CONSTRUCTION SPECIFICATION FOR PRESTRESSED SOIL AND ROCK ANCHORS

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942.01 SCOPE

942.01.01 General

This specification covers the requirements for the design, installation, and testing of prestressed anchors in soil and rock.

942.01.02 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.

942.01.03 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.

942.02 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 specifications, standards, or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 903	Deep Foundations
OPSS 906	Structural Steel for Bridges

Ontario Provincial Standard Specifications, Material

OPSS 1301	Cementing Materials
OPSS 1302	Water
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete

CSA Standards

A23.1-24/A23.2-24	Concrete Materials and Methods of Concrete Construction/Test Methods and Standard Practices for Concrete
A23.2-1B	* [Part of A23.1:24/A23.2:24 - Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete]
A283-24	Certification of Laboratories for Concrete
G40.20-13/G40.21-13 (R2023)	General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steels

ASTM International

A53/A53M-24	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A416/A416M-24	Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete

A500/A500M-23	Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
A722/A722M-18	High Strength Steel Bars for Prestressed Concrete
D1143/D1143M-20e1	Deep Foundations Under Static Axial Compressive Load
D1248-16	Polyethylene Plastics Extrusion Materials for Wire and Cable
D1784-20	Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
D3350-24	Polyethylene Plastics Pipe and Fittings Materials
D4101-24	Classification System and Basis for Specification for Polypropylene Injection and Extrusion Materials

American Petroleum Institute (API)

13A	Drilling Fluid Materials, 19th Edition, 01.02.19
RP 13B-1	Procedure for Field Testing Water Based Drilling Fluids, 5th Edition

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025 General Requirements for the Competence of the Testing and Calibration Laboratories

Post Tensioning Institute (PTI)

PTI DC 35.1-14 Recommendations for Prestressed Rock and Soil Anchors

942.03 DEFINITIONS

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

Alignment Load means a nominal minimum load applied to an anchor during testing to keep the testing equipment positioned correctly.

Anchor means a system used to transfer tensile loads to soil or rock that includes the prestressing steel, anchorage, corrosion protection, sheathings, spacers, centralizers, and grout.

Anchor Head means the device by which the prestressing force is permanently transmitted from the prestressing steel to the bearing plate.

Anchorage means the combined system of anchor head, bearing plate, trumpet, and anchorage corrosion protection that is used to transmit the prestressing force from the prestressing steel to the surface of the ground or the supported structure.

Apparent Free Length means the length of tendon or bar that is apparently not bonded to the surrounding ground or grout, as calculated from the elastic movement measured during the load test.

Bond Length means the length of the tendon that is bonded to the primary grout and capable of transmitting the applied tensile load to the surrounding soil or rock.

Centralizer means a device to support and position the tendon and sleeves in the drill hole throughout the bond length of the tendon so that a minimum grout cover is achieved.

Certificate of Conformance means a document issued by the Quality Verification Engineer confirming that the specified components of the work are in General Conformance with the requirements of the Contract Documents.

Coupler means the method by which the prestressing force can be transmitted from one partial length of prestressing tendon to another.

Design Load means the anticipated final maximum effective load in the anchor after allowance for time-dependent losses or gains. The design load includes appropriate load factors to ensure that the overall structure has adequate capacity for its intended use.

Free Stressing Length means the designed length of the tendon that is not bonded to the surrounding ground or grout during stressing.

Lift-Off means checking the load in the tendon at any specified time with the use of a hydraulic jack at the moment of lifting of the anchor head off the bearing plate.

Lock-Off Load means the prestressing force in an anchor immediately after transferring the load from the jack to the stressing anchorage.

Log Time Cycle means one rotation of a log cycle of a semilogarithmic plot for the purpose of recording the measurement of movement and time.

Performance Test means cyclic and incremental loading and unloading of an anchor, while recording the total movement of the pulling head in each cycle at each increment, including the residual movement at alignment load.

Permanent Anchor means a prestressed anchor intended for permanent use.

Post-Grouting means regrouting an anchor after the primary grout has set.

Pre-Production Test Anchor means an anchor installed and then loaded to verify the design parameters, prior to the installation of the production anchors.

Prestressing Steel means steel strand or bar that exhibits the principal attributes of high tensile strength and ductility because of its composition and method of production,

Primary Grout means Portland cement based grout that is injected into the anchor hole prior to or after the installation of the anchor tendon to provide for the force transfer to the surrounding ground along the bond length of the tendon.

Production Anchor means an anchor installed and loaded that forms part of the final foundation support system.

Production Test Anchor means an anchor installed and then loaded to verify the design parameters, prior to the installation of the production anchors.

Proof Test means incremental loading of an anchor and recording the total movement of the anchor at each increment.

Quality Verification Engineer means an Engineer retained by the Contractor qualified to provide the services specified in the Contract Documents.

Residual Movement means the non-recoverable movement of the pulling head measured at alignment load.

Temporary Anchor means a prestressed anchor intended for temporary use.

Test Load (TL) means the maximum load that the anchor is subjected during testing.

Total Movement means the total movement of the pulling head measured at maximum load in each cycle.

942.04 DESIGN AND SUBMISSION REQUIREMENTS

942.04.01 Design Requirements

942.04.01.01 General

Except for Owner designed anchors, the Contractor shall be responsible for the detailed design of the anchor, including the determination of the applied loads, design assumptions, and installation procedures. The Contractor shall also be responsible for the design of the anchor testing equipment and reaction system.

The anchors shall be designed to safely withstand the applied loads specified in the Pre-Production Test Anchor clause and fulfill the acceptance criteria specified in the Production Anchor clause and perform satisfactorily at the design load through the required service life.

The design assumptions shall accurately represent the subsurface conditions prevalent at the site.

Temporary anchors in a corrosive environment shall be designed as permanent anchors. Except as specified in this specification, the anchors shall be designed according to the design recommendation of the PTI DC-35.1

942.04.02 Submission Requirements

942.04.02.01 Working Drawings

942.04.02.01.01 Rock Anchor

One hard copy and one electronic copy of the prestressed soil and rock anchor Working Drawings shall be submitted to the Contract Administrator at least 15 Business Days prior to the commencement of the work of prestressed rock and soil anchors, for information purposes only. Prior to making a submission, the seals and signatures of a design Engineer and a design-checking Engineer shall be affixed on the Working Drawings verifying that the drawings are consistent with the Contract Documents.

Where multi-discipline engineering work is depicted on the same Working Drawing and the design or design-checking Engineer or both are unable to seal and sign the Working Drawing for all aspects of the work, the drawing shall be sealed and signed by as many additional design and design-checking Engineers as necessary.

Information to be shown on the Working Drawings shall describe and illustrate the complete details of the anchor system, anchor testing equipment, and reaction system for the production anchors and, when specified in the Contract Documents, pre-production test anchors. This information shall include as a minimum:

a) Plans, Elevations, and Sections

   i. Anchor spacing.
   ii. Orientation.
   iii. Minimum total anchor length.
   iv. Free stressing length.
   v. Design load.vi. A unique identification number for each anchor.
   vii. Anchor components and details.

b) Installation

   i. Construction methods.
   ii. Work restrictions.
   iii. Schedule.
   iv. Sequence and coordination of work.
   v. Monitoring.
   vi. Type and number of tests
   vii. Evaluation of test results.

c) Materials

i. Physical properties of monobar and multistrand anchors.
ii. Primary grout materials and mix proportions.
iii. Post grouting materials and mix proportions.
iv. Free stressing length materials and mix proportions.
v. Corrosion protection material physical and mechanical properties.

d) Anchor Hole Construction

i. Method of constructing the anchor holes and maintaining the stability of the holes during the anchor installation. The drilling equipment and materials including drill bit or auger diameter and lengths, casing diameter and lengths, and slurry material used to facilitate the construction of the anchor hole. The method of verifying the hole length shall also be identified.
ii. Details for assembling the anchor in the anchor hole.
iii. Method of placing and centring the anchor tendons, including the method used to maintain them in the centre of the hole over the design bond length.
iv. Bond zone primary grout placement. Grout mixing procedure and the method of installation, including grout pressures. The method to determine the surface of the hardened bond length grout shall be identified.
v. Bond zone post grout placement. Grout mixing procedure and the method of installation, including grout pressures.
vi. Free stressing zone grout placement. Grout mixing procedure and the method of installation, including grout pressures.
vii. Waterproofing of holes drilled in rock for permanent anchors. Details of water tightness tests, including setup, water pressure, method of applying pressure, details of consolidation, grouting, redrilling, and retesting.

e) Stressing Information

i. Anchor stressing schedule that includes the working loads and test loads.
ii. Anchor stressing equipment, and the method for testing the stressing of pre-production and production test anchors and production anchors. Details of the reaction system used to support the applied loads.
iii. Equipment, including the calibration records of the gauges and jacks, and procedure to monitor the applied loads and movements during anchor testing.
iv. Details of the reference system and equipment to monitor the movement.

f) All design assumptions, loads, parameters, and bond stresses used for pre-production and production test anchors and production anchors.

g) Testing records when testing has been done to determine bond stress.

h) Details of destressing and removal of temporary anchors.

942.04.02.02 Slurry

At least 14 Days prior to commencement of the work, the following information for the slurry shall be submitted to the Contract Administrator, for information purposes only:

a) The type, source, and physical and chemical properties of the bentonite or polymer.

b) The source of water.

c) Method of mixing slurry.

d) The water solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to produce slurry with the required physical properties.

e) Details of procedure to be used for monitoring the quality of the slurry.

f) A test report showing the properties of the slurry and certifying that the slurry meets the requirements of API 13A.

g) Method of disposal of the slurry.

942.04.02.03 Couplers

At least 14 Days prior to commencement of the work, a copy of the following shall be submitted to the Contract Administrator:

a) Manufacturer's catalogue giving the complete data on the coupler material and installation procedures.

b) Test reports from the manufacturer certifying strength and fatigue requirements.

942.04.02.04 Prestressing Steel

942.04.02.04.01 Mill Certificates

One copy of the mill test certificates, indicating that the steel meets the requirements of the Contract Documents, shall be submitted to the Contract Administrator at the time the prestressing steel is delivered to the job site.

Identification on the anchor tendon shall allow tracing of the prestressing steel to its heat or reel number.

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 certificate verified by testing by a Canadian testing laboratory. The laboratory shall be accredited by the Standards Council of Canada as complying 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 testing laboratory and appropriate wording stating that the material is according to the Contract Documents. The stamp shall include the appropriate material specification number, testing date (i.e., yyyy-mm-dd), and signature of an authorized officer of the testing laboratory.

One copy of the stress-strain curves that are representative of the lots to be used shall be submitted to the Contract Administrator together with the mill certificates specified detailed in OPSS 1440.

942.04.02.04.02 Prestressing Steel Bond Capacity

If not available from the prestressing steel manufacturer, a prestressing strand bond capacity test shall be conducted on the strand according to Appendix A of the PTI DC 35.1. The test information shall be submitted to the Contract Administrator prior to commencement of work.

942.05 MATERIALS

942.05.01 Permanent Anchors

942.05.01.01 General

Tendons shall be manufactured from steel bars or strand either in single or multiple element tendons.

The permanent anchors shall be Dywidag Threadbar Anchors, BBR Cona Multi-Strand Anchors, VSL Multi-Strand Anchors, or other approved equivalent anchors.

942.05.01.02 Anchorages

The components of the anchorage shall be capable of developing at least 100% of the guaranteed minimum ultimate capacity of the tendon or bar.
The anchor head shall be wedges for prestressing strands and anchor nuts for prestressing bars. The wedges shall be designed to uniformly engage the strand with no notch or pinching effects.

The bearing plate shall be fabricated from steel according to CSA G40.20/G40.21.

The trumpet shall be fabricated from steel pipe according to ASTM A53M or tubing according to ASTM A500M. The trumpet shall have a minimum wall thickness of 3 mm for diameters up to and including 100 mm and 5 mm for larger diameters. The joint between the trumpet and the bearing plate and the joint between the trumpet and sheath shall be watertight. The trumpet shall overlap the free stressing length corrosion protection by at least 100 mm. The trumpet shall be long enough to accommodate movements of the structure and the tendon during stressing and testing.

The anchorage covers shall completely encapsulate the anchor head with a watertight seal between the cover and the bearing plate.

942.05.01.03 Bond Breaker

The bond breaker shall be fabricated from plastic tube or pipe made from medium to high density polyethylene according to ASTM D 1248 or from polyvinyl chloride according to ASTM D1784, Class 13464-B or equivalent, with a minimum wall thickness of 1.0 mm.

942.05.01.04 Cement

Cement shall be according to OPSS 1301 and shall be certified free of false set.

942.05.01.05 Centralizers and Spacers

Centralizers and spacers shall be steel or plastic.

942.05.01.06 Couplers

Couplers for bars shall be as specified by the supplier of the anchor and shall develop at least 100% of the guaranteed minimum ultimate strength of the tendon. Strand tendons shall not be coupled.

942.05.01.07 Corrosion Inhibiting Compound

The corrosion inhibiting compound placed in either the free stressing length or the anchorage area shall be an organic compound, grease, or wax with appropriate polar moisture displacing and self-healing properties and corrosion inhibiting additives. The compound shall permanently stay viscous and be chemically stable and non-reactive with the prestressing steel, sheathing material, and anchor grout.

942.05.01.08 Corrosion Protection

The anchor shall be provided with Class I, encapsulated tendon, double corrosion protection according to the Recommendation for Prestressed Rock and Soil Anchors publication.

The tendon shall be fully encased within a corrugated PVC sheathing that is, in turn, encased within a smooth PVC sheathing over the length of the free stressing zone and protected with grout having the 7-Day and 28-Day compressive strengths.

942.05.01.09 Grout

The grout cube compressive strength for high early strength grout shall be at least 20 MPa at 7 Days and 30 MPa at 28 Days. The type of cement used shall be suitable for the required use of the grout. Accelerators shall not be used. The grout shall bleed less than 2% when allowed to stand for 1 hour.

942.05.01.10 Grout Tubes

Grout tubes shall have an adequate inside diameter to enable the grout to be pumped to the bottom of the drill hole. They shall be able to withstand 1 MPa pressure.

Post-grout tubes shall be strong enough to withstand the post-grouting pressure.

942.05.01.11 Heat Shrinkable Sleeves

Heat shrinkable sleeves shall be fabricated from a radiation cross-linked polyolefin tube internally coated with an adhesive sealant.

942.05.01.12 Prestressing Steel

Prestressing steel shall be according to ASTM A416M and ASTM A722M.

Bars shall be high-tensile strength bars grade 1,030 MPa, 1,100 MPa, or 1,230 MPa.

Strand shall be seven-wire, uncoated, stress relieved and low relaxation strand grade 1,720 MPa, 1,760 MPa, or 1,860 MPa.

The strand and bar shall meet the bond capacity test specified in the Prestressing Steel Bond Capacity clause.

942.05.01.13 Sheathing

Plastic sheathing shall be high density polyethylene according to ASTM D1248, type III, or polyvinyl chloride (PVC) according to ASTM D1784, Class 13464-B or equal. The plastic sheathing shall be such that a bond of 5 MPa is developed when grout with a compressive strength of 30 MPa is used.

Hot melt extruded plastic tubing made from polyethylene according to ASTM D3350 and ASTM D1248 shall have an average minimum wall thickness of 1.5 mm. Hot melt extruded plastic tubing from polypropylene according to ASTM D4101 shall have an average minimum wall thickness of 1.5 mm. Steel tubing or pipe shall have an average minimum wall thickness of 5.0 mm.

The materials for the sheathing accessories such as end caps, grouting caps, grout tubes, and sealing caps shall have properties equal to the plastic sheathing.

942.05.01.14 Water

Water shall be according to OPSS 1302.

942.05.02 Bentonite Cement Slurry

Bentonite and polymers shall meet the requirements of API 13A.

The bentonite cement slurry shall consist of a stable mixture of cement and a colloidal suspension of pulverized solids or polymers thoroughly mixed with water. The density, viscosity, sand content, and pH of the slurry while being used during excavation shall be according to API RP13B-1.

942.05.03 Concrete

Concrete shall be according to OPSS 1350 with a nominal 28-Day compressive strength of 30 MPa.

The slump shall be 150 to 180 mm.

942.05.04 Pre-Production Test Anchors

The material for the pre-production test anchors shall be the same as specified for the production anchor being evaluated.

942.05.05 Temporary Anchors

The material for temporary anchors shall be the same as specified for the permanent anchors except the double protection system is not required.

942.06 EQUIPMENT

942.06.01 General

All equipment for the installation of the anchor, anchor stressing, anchor testing, and monitoring of the anchor test shall be suitable for the intended purposes and capable of working on the site under the prevailing access and clearance conditions.

The equipment used shall not cause damage to the anchor tendon, corrosion protection, or retained structural members.

942.06.02 Anchor Testing Equipment

The rated capacity of the equipment shall not be exceeded when stressing the tendon to the maximum specified test load. The pump shall be capable of applying each load increment in less than 60 seconds.

The equipment shall permit the tendon to be stressed in increments so that the load in the tendon can be increased or decreased according to the test specifications and to allow the anchor to be lift-off tested to confirm the lock-off load.

Dial gauges shall have at least a 75 mm travel. Longer gauge stems or sufficient gauge blocks shall be provided to allow for greater travel where required. Gauges shall have precision of at least 0.02 mm.

Dial gauges shall permit the measurement of total tendon movement to the nearest 0.02 mm at every load increment. The gauge shall have sufficient travel to record the total anchor movement at test load without the need to reset at an interim point.

Jacks used for stressing tendons shall have a minimum ram extension of 150 mm.

Stressing equipment shall be calibrated within an accuracy of $\pm$ 2% immediately prior to use.

Current calibration curves bearing the seal and signature of an Engineer shall be provided for all gauges and jacks.

942.06.03 Grouting Equipment

Mixers and pumps shall be of an adequate capacity and hoses shall be sized to allow continuous grouting of an individual anchor within one hour. A colloidal mixer with a gauge to measure the water shall be used.

942.06.04 Temporary Anchor Concrete Placement Equipment

Continuous flight augers shall be used for the placement of concrete for temporary anchors up to a maximum ratio of hole diameter to length of 1:35. Open hole concrete placement shall be limited to a minimum hole diameter of 600 mm and a maximum ratio of hole diameter to length of 1:15.

942.07 CONSTRUCTION

942.07.01 General

The Contractor shall be responsible for the material, fabrication, installation, testing, and monitoring of pre-production and production test anchors and production anchors.

In addition, for non-Owner designed anchors, the Contractor shall be responsible for the preparation of a soils report, the determination of design parameters, and the design of the anchors.

The anchor system shall be according to this specification and the Working Drawings.

Concrete placement according to the Concrete clause of the Caisson Piles subsection of OPSS 903 can be used for temporary anchors inclined a minimum of 30 degrees below the horizontal and having a minimum hole diameter of 450 mm.

942.07.02 Structural Steel

Structural steel components shall be fabricated according to OPSS 906.

942.07.03 Anchor Fabrication

Anchors shall be either shop or field fabricated by personnel trained and qualified for this work, according to the Working Drawings and Schedules.

Prestressing steel shall be cut with an abrasive saw or, when approved by the prestressing steel supplier, an oxyacetylene torch may be used.

All of the bond length shall be free of dirt, manufacturers' lubricants, corrosion-inhibiting coatings, or other deleterious substances that may significantly affect the grout-to-tendon bond or the service life of the anchor.

When encapsulated anchors are pregrouted, they shall be done on an inclined, rigid frame or bed by injecting the grout from the low end of the tendon.

Joints in the protection system shall be made watertight by use of an epoxy bonding agent.

942.07.04 Milestone Inspections

The Quality Verification Engineer shall witness the following interim inspections of the work:

a) Construction of anchor holes.

b) Anchor installation.

c) Primary grouting.

d) Post grouting.

e) Placement of slurry in free stressing length.

f) Anchorage installation.

g) Pre-production anchor testing.

h) Production anchor testing.

A written request for permission to proceed shall be submitted to the Contract Administrator prior to commencement of the successive operation.

942.07.05 Storage and Handling

Upon delivery, the fabricated anchors and the prestressing steel for fabrication of the tendons and all hardware shall be stored and handled in a manner that avoids mechanical damage, corrosion, and contamination with dirt or deleterious substances.

Handling of the tendons shall not cause mechanical damage or contamination to the prestressing steel, the corrosion protection, or the epoxy coating.

Rope or nylon slings shall be used.

Cement and additives for grout shall be stored under cover and protected against moisture.

Lifting of any pregrouted tendons shall not cause excessive bending that may debond the prestressing steel from the surrounding grout.

942.07.06 Corrosion Protection

942.07.06.01 Anchorage Protection

The corrosion protection of the tendon in the vicinity of the anchorage shall ensure proper protection.

All stressing anchorages permanently exposed to the atmosphere or that has a concrete cover less than 50 mm shall be covered with a corrosion inhibiting compound-filled or grout-filled cover.

On strand tendons, the trumpet shall be long enough to enable the tendon to make a transition from the diameter of the tendon along the free stressing length to the diameter of the tendon at the wedge plate without damaging the encapsulation.

The trumpet shall be completely filled with a corrosion inhibiting compound or grout. Compounds may be placed any time during construction. Grout shall be placed after the anchor has been tested and stressed to the lock-off load.

Corrosion inhibiting compound-filled trumpets shall have a permanent seal between the trumpet and the free stressing length corrosion protection.

Trumpets filled with grout shall have either a temporary seal between the trumpet and the free stressing length corrosion protection or the trumpet shall fit tightly over the free stressing length corrosion protection for a minimum of 0.3 m.

942.07.06.02 Free Stressing Length Protection

The tendon shall be fully encased within a corrugated PVC sheathing that is in turn encased within a smooth PVC sheathing over the length of the free stressing zone and protected with grout.

Corrosion protection of the free stressing length shall be provided by a sheath filled with a corrosion inhibiting compound or grout or a heat shrinkable tube internally coated with a mastic compound. The corrosion inhibiting compound shall completely coat the tendon elements, fill the void between them and the sheath, and fill the interstices between the wires of 7-wire strands. Provisions shall be made to retain the compound within the sheath.

The corrosion protective sheath surrounding the free stressing length of the tendon shall be long enough to extend into the trumpet but shall not come into contact with the stressing anchorage during testing.

For pregrouted encapsulations, a separate bond breaker shall be provided to prevent the tendon from bonding to the grout surrounding the free stressing length.

Fusion bonded epoxy may be used to provide an additional layer of protection to the prestressing steel.

942.07.06.03 Free Stressing Length and Bond Length Transition

The transition between the corrosion protection for the bonded and free stressing lengths shall be designed and fabricated to ensure continuous protection from corrosion.

The corrosion protection surrounding the free stressing length of the tendon shall not contact the bearing plate or anchor head.

942.07.06.04 Coupler Protection

On encapsulated bar tendons, the coupler and any exposed bar section next to it shall be covered with a corrosion proof compound or wax impregnated cloth tape. The coupler area shall be covered by a smooth plastic tube overlapping the adjacent sheathed tendon by at least 25 mm. The two joints shall be sealed each by a coated heat shrink sleeve of at least 150 mm length or approved equivalent. The corrosion proof compound shall completely fill the space inside the cover tube.

942.07.07 Construction of Anchor Holes

942.07.07.01 General

The anchor holes shall be constructed to the diameter, orientation, and length specified in the Contract Documents and detailed on the Working Drawings. A drilling method that establishes a stable anchor hole within the tolerances specified in the Contract Documents shall be used.

The sides and end of the completed anchor holes shall be maintained in a stable condition.

The anchor hole entry shall be located within 300 mm of its plan location. The deviation of the anchor hole entry angle from its inclination specified the Contract Documents shall be no greater than $\pm$ 3 degrees.

Open anchor holes and drilled casings shall be cleaned upon completion of drilling.

Anchor holes open for longer than eight hours shall be recleaned prior to insertion of the tendon and primary grouting.

The following information shall be recorded for each anchor hole and submitted to the Contract Administrator:

a) Identification number.

b) Anchor hole diameter.

c) Anchor hole length.

d) Drilling procedure.

e) Soil, rock, and ground water conditions encountered.

f) Time required to drill the anchor hole.

g) Problems encountered.

942.07.07.02 Waterproofing Anchor Holes

Waterproofing of anchor holes shall be carried out when specified in the Contract Documents and according to the Working Drawings, procedures, and equipment.

If during the water tightness test, the leakage from an anchor hole over a ten-minute period exceeds 9.5 L, the anchor hole shall be consolidation grouted, redrilled, and retested.

Redrilling shall be done when the grout strength is considerably less than the strength of the surrounding rock.

942.07.08 Anchor Installation

The anchors shall be installed as specified in this specification and according to the Working Drawings.

Care shall be taken to ensure the sheathing, corrosion protection, and grout tubes are not damaged during installation of the anchors.

Damaged anchors that cannot be repaired to the satisfaction of the Contract Administrator shall be replaced.

Method of repair shall be submitted to the Contract Administrator for approval.

The prestressing steel in the tendon bond length shall be protected with a grout filled corrugated plastic encapsulation. Centralizers shall be used to ensure a grout cover of at least 12 mm over the encapsulation.

The centralizers shall be maintained in position during installation.

The centralizer shall support the tendon in the drill hole and position the tendon so a minimum grout cover of 12 mm is achieved. Centralizers used inside a sheath shall provide a nominal grout cover of 5 mm over the prestressing steel. All centralizers shall be designed to permit grout to flow freely around the tendon and up the drill hole.

The Contractor shall determine the number of centralizers required; however, one unit shall be placed within 1 m of the bottom of the hole and another at the bond length and free stressing length interface. The centralizers shall not interfere with the placement of grout.

Spacers shall be used in multiple element tendons to separate the strands or bars individually or into small groups.

942.07.09 Primary Grouting of Anchors

The grout shall be placed as specified in this specification and as detailed on the Working Drawings.

The grout shall entirely fill the annular space between the anchor and the borehole wall in the bond length.

Anchors shall be grouted as soon as practical after installation. The stressing tails of prestressing steel strands shall be aligned prior to initial set of the grout.

After grouting, the anchor shall remain undisturbed until the grout has reached the strength specified in the Contract Documents.

The following information shall be recorded for each anchor and submitted to the Contract Administrator:

a) Identification number.

b) Type of grout.

c) Grout pressure.

d) Volume of grout used.

e) Location of the top of the bond length grout.

942.07.10 Post-Grouting of Bond Length

When specified in the Contract Documents, post-grouting of the bond length shall be carried out as specified in the submitted procedures and equipment.

The information required to be recorded for primary grouting shall be recorded for post grouting.

Ground movement shall be monitored and, if excess movement is observed, the grouting shall be terminated and the situation reported to the Contract Administrator.

The Contract Administrator shall be notified prior to the commencement of post-grouting of both permanent and temporary anchors.

942.07.11 Placing of the Cement Bentonite Slurry in the Free-Stressing Length

The method of placing the cement bentonite slurry shall be as specified in this specification and as detailed on the Working Drawings.

The cement bentonite slurry for the free stressing length shall completely fill the annular space between the prestressing steel and the borehole wall and shall prevent any transfer of the anchor load to the free stressing zone.

942.07.12 Installation of Anchorage

The anchor bearing plate and the anchor head or nut shall be installed perpendicular to the tendon within $\pm$ 3 degrees and centred on the bearing plate, without bending or kinking of the prestressing steel elements. Wedge holes and wedges shall be free of rust, grout, and dirt. Special care shall be exercised to obtain the continuity of corrosion protection in the vicinity of the anchorage as specified in the Corrosion Protection subsection. The stressing tail shall be cleaned and protected from damage until final testing and lock-off.

The tendon stressing tail shall be cut to its final length according to the tendon manufacturer's recommendations after the anchor is accepted by the Contract Administrator.

Anchorages permanently exposed to the atmosphere shall be covered with a corrosion inhibiting compound filled or grout filled cover.

942.07.13 Testing

942.07.13.01 General

Testing shall be carried out as specified in the Working Drawings and this specification.

Testing shall be carried out generally in accordance with the prevailing requirements of ASTM D1143 and PTI DC35.1-14, superseded where applicable by the procedure specified in this specification.

Testing shall be carried out according to the requirements of ASTM D1143 and PTI DC35.1-14, or as specified otherwise in this specification.

The maximum anchor load shall not exceed 80% of the guaranteed minimum ultimate strength of the tendon.

Rock or soil anchor grout shall achieve a minimum compressive strength of 21 MPa at time of stressing. Additionally, soil anchor grout should be cured for 7 days before stressing to enhance grout/soil bond strength due to soil re-consolidation in the bond length.

Anchor tests shall be conducted at a time mutually acceptable to the Contractor and Contract Administrator. The Contractor's Engineer shall witness the testing.

942.07.13.02 Reaction System

The reaction system shall be installed as specified in the Working Drawings.

942.07.13.03 Reference System and Testing Equipment

The layout of the reference systems and testing equipment required for testing shall be as specified in the Working Drawings and this specification.

All reference beams shall be independently supported with the support firmly embedded in the ground. Reference beams and their supports shall be sufficiently rigid to support instrumentation and to prevent movement relative to the test anchor as a result of stressing or other construction activity during testing.

Dial gauges shall bear on the pulling head of the jack and their stems shall be co-axial with the tendon direction.

The jacks shall be secured with chains to provide adequate protection to personnel in the event of breakage of the anchor or stressing system.

942.07.13.04 Reference System Enclosures

Suitable enclosures shall be constructed to provide complete protection for personnel, equipment, and instruments from variations in the weather conditions and disturbances during the test program.

942.07.13.05 Pre-Production Test Anchors

942.07.13.05.01 General

Pre-production tests shall be conducted to determine the bond stress when:

a) A bond stress is not specified in the Contract Documents.

b) A higher bond stress than specified in the Contract Documents is used in the design.

c) To establish the adequacy of other components of the anchor in advance of the production anchors.

For Contractor designed anchors, one pre-production test anchor shall be installed and tested in each bond zone in rock, cohesive soil, and cohesionless soil. Significantly different ground conditions should be approved by the Contract Administrator.

a) Rock

b) Cohesive soil:

   i. Soft to firm
   ii. Stiff to very stiff
   iii. Hard

c) Cohesionless soil

   i. Very loose to loose
   ii. Compact
   iii. Dense to very dense

For Owner designed anchors, the number of pre-production test anchors shall be as specified in the Contract Documents.

The test anchor shall be constructed using the materials, methods, and procedures specified in this specification and the Working Drawings.

Pre-production test anchors shall not be incorporated into the permanent or temporary work unless approved by the Contract Administrator.

942.07.13.05.02 Pre-Production Test Procedures and Measurements

The pre-production test shall be conducted by cyclically and incrementally loading and unloading the anchor according to the schedule below or until the anchor fails:

AL, 0.25 DL, AL
AL, 0.25 DL, 0.50 DL, AL,
AL, 0.25 DL, 0.50 DL, 0.75 DL, AL
AL, 0.25 DL, 0.50 DL, 0.75 DL, 1.00 DL, AL,
AL, 0.25 DL, 0.50 DL, 0.75 DL, 1.00 DL, 1.25 DL, AL,
AL, 0.25 DL, 0.50 DL, 0.75 DL, 1.00 DL, 1.25 DL, 1.50 DL, AL
AL, 0.25 DL, 0.50 DL, 0.75 DL, 1.00 DL, 1.25 DL, 1.50 DL, 1.75 DL, AL,
AL, 0.25 DL, 0.50 DL, 0.75 DL, 1.00 DL, 1.25 DL, 1.50 DL, 1.75 DL, 2.00 DL, AL
AL, Lock-off Load

Where:

AL = alignment load
DL = design load of anchor
Lock-off Load = 1.10 DL

At each load increment, the total movement of the pulling head shall be recorded to the nearest 0.03 mm with respect to the independent fixed reference point.

The load shall be maintained at each increment to obtain the movement reading and shall be held for a minimum of 1 minute.

Movement readings at the test load of 2.00 DL shall be taken at 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes.

Vertical and horizontal movement of the reaction system and tendon elongation shall be recorded with respect to an independent fixed reference point. The ambient temperature shall also be recorded.

During the load hold periods, the anchor load shall not be allowed to deviate from the test pressure by more than 0.35 MPa.

When required, repumping back to test load shall be done to compensate for small movements, hydraulic oil seepage, and changes in temperature of the hydraulic oil.

The load shall always be returned to the specified test load prior to taking the movement reading at the specified interval. The test load shall not be exceeded during the period of observation.

942.07.13.05.03 Removal of Pre-Production Test Anchors

The test anchors not approved to be incorporated into the work shall be removed flush with the surrounding ground and the test site restored to its pretest conditions.

The test anchorages shall not be removed until the Contract Administrator has given permission in writing to remove them.

942.07.13.06 Production Anchors

942.07.13.06.01 General

Every temporary and permanent anchor shall be tested according to the Proof Test - Permanent Anchors or Proof Test - Temporary Anchors clauses, as appropriate.

942.07.12.06.02 Proof Test - Permanent Anchors

The following proof test shall be applied to the anchorages:

The proof test shall be conducted by incrementally loading and unloading the anchor according to the following schedule or until the anchorage fails:

a) AL, 0.25 DL, 1.00 DL, 1.50 DL, 1.00 DL, 0.25 DL, AL, Lock-off Load.

Where:
AL = alignment load
DL = design load of anchor
Lock-off Load = 1.10 DL_{tt}

At each load increment, the total movement of the pulling head shall be recorded to the nearest 0.03 mm with respect to the independent fixed reference point.

The load shall be held at each increment to obtain the movement reading and shall be held for a minimum of 1 minute.

Movement readings at the test load of 1.50 DL shall be taken at 1, 2, 3, 6, 9, 12, 15, 18, and 30 minutes. If the total creep movement between 3 and 30 minutes exceeds 1.5 mm, the test load shall be maintained for up to an additional 150 minutes as required, with readings at 30-minute intervals.

During the load hold periods, the anchor load shall not be allowed to deviate from the test pressure by more than 0.35 MPa.

When required, repumping back to test load shall be carried out to compensate for small movements, hydraulic oil seepage, and changes in temperature of the hydraulic oil.

The load shall always be returned to the specified test load prior to taking the movement reading at the specified interval. The test load shall not be exceeded during the period of observation.

942.07.13.06.03 Proof Test - Temporary Anchors

The proof test shall be conducted by incrementally loading and unloading the anchor according to the following schedule or until the anchorage fails:

a) AL, 0.25 DL, 0.50 DL, 0.75 DL, 1.00 DL, 1.20 DL, 1.33 DL, AL, and adjust to lock-off load

Where:
AL = alignment load
DL = design load of anchor
Lock-off Load = 1.10 DL

At each load increment, the total movement of the pulling head shall be recorded to the nearest 0.03 mm with respect to the independent fixed reference point.

The load shall be held at each increment to obtain the movement reading and shall be held for a minimum of 1 minute.

Movement readings at the test load of 1.33 DL shall be taken at 1, 2, 3, 4, 5, 6, and 10 minutes after reaching the test load. If the total creep movement between 1 and 10 minutes exceeds 1.0 mm, the test load shall be maintained for an additional 50 minutes. Total movements shall then be recorded at 20, 30, 40, 50, and 60 minutes.

During the load hold periods, the anchor load shall not be allowed to deviate from the test pressure by more

than 0.35 MPa.

When required, repumping back to test load shall be done to compensate for small movements, hydraulic oil seepage, and changes in temperature of the hydraulic oil.

The load shall always be returned to the specified test load prior to taking the movement reading at the specified interval. The test load shall not be exceeded during the period of observation.

942.07.13.06.04 Lock-Off Procedure

After testing has been completed, the load in the tendon shall be such that, after seating losses (wedge seating), the specified lock-off load has been applied to the anchor tendon.

The magnitude of the lock-off load shall be 1.10 DL or as specified by the Contract Administrator and shall not exceed 70% of the ultimate load of the tendon or bar (F_{pu}).

The wedges shall be seated at a minimum load of 50% of F_{pu}. If the lock-off load is less than 50%, shims shall be used under the wedge plate and the wedges seated at 50% of F_{pu}. The shims shall then be removed to reduce the load in the tendon to the desired lock-off load. Bar tendons may be locked off at any load less than 70% of F_{pu}.

942.07.13.06.05 Lift-Off Tests

A minimum of three lift-off tests shall be conducted at each site. The location of the anchor to be tested and the time of test shall be as determined by the Contractor's engineer. The lift-off test shall not be performed until 48 hours has elapsed after transferring the lock-off load. The method of testing shall be as detailed on the Working Drawings.

The lift-off test shall be performed after transferring the load to the anchor and prior to removing the jack from its location. The lift-off load shall be determined by re-applying the load to the tendon or bar to lift off the wedge plate or anchor nut without unseating the wedges or turning the anchor nut.

942.07.13.07 Acceptance Criteria

An anchor shall be considered acceptable when all three of the following acceptance test criteria are satisfied:

a) The total creep movement at test load during the last log time cycle is less than 1.5 mm.

b) The apparent free stressing length based on the elastic movement at the test load is not less than 80% of the designed free stressing length.

c) The load measured during the lift-off test is within 10% of the designed lock-off load.

942.07.13.08 Unacceptable Stressing Results

For the anchorages that do not meet the acceptance criteria for the performance test or the proof test, the Contractor shall submit one of the following alternatives as a proposal to the Contract Administrator for approval:

a) Abandon the deficient anchor and install a new anchor.

b) Lock-off the anchors at no more than 50% of the accepted test load sustained during test or as determined by the Contract Administrator and install an additional anchor to compensate for the deficiency.

c) Post grout the anchor at a grouting pressure not exceeding 3.6 MPa or as recommended by the Contract Administrator and then conduct a proof test and apply the acceptance criteria to the test results. The post grouting shall be terminated immediately if any distress on the ground surface is observed during grouting.

d) Readjust the transfer load to 1.10 DL for an anchor that does not meet the lift-off criteria and repeat the test after a minimum of 48 hours. If the anchor does not meet the lift-off test criteria after completing this procedure, it shall be considered unacceptable.

942.07.14 Quality Control

942.07.14.01 General

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

942.07.14.02 Quality of Grout Mixture

942.07.14.02.01 General

The Contractor shall be responsible for testing of bleeding, preparation and initial storage of grout cubes for determination of compressive strength, and delivery of the grout cubes to a testing laboratory designated by the Owner.

The Contractor shall employ staff from a testing company certified according to CSA A283, Certification for Additional Tests 1B, by an organization accredited by the Standards Council of Canada to carry out testing for bleeding, making, and curing of grout cubes and early strength determination.

Grout cubes for compressive strength test and testing of bleeding shall be made on a level, vibration free surface.

942.07.14.02.02 Testing for Bleeding

The testing for bleeding of the grout shall be according to CSA A23.2-1B.

Prior to the grouting operation, in the presence of the Contract Administrator, a trial batch shall be mixed and the grout tested for bleeding to ensure that the grout meets the requirements of this specification. The trial batch of grout shall not be used in the actual grouting operation.

During the grouting operation, bleeding measurements shall be performed on the grout sampled at the mixer. The measurements shall be performed at least once a Day and as requested by the Contract Administrator.

The bleeding test results shall be submitted to the Contract Administrator in writing. The test results that indicate the grout is not meeting the requirements of the Contract Documents shall be reported immediately to the Contract Administrator and the grouting operation halted until the cause of the problem is identified and corrected.

942.07.14.02.03 Making, Curing, and Transportation of Cubes for Compressive Strength Tests

Grout cubes shall be prepared as follows on site from the grout pumped into the anchor body:

a) One set of grout cubes, consisting of three cubes, shall be made each day the grouting operations are carried out.

b) The grout cubes shall be prepared according to CSA A23.2-1B and stored at a temperature between 15 and 25°C and shall not be moved prior to demoulding.

c) The grout cubes shall be demoulded and transported to the laboratory designated by the Owner within 24 hours.

d) The grout cubes shall be transported in a sealed white opaque plastic bag containing at least 250 mL of water and maintained at a temperature between 15 and 25°C.

942.07.14.02.04 Early Strength Determination

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

The laboratory conducting the test shall be certified as specified in this specification.

942.07.14.03 Certificate of Conformance

A completed Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the anchor installation and stressing operations. The Qualification Verification Engineer's seal and signature shall be affixed on the completed Certificate of Conformance confirming that the anchors have been supplied, installed, and stressed in general conformance with the Working Drawings. The Certificate of Conformance shall also certify that the interim milestone inspections have been completed as specified.

942.07.15 Management of Excess Materials

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

942.09 MEASUREMENT FOR PAYMENT

942.09.01 Actual Measurement

942.09.01.01 Pre-Production Test Anchors and Production Anchors

Measurement of pre-production test anchors and production anchors shall be by length in metres along the actual length of the anchor from the anchor plate to the tip.

942.09.01.02 Post-Grouting of Bond Length

Measurement of post-grouting of bond length shall be by mass in kilograms of mixed grout used.

942.10 BASIS OF PAYMENT

942.10.01 Pre-Production Test Anchors - Item
Production Anchor - Item
Post-Grouting of Bond Length - 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.

Appendix 942-A, April 2025
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 designer should specify the following in the Contract Documents:

- Anchor hole diameter, orientation, and length tolerances and inclination. (942.07.06.01)

- Grout strength. (942.07.08)

- Number of pre-production test anchors for Owner designed systems. (942.07.12.05.01)

- Grout testing laboratory. (942.07.13.02.01)

The designer should determine if the following are required and, if so, they should be specified in the Contract Documents:

- Waterproofing anchor holes. (942.07.06.02)

- Post-grouting of bond length of anchors. (942.07.09)

- Bond stress. (942.07.12.05.01)

OPSS 942 contains information written for provincial contracts. To ensure completeness of municipal Contract Documents, the designer should invoke Appendix 942-B. The appendix contains supplemental requirements that modify OPSS 942 so it can be used by a municipality in its contracts.

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

No information provided here.