324420C, and shall be vapour-tight and remain so after tendon installation and stressing.

Plastic for the external post tensioning ducts shall be treated to resist deterioration from ultraviolet light according to ASTM D 3350 and coded D or E.

The plastic duct shall be manufactured according to ASTM D 2239.

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 be such that for the specified minimum radius of curvature the remaining wall thickness, after a tendon movement of 750 mm under a tendon stress of 80% of the specified strength, shall not be less than 1 mm. 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 be according to the following:

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.

Ducts and their splices for external post-tensioning shall be smooth, seamless, and capable of withstanding a grouting pressure of at least 1,000 kPa.

d) Material thickness shall be as follows:

i. Corrugated, internal duct 1.25 mm ± 0.25 mm.
ii. External ducts shall have an external diameter to wall thickness ratio of 21 or less.

910.05.01.04 Ducts at Deviators

Ducts within a deviator for post-tensioning tendons shall be galvanized steel pipe according to ASTM A 53/A 53M, 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.

910.05.01.05 Vents

Vents shall be a 20 mm minimum diameter flexible tubing material capable of withstanding the applied grouting pressures.

910.05.02 Prestressing Steel

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

910.05.03 Anchorages and Couplers

910.05.03.01 General

When tested in an unbonded condition, anchorages and couplers for post-tensioning 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.

910.05.03.02 Anchorages

The manufacturer of the post-tensioning system establishes 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 provided with steel end caps that cover the strand ends and wedges. The steel cap 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.

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.

910.05.03.03 Couplers

Couplers shall be according to the submitted manufacturer's data that is approved by the Contract Administrator.

910.05.03.04 Testing

A dynamic test for unbonded 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 need not be the same used for the first dynamic test. Systems using multiple strands, wires, or 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. Dynamic tests are not required on bonded tendons, unless the anchorage is located or used in such manner that repeated load applications could be expected on the anchorage.

910.05.04 Associated Hardware

Only hardware, including spacers and support devices for the ducts, that is capable of withstanding the loads placed on it and that is approved by the Owner shall be used. All embedded hardware within 50 mm of exposed faces shall be coated with an acceptable material or be of an acceptable non-metallic material.

910.05.05 Steel Reinforcement

Steel reinforcement shall be according to OPSS 1440.

910.05.06 Dry Grout Mixture

The silica fume dry grout mixture shall be packaged, commercially available grout, according to OPSS 1304. The packaged dry grout mixture shall be stored in dry conditions up to the time of its use and shall be used within one month of packaging.

910.05.07 Grout

The grout shall have the following physical properties:

a) A 28-Day compressive strength of not less than 60 MPa.

b) No bleeding or segregation when allowed to stand for 1 hour.

c) An expansion of 6% ± 2% of its original volume when measured at 1 hour.

d) The time measurement for the viscosity of the grout shall be between 11 and 25 seconds when the measurements are performed immediately after the grout is removed from the mixer and when measured 30 minutes after mixing.

The grout used for the first set of viscosity 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.

910.05.08 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 D 4285.

910.06.02 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 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.

910.06.03 Grouting

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

The mixer shall be of the mechanical type with a speed of 1200 to 2000 rpm. The mixer shall be equipped with a calibrated measuring device for determining the quantity of mixing water. The device shall measure the total quantity of water used in each batch of the grout to an accuracy of ± 2%, shall be accompanied by a certified calibration curve that bears the seal and signature of an Engineer, and shall have been calibrated within the six-month period preceding the work. The mixer shall be equipped with a visible timing device suitable for controlling the mixing time.

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.

Standby equipment, such as a water flushing system or compressed air, 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.

910.06.04 Grout Testing

The following grout testing equipment shall be provided:

a) Equipment according to CSA A23.2-1B for the viscosity, bleeding, and expansion measurements.

b) Stainless steel moulds for preparing cubes for compressive strength tests.

c) Thermometers for measuring air and grout temperature.

910.06.05 Malfunction of Gauges

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

910.07 CONSTRUCTION

910.07.01 General

910.07.01.01 Prestressing Personnel

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

Staff 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.

910.07.01.02 Welding

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

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.

910.07.01.03 Surface Condition

All material shall be clean and free of oil, dirt, scale, and pitting. A light rust coating on the steel is acceptable

910.07.02 Installation

910.07.02.01 Post-Tensioning System

Post-tensioning steel, ducts, anchorages, couplers, and local steel reinforcement at anchorages shall be placed in the position shown 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 1 m and a smooth profile shall be maintained. All joints between ducts and ducts and other 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 placed according to the Contract Documents and within the following vertical and horizontal tolerances:

a) Longitudinal sheath ± 15 mm.

b) Transverse sheath ± 10 mm.

c) Anchorage ± 10 mm.

Couplers for strand or high strength 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.

Upon completion of the placement of the post-tensioning system, including all anchorages, anchorage zone reinforcement, and grout tubes, the Quality Verification Engineer shall make an interim inspection of the work to verify that the post-tensioning system meets the requirements of and has been placed as specified in the Contract Documents. The quality Verification Engineer shall then issue written permission to proceed with the post-tensioning.

910.07.02.02 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.

Vents 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.

910.07.02.03 Steel Reinforcement

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

910.07.03 Post-Tensioning

910.07.03.01 General

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

Post-tensioning steel samples selected by the Contract Administrator for testing shall be labelled by the Contractor and contain the following information:

a) Manufacturers identification number

b) Reel number

c) Heat number

d) Location of sampled area

The Quality Verification Engineer shall witness the stressing to verify that it is carried out according to the signed and sealed Working Drawings and Stressing Details and issue written permission to proceed with grouting.

910.07.03.02 Material Samples

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 bar, 1 sample 1.0 m long.

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.

910.07.03.03 Tensioning

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 and the Working Drawings.

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

910.07.03.04 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.

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

910.07.03.05 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.

910.07.03.06 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.

910.07.03.07 Cutting of Tendons

Tendons shall not be cut back until the Contractor has received written permission from the Quality Verification Engineer to proceed with the grouting. Care shall be exercised at all times in the cutting of tendons to avoid the possibility of adversely affecting the prestressing steel.

Cutting of the tendons shall be by mechanical means.

910.07.04 Grouting

910.07.04.01 General

The tendons shall not be grouted until written permission to proceed with the grouting has been given by the Quality Verification Engineer. Once written permission has been given, grouting shall be carried out as soon as possible, but in no case shall any post-tensioning ducts be left ungrouted for more than 7 Days from the date written permission was given or more than 14 Days from the time of completion of stressing.

910.07.04.02 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 cleaned and made free of all deleterious material that may impair bonding of the grout to the ducts and tendons by flushing with water and blowing out with dry, oil free compressed air. Steam shall not be used for cleaning.

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.

910.07.04.03 Grout Mixing

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 mixing procedure for the grout shall be as follows:

a) The required amount of water shall be added to the mixer by means of the calibrated measuring device.

b) Packaged dry grout mixture shall be added to the mixer.

c) The grout shall be mixed for a minimum of 1 minute after the dry grout mixture is added and until the grout is mixed thoroughly and uniformly.

The time interval between the addition of the dry grout 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.

910.07.04.04 Temperature of Grout

The temperature of the grout in the holding tank at the time of injection shall not be less than 15 °C nor more than 30 °C and shall be measured hourly.

910.07.04.05 Grouting Procedures

The temperature of the concrete and the duct shall be at least 5 °C before grouting commences and shall be maintained at that level, or higher, for at least 72 hours after grouting has been completed.

Grouting shall commence as soon as possible after mixing and shall be carried out in one operation without interruption. A continuous, one-way flow of grout shall be maintained. The pumping pressure at the injection vent shall not exceed 1 MPa. The grout shall be pumped from the lowest grout inlet.

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.

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. Pumping shall be resumed and the high point vents along the duct shall be reopened, one at a time, starting with the vent closest to the injection vent. Vents shall not be resealed until grout of original consistency emerges. 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.

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 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.

910.07.05 Quality Control

910.07.05.01 General

The 28-Day compressive strength test results of the grout from the manufacturer shall be submitted to the Contract Administrator.

In addition to the quality control procedures initiated by the Contractor, the following work shall also be done.

910.07.05.02 Grout Mixture

910.07.05.02.01 General

Viscosity, bleeding, and expansion measurements and preparation of cubes for compressive strength tests shall be done on a level, vibration free surface.

The Contractor shall use staff 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 A23.2-1B. This staff shall also prepare the test cubes.

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

910.07.05.02.02 Bleeding, Expansion, and Viscosity Tests

Prior to the grouting operation and in the presence of the Quality Verification Engineer, a trial batch of grout shall be mixed and tested according to CSA A23.2-1B for bleeding, expansion, and viscosity to ensure that the grout meets the requirements specified herein. The trial batch of grout shall not be used in the actual grouting operation.

During the grouting operation, the bleeding, expansion, and viscosity tests shall be performed according to CSA A23.2-1B on the grout sampled from the mixer. The grout tests shall be performed at least once a day and as requested by the Contract Administrator.

Copies of the results of the bleeding, expansion, and viscosity 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 and the grouting operation shall be halted. The duct being grouted shall immediately be flushed with clean water and then blown out with dry, oil free compressed air. Grouting shall recommence only after the problem has been identified and corrected. The grout supplier shall also be immediately notified when the grout, mixed as specified, fails to meet the test requirements for bleeding, expansion, and viscosity.

910.07.05.02.03 Sampling for Compressive Strength Tests

Cubes for compressive strength tests shall be prepared according to CSA A23.2-1B on site from the grout pumped into the ducts, as follows:

a) The total volume of grout used for grouting one structure represents one lot.

b) At least four random sublots of grout samplings shall be taken at the mixer for each lot. Six cubes shall be made from each sublot sampling to be used for the 28-Day compressive strength tests.

c) Three cubes shall be made from each sampling taken at the anchorage outlet. This sampling is for the Owners use only.

The cubes shall be identified as coming from the mixer or the anchorage outlet and shall be stored at a temperature between 15 and 25 °C and shall not be moved prior to demoulding. The cubes shall be demoulded within 24 hours ± 4 hours and the cubes representing the Owner's sample shall be given to the Contract Administrator. The cubes shall be presented in a sealed white opaque plastic bag containing at least 250 ml of water.

910.07.05.02.04 Early Compressive Strength Tests

The Contractor shall prepare and test the grout compressive strength test cubes according to OPSS 1304 to determine when the grout has attained a compressive strength of 20 MPa.

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

910.07.06 Prestressing Steel Friction Test

Where the theoretical and actual elongations are significantly different, the Quality Verification Engineer may call for a friction test on one or more tendons to check the theoretical value of friction used in the design and elongation calculation.

The results of these tests shall be submitted to the Contract Administrator.

910.07.07 Test Reports

A copy of all test reports shall be submitted to the Contract Administrator.

910.07.08 Certificate of Conformance

Upon completion of grouting, the Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by a Quality Verification Engineer. The Certificate of Conformance shall state that the placement, stressing, and grouting of the post-tensioning system have been carried out as specified in the Contract Documents.

910.07.09 Management of Excess Material

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

910.08 QUALITY ASSURANCE

910.08.01 Grout

When requested, representative samples of the packaged grouting material shall be submitted to the Contract Administrator.

910.08.02 Acceptance Based on Compressive Strength

The total volume of grout used for grouting one structure represents one lot. Each lot shall be divided into sublots with a minimum of four sublot results in each lot. A sublot shall be represented by an average of six 28-Day compressive strength results sampled from one batch of grout. The individual compressive strength results shall be rounded to one decimal place.

Acceptance of the compressive strength for each lot shall be based on the mean and the standard deviation of the lot measurements calculated by the Contract Administrator as detailed in the Payment Adjustment Section.

Lots with per cent within limits (PWL) greater than 98% shall be accepted with a bonus payment. Lots with PWL equal to or greater than 90% and lower than or equal to 98% shall receive full payment, and lots where the PWL is less than 90% shall be accepted at a reduced payment.

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.

910.10.01.01 Payment Adjustment Based on Compressive Strength of Grout

The payment adjustment factor for the Contract price for longitudinal and transverse stressing systems shall be determined as follows.

Acceptance formula:

The quality index for the lower specification limit, Q_L, shall be determined from the following formula:

$Q_L = (X - 60) / s$

Where: X is the Mean
s is the Standard Deviation

The mean shall be rounded to one, and the standard deviation and lower quality index shall be rounded to two decimal places. The rounding procedure shall be according to LS-100.

The PWL shall be determined from Table 1 based on the Lower Quality Index (Q_L) and using the number of sublots (n).

The payment adjustment factor corresponding to the PWL shall be determined from Table 1. The payment adjustment factor shall apply down to a minimum of 70% of the Contract price for longitudinal and transverse stressing systems for the lot.

910.10.02 Concrete

Concrete for the anchorage recesses shall be paid according to OPSS 904.

Table 1
Quality Index Values for Estimating Per Cent Within Limits and Payment Adjustment Factor

PWL	n=4	n=5	n=6	n=7	n=8	n=9	n=10	n=11	n=12	n=15	Payment
100	1.50	1.79	2.03	2.23	2.39	2.53	2.65	2.65	2.83	3.03	1.02
99	1.47	1.67	1.80	1.89	1.95	2.00	2.04	2.04	2.09	2.14	1.01
98	1.44	1.60	1.70	1.76	1.81	1.84	1.86	1.86	1.91	1.93	1.00
97	1.41	1.54	1.62	1.67	1.70	1.72	1.74	1.74	1.77	1.80	1.00
96	1.38	1.49	1.55	1.59	1.61	1.63	1.65	1.65	1.67	1.69	1.00
95	1.35	1.44	1.49	1.52	1.54	1.55	1.56	1.56	1.58	1.59	1.00
94	1.32	1.39	1.43	1.46	1.47	1.48	1.49	1.49	1.50	1.51	1.00
93	1.29	1.35	1.38	1.40	1.41	1.42	1.43	1.43	1.44	1.44	1.00
92	1.26	1.31	1.33	1.35	1.36	1.36	1.37	1.37	1.37	1.38	1.00
91	1.23	1.27	1.29	1.30	1.30	1.31	1.31	1.31	1.32	1.32	1.00
90	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.26	1.26	1.27	1.00
89	1.17	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.21	1.22	0.99
88	1.14	1.15	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	0.98
87	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	0.97
86	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	0.96
85	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	0.95
84	1.02	.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94
83	0.99	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.93
82	0.96	0.95	0.94	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92
81	0.93	0.91	0.90	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.91
80	0.90	0.88	0.87	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.90
79	0.87	0.85	0.84	0.83	0.82	0.82	0.82	0.82	0.82	0.82	0.89
78	0.84	0.82	0.80	0.80	0.79	0.79	0.79	0.79	0.78	0.78	0.88
77	0.81	0.78	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.87
76	0.78	0.75	0.74	0.73	0.73	0.72	0.72	0.72	0.72	0.72	0.86
75	0.75	0.72	0.71	0.70	0.70	0.69	0.69	0.69	0.69	0.69	0.85
74	0.72	0.69	0.68	0.67	0.66	0.66	0.66	0.66	0.66	0.66	0.84
73	0.69	0.66	0.65	0.64	0.63	0.63	0.63	0.63	0.62	0.62	0.83
72	0.66	0.63	0.62	0.61	0.60	0.60	0.60	0.60	0.59	0.59	0.82
71	0.63	0.60	0.59	0.58	0.57	0.57	0.57	0.57	0.57	0.56	0.81
70	0.60	0.57	0.56	0.55	0.55	0.54	0.54	0.54	0.54	0.54	0.80
69	0.57	0.54	0.53	0.52	0.52	0.51	0.51	0.51	0.51	0.51	0.79
68	0.54	0.51	0.50	0.49	0.49	0.48	0.48	0.48	0.48	0.48	0.78
67	0.51	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.77
66	0.48	0.45	0.44	0.44	0.43	0.43	0.43	0.43	0.42	0.42	0.76
65	0.45	0.43	0.41	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.75
64	0.42	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.37	0.74
63	0.39	0.37	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.73
62	0.36	0.34	0.33	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.72
61	0.33	0.31	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.29	0.71
60	0.30	0.28	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.25	0.70

Appendix 910-A, April 2008
FOR USE WHILE DESIGNING MUNICIPAL CONTRACTS

Note: This is a non-mandatory Commentary Appendix intended to provide information to a designer, during the design stage of a contract, on the use of the OPS specification in a municipal contract. This appendix does not form part of the standard specification. Actions and considerations discussed in this appendix are for information purposes only and do not supersede an Owner's design decisions and methodology.

Designer Action/Considerations

No information provided here.

Related Ontario Provincial Standard Drawings

No information provided here.