CONSTRUCTION SPECIFICATION FOR STRESSING SYSTEMS FOR POST-TENSIONING

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910.01 SCOPE

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

910.01.01 Specification Significance and Use

This specification is written as a municipal-oriented specification. Municipal-oriented specifications are developed to reflect the administration, testing, and payment policies, procedures, and practices of many municipalities in Ontario.

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

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

Ontario Provincial Standard Specifications, Construction

OPSS 905 Steel Reinforcement for Concrete

Ontario Provincial Standard Specifications, 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

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
S6-00 Canadian Highway Bridge Design Code

ASTM International

A 53/A 53M-04a	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
A 416/A 416M-02	Steel Strand, Uncoated Seven-Wire for Prestressed Concrete
D 2239-03	Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
D 3350-04	Polyethylene Plastics Pipe and Fittings Materials
D 4285-83 (1999)	Indicating Oil or Water in Compressed Air

International Organization 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.

Cementing Materials means as defined in OPSS 1304.

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

Deviator means a length of steel pipe placed in deviation blocks or deviation diaphragms to provide a means of changing direction of external tendons.

Engineer means a professional engineer licensed by the Professional Engineers Ontario to practice in the Province of Ontario.

Grout means an initially fluid mixture of cementing materials, aluminum 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.

Sublot means the six cubes prepared at one grout material sampling used to determine the 28-Day compressive strength.

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 injecting 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 SUBMISSION AND DESIGN REQUIREMENTS

910.04.01 Submission Requirements

910.04.01.01 General

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

When other authorities are involved in the approval of the design or construction of a highway structure, the submission shall be made at least 5 weeks prior to commencement of work and one additional copy of the required submission shall be provided for each authority.

Work shall not commence until written notice to proceed has been given by the Contract Administrator.

At least five weeks prior to commencement of the work, five copies of any proposal shall be submitted to the Contract Administrator.

910.04.01.02 Post-Tensioning Working Drawings

At least three weeks before commencement of the placing of post-tensioning materials, five sets of all Working Drawings shall be submitted to the Contract Administrator. These drawings shall include the following information:

a) Design details

b) Slip

c) Calculation data

d) Sequence of stressing

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, anchorage 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 information:

f) Anchorage bulb dimensions

g) Spacing of bulbs

h) Length of strand embedded in concrete

i) Ultimate load capacity of the anchorage

910.04.01.03 Stressing Details

At least two weeks prior to the commencement of stressing operations, three copies of the following information shall be submitted to the Contract Administrator:

a) The elongation calculations that take into account losses due to friction, elastic shortening, relaxation, shrinkage, and creep of concrete where these are applicable and all other causes.

b) The type of jack.

c) Friction of jack.

d) Jacking pressure.

e) Method of attaining the required slip.

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

910.04.01.04 Couplers

At least three weeks prior to 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 strength and fatigue requirements shall be submitted to the Contract Administrator.

910.04.01.05 Prestressing 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 when the material is shipped from the fabrication plant.

910.04.01.06 Certificate of Compliance

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

910.04.01.07 Return of Submissions

Two copies of each submission to be returned shall be marked as one of the following:

a) Stamped with the wording that allows for permission to construct.

In this case, work can commence on receipt of the drawing by the Contractor. A copy of these drawings shall be available at the site prior to and during construction.

b) Stamped with the wording that allows for permission to construct as noted.

In this case, work can start on receipt of the drawings by the Contractor. The drawings shall be updated as noted and shall have a stamp affixed that is signed by an Engineer stating the drawings have been revised according to the noted comments. A copy of the stamped updated drawings shall be available at the site prior to and during construction.

c) Showing only required changes.

In this case, the drawings shall be updated as required and the submission process repeated.

910.04.02 Design Requirements

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

910.05 MATERIALS

910.05.01 Ducts

910.05.01.01 General

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

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

All sheaths 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 tendon sheaths that are continuous over more than one span. Air and drainage vents shall be provided at other locations as specified in the Contract Documents.

Sheaths shall be capable of withstanding concrete pressures without excessive deformation or permitting the entrance of cement paste during the placing of concrete. The ducts shall have sufficient rigidity to maintain the required profile between points of supports.

For single strand or bar tendons, the inside diameter of the sheaths for post-tensioning 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 sheath shall be at least twice the cross-sectional area of the prestressing 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 duct.

910.05.01.02 Steel Sheaths

Rigid steel sheaths shall have a wall thickness of at least 0.60 mm and shall be capable of being formed to an inside radius of 9 m without distress. Semi-rigid steel sheaths shall have a wall thickness of at least 0.25 mm and shall be capable of being formed to an inside radius of 3.50 m without distress.

910.05.01.03 Plastic Sheaths

Plastic sheaths, 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 sheaths shall be treated to resist deterioration from ultraviolet light according to ASTM D 3350 and coded D or E.

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

Plastic sheaths shall not be used when the radius of curvature of the tendon is less than 10 m. The sheaths shall be capable of bending to the specified minimum radius of curvature without damage. The sheath 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 sheaths, the radial force as exerted by a single strand on the sheath wall shall not exceed 40 kN/m.

The plastic sheaths shall be according to the following:

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

   Sheaths 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 $\pm$ 0.25 mm.
   ii. External duct shall have an external diameter to wall thickness ratio of 21 or less.

910.05.01.04 Sheaths at Deviators

The sheaths 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 sheath shall be formed to conform to the tendon alignment.

910.05.01.05 Duct Vents

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

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 strength of the tendons, without exceeding the anticipated set. After tensioning and seating, anchorages shall be capable of sustaining the applied loads without slippage, distortion, or other changes that could result in loss of prestress.

910.05.03.02 Anchorages

The dimensions and details of anchorages, including any reinforcement required to resist tensile, bursting, and anchorage bearing stresses within the local zone, shall be based on the strength of the tendon and the strength of the concrete at transfer as specified in the Contract Documents.

Primary tendon anchorages shall be provided with steel end caps which cover the strand ends and wedges. The steel cap shall have 3 mm minimum wall thickness, and shall have attachments and gaskets that will allow the cap to withstand full grouting pressures. End caps should be vented to ensure complete filling with grout.

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

910.05.03.03 Couplers

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

When specified in the Contract Documents, all coupling components for low alloy steel bar shall be protected by a coating material.

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 involves 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 behavior 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 can be expected on the anchorage.

910.05.04 Associated Hardware

Only hardware, including spacers and support devices for the sheaths, 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 a packaged, commercially available grout, according to OPSS 1304. The packaged dry grout mixture shall be stored in a dry condition up to the time of its use and shall be used within one month of packaging.

910.05.07 Water

Water shall be according to OPSS 1302.

910.05.08 Grout

The grout shall have the following physical properties:

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

b) Shall not bleed or segregate when allowed to stand for 1 hour.

c) An expansion of 6% $\pm$ 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.

910.06 EQUIPMENT

910.06.01 Air Compressor

The air compressor for air blasting shall have a minimum capacity of 3.5 m^3/min. The compressed air shall be free of water and oil according to ASTM D 4285.

910.06.02 Stressing Equipment

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) Capable of measuring the forces to an accuracy of $\pm$ 2%.

b) Each gauge shall be capable of indicating forces directly in Newtons or be accompanied by a chart by which the reading can be converted into such units of force.

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

d) Friction losses in jacks, hoses, and connections shall be determined and recorded.

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

f) The gauges shall have been calibrated within the six-month period immediately preceding the commencement of the work.

g) The forces to be measured shall be within 25 and 75% of the maximum graduated capacity of the gauge unless calibration data clearly establishes the gauge is accurate over a wider range.

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

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

j) Provision shall be made for accommodating two gauges at each jack and pump combination.

910.06.03 Grouting Equipment

The grouting equipment shall consist of a mixer, separate holding tank, and 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 $\pm$ 2%. The device shall be accompanied by a certified calibration curve that bears the seal and signature of an Engineer. The device shall have been calibrated within the six-month period immediately preceding the commencement of 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 relief valve set to release at a pressure of 1 MPa. The pressure gauge shall be accompanied by a certified calibration curve which bears the seal and signature of an Engineer, shall have an accuracy of $\pm$ 5% 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 and compressed air shall be available at the site before the commencement of grouting in case of a breakdown of the equipment during grouting operations. Suitable equipment to grout a number of ducts simultaneously shall be readily available.

910.06.04 Grout Testing Equipment

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

Gauges shall be replaced immediately when a malfunction is noted.

910.07 CONSTRUCTION

910.07.01 General

910.07.01.01 Prestressing Staff

The work shall be done by staff employed by or licensed by the manufacturer of the stressing system used.

The staff employed to supervise the work of tensioning and grouting shall have a working knowledge of the prestressing system used and shall be capable of evaluating the forces, gauge pressures, elongations, and method by which the prestressing 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. The staff shall be present during these operations and during the concreting operations to ensure the post-tensioning components of the work are not adversely affected.

910.07.01.02 Welding

Except as permitted in the following paragraph, welding equipment shall not use the prestressing steel or sheath as an electrical ground. Welding shall not be permitted within 3 m of the prestressing steel.

Welding of the prestressing tendons will only be permitted to facilitate pulling the tendon through the sheath as specified below. Where the ends of strands are welded together to facilitate pulling the tendon through the sheath, 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.

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 Prestressing Steel, Sheaths, and Anchorages

910.07.02.01 Installation

Prestressing steel, sheaths, anchorages, couplers, and local reinforcing steel at anchorages shall be placed in the positions shown in the Contract Documents and held in the correct location during the operations of placing and consolidating concrete.

The sheaths shall be secured at intervals not exceeding 1 m and a smooth profile shall be maintained. All joints in sheaths and between the sheath 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 concreting.

Sheaths and anchorages shall be placed according to the following tolerances that apply to horizontal and vertical placement:

a) Longitudinal sheath $\pm$ 15 mm.

b) Transverse sheath $\pm$ 10 mm.

c) Anchorage ± 10 mm.

Couplers in strand or high strength bars 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 prestressing system used.

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.

Holes in the duct shall be the same as the inside diameter of the vent.

910.07.02.03 Reinforcing Steel

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

910.07.03 Prestressing Steel Post Tensioning

910.07.03.01 General

The Contract Administrator shall be notified when the prestressing steel is available for sampling at least one week in advance of stressing.

Prestressing 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.

910.07.03.02 Provision of Material Samples

Samples of prestressing materials and 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 will 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 attained the strength specified in the Contract Documents.

Tensioning shall be carried out as specified in the Contract Documents and as shown on the stamped Working Drawings.

After tensioning, all openings and vents along the ducts shall be temporarily plugged or sealed until the grouting is performed.

910.07.03.04 Measurement of Tensioning and Variation in the Prestress Force

The force in the tendons shall be determined by means of the pressure gauge and shall be continually verified by means of measuring the tendon elongation. The pressure gauge readings and the elongations for the first five tendons of each type stressed shall be recorded at intervals of 25% of the maximum prestress force including the final reading.

The measured elongations of individual tendons at the specified jacking force, based on the gauge pressures, shall be within -3 to +9% of the calculated values.

When the actual elongation is outside the tolerance of -3 to +9%, jacking shall be stopped at that tendon and the Contractor shall prepare and submit a report rationalizing the observed difference.
The variation from specified total prestress force over the complete component cross-section, including broken strands, shall not exceed $\pm$ 5%. The distribution of the variation of this total prestress force across the component cross-section shall be subject to approval by the Contract Administrator.

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 Stressing Records

Records of elongation, calibrated jacking pressure readings, and slippage shall be kept at all times and submitted to the Contract Administrator.

910.07.03.07 Cutting of Tendons

Tendons shall not be cut until the stressing records have been reviewed by the Contract Administrator and written permission to grout has been given by the Contract Administrator. Care shall be exercised at all times in the cutting of tendons to avoid the possibility of adversely affecting the prestressing steel.

Unless other methods are approved by the Contract Administrator 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 concrete has been placed in the anchorage recesses and permission to grout has been given by the Contract Administrator. Where it is not possible to place concrete in the anchorage recesses prior to grouting, the anchorages shall be sealed to resist the pressure during grouting. Once permission to grout has been received in writing from the Contract Administrator, grouting shall be carried out as soon as possible, but in no case shall any prestressing steel be left ungrouted for more than 7 Days after receipt of permission to grout or more than 14 Days after completion of tensioning.

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 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 ejection 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 the 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 attached.

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 between the addition of the dry grout mixture 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 at least 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 or 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 above this minimum temperature at all times during the grouting operation and for 72 hours after grouting is complete.

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 the same consistency as that being pumped in at the injection vent. When the grout is of the same consistency, an additional five litres of grout shall be permitted 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 re-opened, 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 a 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 compressive strength of at least 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 upon receipt.

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. The test cubes shall be prepared by this staff.

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 Contract Administrator, a trial batch shall be mixed and the grout tested according to CSA A23.2-1B for bleeding, expansion, and viscosity to ensure that the grout meets the requirements specified herein before the grouting is to proceed. 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 at the mixer. The tests shall be performed at least once a day and as requested by the Contract Administrator.

Copies of the bleeding, expansion, and viscosity test shall be submitted to the Contract Administrator. Any test result which indicates the grout is not meeting the requirements specified herein shall be reported immediately to the Contract Administrator and the grouting operation halted until the cause of the problem is 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 sampling shall be taken once per day and as directed by the Contract Administrator.

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 $\pm$ 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 strength of 20 MPa.

The laboratory conducting the test shall be CSA certified as specified herein.

910.07.06 Prestressing Steel Friction Test

Where the elongations shown on the stamped stressing details of the Working Drawing submission and the actual elongations differ from the clause for Measurement of Tensioning, the Contract Administrator may require the Contractor to conduct 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 As Built Drawings

As built drawings shall be prepared by the Contractor as follows:

a) For all work incorporated into the completed structure that required the submission of Working Drawings.

b) For all changes from the original Contract Document requirements.

The as built drawings shall be submitted to the Contract Administrator in a reproducible format prior to final acceptance of work.

The as built drawings shall bear the seal and signature of an Engineer.

910.07.09 Management of Excess Material

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

910.08 QUALITY ASSURANCE

910.08.01 Testing of Prestressing Steel

The testing of prestressing steel strand and bars shall be according to ASTM A 416/A 416M

910.08.02 Anchorages, Spirals, and Couplers

Anchorages, spirals, and couplers shall be examined for conformance with the Contract Documents and the manufacturers requirements.

910.08.03 Grout

Using the prepackaged samples submitted to the Contract Administrator, a trial batch may be made according to OPSS 1304 and tested for the specified properties.

The compressive strength test shall be according to CSA A23.2-1B.

Samples of the grout may be taken from the mixer and tested.

The grout shall be examined for acceptability as it flows from the vents and anchorages prior to closure.

910.08.04 Anchorage Outlet Sampling of Grout

The grout samples obtained from the anchorage outlet shall be tested and compared with the 28-Day compressive strength test cubes.

910.08.05 Material, Stressing Records, and Test Results

Post-tensioning material, stressing records, and test results shall be examined for conformance to the Contract Documents.

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 Material to do the work.

Fifty percent of the Contract price shall be paid on completion of the stressing. The remainder shall be paid after completion of the grout curing and review of the 28-Day compressive strength test results by the Contract Administrator and be based on any payment adjustment calculated.

910.10.02 Stressing System Payment Adjustment

The results of the compressive strength tests of the six cubes made for each sublot shall be averaged. The average of the test results for all sublots shall then be averaged. The Contract price for the stressing system will be reduced by 2% for each MPa this average is below 60 MPa.

The calculations will be based on the compressive strength of the cubes made from samples taken at the mixer.

Appendix 910-A, November 2005
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

The following shall be specified in the Contract Documents:

- Proposed post-tensioning systems, induced slip requirements. (910.04.01.02)

- Other locations for air and drainage vents. (910.05.01.01)

- Strength of tendon and strength of concrete at transfer. (910.05.03.02)

- Coupling components for low alloy steel bar to be protected by a coating material. (910.05.03.03)

- Ultimate strength. (910.05.01.03.04)

- Location of prestressing steel, sheaths, anchorages, couplers, and local reinforcing steel at anchorages. (910.07.02.01)

- Couplers in strand or high strength bars when permitted in the work. (910.07.02.01)

- Concrete strength required for tensioning and tensioning procedures. (910.07.03.03)

- Anchorages, spirals, and couplers. (910.08.02)

- Post-tensioning materials, stressing records, and test results. (910.08.05)

The designer should ensure that the General Conditions of Contract and the 100 Series General Specifications are included in the Contract Documents.

Related Ontario Provincial Standard Drawings

None