



CONSTRUCTION SPECIFICATION FOR ROCK STABILIZATION

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203.01 SCOPE

This specification covers the requirements for the stabilization of a rock face ~~of mass~~ using ~~a combination of rock bolts, shotcrete or concrete buttresses, or both~~ a combination of the aforementioned.

203.02 REFERENCES

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

Ontario Provincial Standard Specifications, Construction

OPSS 904 Concrete Structures
OPSS 905 Steel Reinforcement for Concrete
OPSS 931 Structure Rehabilitation - Shotcrete
OPSS 932 Crack Repair - Concrete

Ontario Provincial Standard Specifications, Material

OPSS 919 Formwork and Falsework
OPSS 1002 Aggregates, Concrete
OPSS 1301 Cementing Materials

OPSS 1302 Water
OPSS 1303 Admixtures for Concrete
OPSS 1306 Burlap
OPSS 1350 Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete

Ontario Ministry of Transportation Publications

MTO Laboratory Testing Manual:

LS-410 Method of Test for Compressive Strength of Concrete Cores

MTO Forms:

PH-CC-322 Concrete Construction Report
PH-CC-340 Field Sample Data Sheet – Concrete
PH-CC-433A Concrete Mix Design Submission Form A
PH-CC-701 Request to Proceed
PH-CC-702 Notice to Proceed

CSA Standards

A23.2-1B Testing for properties of flowable grout*
A23.2-14C Obtaining and Testing Drilled Cores for Compressive Strength Testing*
A3001 Cementitious Materials for Use in Concrete**
*[Part of A23.1:19/A23.2:19 - Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete]
**[Part of A3000-18 - Cementitious Materials Compendium]
G40.21-13(R2018) General requirements for rolled or welded structural quality steel / Structural quality steel

ASTM International

A 123 Standard A123/A123M-17 Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A 820-90 Standard A820/A820M-22 Specification for Steel Fibers for Fiber-Reinforced Concrete
C 33 Standard A563/A563M-21ae1 Specification for Concrete Aggregates
C 42 Standard Test Method for Obtaining Carbon and Testing Drilled Cores and Sawed Beams of Concrete
C 150 Standard A1022/A1022M-22a Specification for Portland Cement Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement
A1064/A1064M-22 Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
C1550-20 Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)
D1784-20 Classification System and Basis for Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
D4285-83(2018) Test Method of Indicating Oil or Water in Compressed Air
F436/F436M-19 Specification for Hardened Steel Washers Inch and Metric Dimensions
F593-22 Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
F1554-20 Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
F2329/F2329M-15 Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

Others

ACI 506.2-77 Specification for Materials, Proportioning and Application of Shotcrete
ISRM (International Society for Rock Mechanics) (ISRM) Suggested Method for Rock Anchorage Testing

203.03 DEFINITIONS

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

Basal Plane means a planar discontinuity within a rock mass along which one portion of the mass could slide over another.

~~**Nozzle Operator** means as defined in OPSS 931.~~

~~**Cold Weather** means those conditions when the air temperature is less than or equal to 10°C. It is also considered to exist when the air temperature is at or is likely to be less than 10°C within 96 hours after concrete placement. Temperature refers to shade temperature.~~

~~**Concrete Buttress** means a structurally reinforced concrete structure designed to support rocks.~~

~~**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.~~

~~**Dry Mix Shotcrete** means the prebagged dry material is mixed and placed into a stream of compressed air. The material is carried by the compressed air through a delivery hose to the nozzle where water is added. Water is added to the mixture as it is jetted from the nozzle.~~

~~**Hot Weather** means those conditions when the air temperature is greater than or equal to 28 °C. It is also considered to exist when the air temperature is at or is likely to be greater than 28 °C within 24 hours after the shotcrete operation. Temperature refers to shade temperature.~~

~~**Nozzleperson** means the qualified worker on the shotcrete crew who has obtained ministry approval for shotcrete nozzleperson certification who manipulates the nozzle, controls consistency, and controls final disposition of the material.~~

Rock Bolting means the pinning of a rock block or rock mass in-situ using anchoring agent or cement grouted steel bars.

~~**Saturated Surface Dry** means concrete or rock face that is fully saturated without free standing water.~~

~~**Wet Mix Shotcrete** means shotcrete in which all of the materials, including water, are mixed before introduction into the delivery hose. Compressed air is introduced to the material flow at the nozzle.~~

203.04 DESIGN AND SUBMISSION REQUIREMENTS

203.04.01 Submission Requirements

203.04.01.01 Mix Design for Shotcrete

The submission of the shotcrete mix design including all supporting documentation shall be according to OPSS 931, with additional documentation showing the steel fibre manufacturer's name, type, product name and fibre content, if applicable.

203.04.01.02 Mix Design for Concrete Buttress

Concrete mix design submissions shall be according to OPSS 1350.

203.04.01.03 Shotcrete Equipment

The submission of the shotcrete equipment shall be according to OPSS 931.

203.04.01.04 Nozzleperson

The submission of the nozzlepersons shall be according to OPSS 931.

203.04.01.05 Cold Weather Protection

The submission of the cold weather protection shall be according to OPSS 931.

203.04.01.06 Hot Weather Shotcreting

The submission of the hot weather shotcreting shall be according to OPSS 931.

203.04.01.07 Curing

The submission of the curing for shotcrete shall be according to OPSS 931.

203.04.01.08 Rock Bolting

The following rock bolting information shall be submitted to the Contract Administrator, for information purposes, a minimum of 2 weeks prior to starting the work:

- a) The name and statement of experience of the persons or firm(s) responsible for installing and testing the rock bolts.
- b) The name of the firm supplying the rock bolts.
- ~~c) The~~
- c) The mill certificates for the rock bolts to be used.
- ~~d) The name of the firm supplying the resin cartridge anchoring agent, if applicable.~~
- d) The type, date of manufacture, set time and dimensions of the resin cartridge anchoring agent, the drill hole diameter, and the installation methodology to be used.
- ~~e) The mill certificates for the rock bolts to be used.~~
- f) The type of grout, ~~the drill hole diameter,~~ and installation methodology for grouted rock bolts, if applicable.

203.04.01.02 Shotcreting09 Steel Fibres

~~A list of equipment and accessories to be used~~ Test reports from the steel fibre manufacturer, for the physical properties of the steel fibres, including the information below tensile strength, according to ASTM A820 shall be submitted to the Contract Administrator at least 2 weeks prior to the use of the product. The steel fibre diameter and length shall be included in the report.

203.04.01.10 Flexural Toughness of Steel Fibre-reinforced Shotcrete

For steel fibre-reinforced shotcrete, test report for flexural toughness according to ASTM C1550 shall be submitted to the Contract Administrator at least 2 weeks prior to the placement of the shotcrete. Test specimens shall be prepared using the same materials and mix design as the shotcrete to be used in the work. Test results shall not be more than 6 months old at the time of submission. Testing shall be carried

out by an independent laboratory, acceptable to the Owner, and certified by the Canadian Council of Independent Laboratories (CCIL) – Concrete Certification or equivalent qualification programme acceptable to the Owner.

The test report shall indicate that the flexural toughness meets the minimum of 2 weeks for information purposes prior to the application of shotcrete requirement specified in the Contract Documents.

~~a) Equipment type and capacity.~~

~~b) Nozzle type and size.~~

~~c) Continuous feed predampener details.~~

~~d) List of additives to be used along with the name of the supplier.~~

203.05 MATERIALS

203.05.01 Admixtures

Admixtures shall be according to OPSS 1303.

203.05.02 Aggregates

Aggregates shall be according to OPSS 1002, except the nominal maximum aggregate size shall be 13.2 mm.

203.05.03 Anchors

Anchors for the attachment of the welded steel wire reinforcement to the rock face shall be of adequate length, diameter, and grade to resist a pull-out force of 1.0 kN. The anchors shall be according to ASTM F1554 and the galvanizing according to ASTM F2329.

When stainless welded steel wire reinforcement is used, anchors and tie wires shall be made of the same type of stainless steel according to ASTM F593.

203.05.04 Burlap

Burlap shall be according to OPSS 1306.

203.05.05 Concrete Buttress

Cast-in-place concrete buttress shall be according to OPSS 1350 with a minimum 28-Day compressive strength of 30 MPa.

203.05.06 Cementing Material

Cementing materials shall be according to OPSS 1301 and CSA A3001.

203.05.07 Formwork

Formwork shall be according to OPSS 919.

203.05.08 Grout Tubes

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

203.05.09 Proprietary Patching Materials

Proprietary patching materials shall be from the Owner's prequalified product list. The list of proprietary patching materials shall be obtained from the Contract Administrator.

203.05.10 Rock Bolts

203.05.10.01 General

Rock bolts shall be a minimum 25M reinforcing steel bars according to OPSS 1440 with a minimum yield strength of 400 MPa and a minimum length of 3.0 m, unless otherwise specified elsewhere in the Contract Documents. ~~Rock bolts shall be fully threaded bars or bars threaded at one end and provided with a faceplate/face plate of at least 100 x 100 mm in area with a nut and beveled or spherical washers as recommended by the manufacturer. All rock bolt components shall be hot-dip galvanized according to ASTM A123.~~

The steel for nuts shall be according to ASTM A563. Washers shall be according to ASTM F436. Face plates shall be according to CSA G40.21.

Rock bolt shall be hot-dip galvanized according to ASTM A123 and all other rock bolt components shall be hot-dip galvanized according to ASTM F2329.

The minimum yield strength of the rock bolt components shall be as specified in the Contract Documents.

203.05.01-04-10.02 Anchoring Agent for Rock Bolts

The anchoring agent for rock bolts shall be supplied in cartridges containing ~~ana~~ polyester resin with a catalyst that has a maximum ~~nominal~~ gel time of 15 minutes. Fully cured anchoring agent shall have a minimum compressive strength of 50 MPa and a minimum tensile strength of 15 MPa. Resin with an expired shelf life shall not be used.

203.05.01-02-10.03 Grout

~~The grout cube for high early strength~~ **Rock Bolts**

Portland cement-based grout shall be at least a proprietary pre-bagged, non-metallic, shrinkage compensating grout placed according to the manufacturer's specifications. The grout shall be mixed, handled, and cured according to the manufacturer's specifications.

The grout shall have a minimum compressive strength of 20 MPa at 7 Days and a minimum compressive strength of 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. when tested according to CSA A23.2-1B.

The grout shall bleed less than 2% ~~when allowed~~ after allowing the grout to stand for 1 hour when tested according to CSA A23.2-1B.

203.05.01.03 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 a pressure of 1 MPa.~~

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~~203.05.02~~ ~~Rock Shotcrete~~

Shotcrete for rock face stabilization shall consist of the following:

- ~~a) Normal Portland cement: 18% - 21% by weight of dry components according to ASTM C150.~~
- ~~b) Silica fume: 10% - 15% by weight of Portland cement containing a minimum of 90% SiO₂ and having a proven record of performance when used in shotcrete.~~
- ~~c) Aggregate: Gradation No.2 in ACI 506.2-77 having a well-graded distribution with maximum size of 10 mm and according to ASTM C33.~~
- ~~d) Steel Fibre Reinforcement: Quantity as recommended by the supplier and quality according to ASTM 820 or Owner-approved equivalent.~~
- ~~e) Water: Clean and free of substances which may be harmful or corrosive to concrete or steel; the ratio of water to total cementitious material shall be in the range of 0.35 to 0.45:1 and in sufficient quantity to provide good placement characteristics.~~
- ~~f) Additives as required to achieve optimum strength and placement characteristics.~~
- ~~g) Hardened shotcrete at 7 Days shall have a minimum compressive strength of 30 MPa.~~

~~203.05.02.01~~ ~~Pipe for Rock Drains~~

Rock drains shall consist of slotted polyvinyl chloride (PVC) pipe according to ASTM D1784 and have a minimum internal diameter of 19 to 25 mm, inclusive.

~~203.05.12~~ ~~Rock Shotcrete~~

~~203.05.12.01~~ ~~General~~

~~Shotcrete shall have a minimum 28-Day compressive strength of 35 MPa. The shotcrete mix shall contain 8% silica fume by mass of total cementing materials.~~

~~Steel fibres or welded steel wire reinforcement shall be used in the shotcrete, as specified in the Contract Documents. When steel fibre-reinforced shotcrete is specified in the Contract Documents, the minimum flexural toughness when tested at 28-Days according to ASTM C1550 shall be a minimum of 400 joules at 40 mm deflection.~~

~~Dry mix shotcrete shall be used, unless otherwise specified in the Contract Documents.~~

~~203.05.12.02~~ ~~Additional Requirements for Dry Mix Shotcrete~~

~~The dry shotcrete mix shall be supplied pre-bagged and unopened. Each bag shall be stamped with the following:~~

- ~~a) Name of the manufacturer;~~
- ~~b) Mix identification;~~
- ~~c) Manufacturer's batch number; and~~
- ~~d) Date of packaging.~~

The pre-bagged mix shall contain cementing materials and aggregates. When specified in the Contract Documents, the pre-bagged mix shall contain the steel fibres. The bags shall be maintained in a dry condition up to the time of use and shall be stored within a temperature range of 10 °C to 30 °C.

Material from bags that contain lumps of hydrated shotcrete or appear to be frozen or otherwise damaged shall not be used in the work. The pre-bagged mix shall be used within 6 months of the date of packaging.

203.05.12.03 Additional Requirements for Wet Mix Shotcrete

Silica fume shall be added to the concrete mix in the form of a blended cement containing silica fume.

When steel fibre for wet mix shotcrete is specified in the Contract Documents:

- a) The steel fibres shall be added to the ready-mix concrete truck at the plant when the shotcrete is delivered using trucks; or
- b) The pre-bagged mix shall contain the steel fibres when the shotcrete is produced using pre-bagged material.

203.05.13 Steel Fibres

Fibre reinforcement shall be steel fibres with a minimum tensile strength of 1,100 MPa when tested according to ASTM A820. The steel fibre shall be bent or deformed low-carbon, cold-drawn steel wire, Type I according to ASTM A820.

203.05.14 Tie Wire

Tie wire shall be according to OPSS 905.

203.05.15 Water

Water used for production, fog-misting, curing, and pre-soaking of burlap shall be according to OPSS 1302.

203.05.16 Welded Steel Wire Reinforcement

The welded steel wire reinforcement shall be welded galvanized or stainless steel according to OPSS 1440 and shall have 100 mm x 100 mm openings fabricated from 4 mm diameter galvanized wires or stainless steel. Galvanized steel wire shall be according to ASTM A1064. Stainless steel wire reinforcement shall be in according to ASTM A1022.

203.06 EQUIPMENT

203.06.01 Shotcreting

203.06.01.01 Compressor - Air Blasting

The compressor for air blasting shall have a minimum capacity of 14.2 m³/min ~~or 500 cfm~~. The compressed air shall be free from oil and other contaminants according to ASTM D4285.

203.06.01.02 Fog Misting Equipment

Fog misting equipment for the curing of shotcrete shall be according to OPSS 904.

203.06.01.03 Hand Finishing Equipment

Where hand finishing is required, only magnesium, wood, or sponge rubber floats shall be used.

203.06.01.03 ~~Mixing Process~~**04** Mixers

Mixers for dry mix process or wet mix process shall be according to OPSS 931.

The dry mix process shall be used:

~~A continuous feed predampener capable of bringing, unless otherwise specified in the dry bagged material to a consistent and suitable moisture content shall be operated at sufficient capacity to allow the work to proceed without delays.~~

~~The delivery equipment shall be capable of discharging the mixture into the delivery hose at a rate sufficient to ensure a continuous smooth stream of uniformly mixed shotcrete mixture being delivered to the nozzle at the required velocity.~~

Contract Documents

~~The discharge nozzle shall be equipped with a manually operated water injection system, for directing an even distribution of liquid through the mixture. The liquid valve shall be capable of ready adjustment to vary the quantity of liquid and shall be convenient for the nozzle operator. The nozzle shall be capable of delivering a conical discharge stream with uniform appearance throughout. The liquid pressure at the discharge nozzle shall be sufficiently greater than the operating air pressure to ensure that the liquid is thoroughly mixed with the other materials. The liquid pressure shall be uniform.~~

203.07 CONSTRUCTION

203.07.01 Rock Bolting

203.07.01.01 Drilling of Rock Bolt Holes

Holes for rock bolts shall be drilled ~~at~~with the diameter recommended by the ~~resin supplier~~anchoring agent manufacturer for the sizes of the rock bolts ~~and cartridges~~ at the locations ~~as~~ specified in the Contract Documents. For cement grouted rock bolts, holes shall be drilled as specified in the Contract Documents.

Holes shall be drilled in a direction angled downward in order to connect the basal planes and to a depth such that when the rock bolt is fully inserted it protrudes 70 + 20 mm from the rock or shotcrete surface.

The drill holes shall be thoroughly cleaned with compressed air prior to the installation of ~~a polyester resin~~the anchoring agent or grout.

203.07.01.02 Installation of Rock Bolts

The holes shall be filled with the anchoring agent or grout to ensure complete encapsulation of the rock bolt and an adequate bond ~~length~~ along the full length of the drill hole while allowing some overflow.

Centralizers shall be maintained in position during installation.

Rock bolts shall be installed according to the ~~resin supplier's~~anchoring agent manufacturer's installation instructions or as specified in the Contract Drawings. For the resin anchor, during the insertion of the rock bolt in the hole, the bolt shall be steadily rotated by means of a pneumatic tool and suitable coupling attached to the threaded end of the bolt according to the ~~resin~~anchoring agent manufacturer recommendations. The rotation shall be continued after the bolt has been inserted for a further 15 seconds or according to the recommendations of the ~~resin~~anchoring agent manufacturer and the bolt shall then be maintained in position until the ~~resin~~anchoring agent has hardened.

After the rock bolts are fully inserted into the drill holes in a vertical or inclined rock face, the rock bolts shall be maintained in position to prevent any further loss of resin while the anchoring agent is setting.

Grout shall be pumped or poured through the grout tube until the hole is filled.

The face plate, washer and nut shall be pneumatically fastened to the rock bolts at angles of less than 30 degrees from the perpendicular in order to provide full contact of the ~~faceplate~~face plate with the rock or shotcrete bearing surface and nominal tensioning of the bolt.

Rock bolts in holes that are not completely filled with anchoring agent or which protrude from the hole by an amount greater or less than the length specified shall not be accepted and shall be replaced at a location as close to the original bolt as possible.

~~Corrosion protection~~203.07.01.03 **Quality Control Testing of Plastic Grout**

203.07.01.03.01 **General**

Field testing of grout shall be performed by a person holding either of the following certifications:

- a) CCIL Certified Concrete Testing Technician;
- b) ACI Concrete Field Testing Technician, Grade 1; or
- c) CSA Standard Concrete Field Testing Technician.

This ~~applied to person~~ shall have a valid original card issued by the certifying agency in their possession at all ~~exposed surface~~times.

Bleeding shall be measured according to CSA A23.2-1B after allowing to stand for 1 hour.

203.07.01.03.02 **Acceptance of Plastic Grout**

The Contractor shall be responsible for all quality control inspection and testing required to ensure that plastic grout meets the specified requirements for bleed water and is mixed, handled, and cured according to manufacture's specifications.

Grout which does ~~not already protected.~~ meet the specified requirements for bleed water or manufacture's specifications for mixing, handing, and curing shall be rejected.

After each Day's work, a daily summary shall be submitted to the Contract Administrator. The daily summary shall include volume of grout used, bleed water test results and shall identify rejected material.

203.07.01.04 **Material Sampling and Testing**

203.07.01.04.01 **Compressive Strength of Grout**

The Contractor shall cast, cure, and transport grout cubes for compressive strength testing at 7 Days and 28 Days by the Owner.

Every time a set of acceptance grout cubes is cast, a second set of grout cubes shall be cast for referee testing purposes.

Grout cubes for compressive strength testing for acceptance and for referee testing purposes shall be cast, cured, and transported according to CSA A23.2-1B. Referee grout cubes shall be cured and transported to

the Regional Quality Assurance Laboratory, along with the acceptance grout cubes. A set of grout cubes shall consist of three 50 mm in dimension cubes, at each specified age.

Test information shall be recorded on MTO form PH-CC 322, Concrete Construction Report, and submitted with each set of the grout cubes.

The Contractor shall continuously record and monitor air temperature immediately adjacent to the grout cubes during the field-curing period. The maximum time interval for recording the temperature shall be every 15 minutes. Curing temperature records shall be submitted to the Contract Administrator at the completion of the field-curing period.

203.07.01.04.02 **Testing of Rock Bolts**

Rock bolt tests shall be conducted as specified in the Contract Documents to demonstrate the performance of the rock bolts by axial pull tests using a calibrated hollow hydraulic jack.

The rock bolt pull testing shall be carried out according to ~~the International Society of Rock Mechanics (ISRM) standard methods for proof tests~~ the International Society of Rock Mechanics (ISRM) Suggested Method for Rock Anchorage Testing in the presence of the Contract Administrator. The axial tensioning equipment shall consist of a hollow plunger type hydraulic jack with a minimum capacity of 200 kN, a hydraulic pump, pressure gauges, displacement gauges capable of measuring displacements of 0.0025 cm, and all necessary accessory items for carrying out the rock bolt performance tests.

Rock bolts that fail to meet the ~~test criteria~~ acceptance requirement shall be reinstalled and tested at no additional cost to the Owner.

203.07.02 **Rock Shotcreting**

203.07.02.01 **Operational Constraints**

The Contract Administrator shall be notified of the intent to apply shotcrete a minimum of 3 Business Days prior to the commencement of the shotcreting operation.

A MTO form PH-CC-701, Request to Proceed shall be submitted to the Contract Administrator at the completion of the surface preparation operation and prior to the commencement of the application of shotcrete.

The application of shotcrete shall not proceed until ~~the rock surface is properly prepared according to this specification and verified by~~ a MTO form PH-CC-702, Noticed to Proceed has been received from the Contract Administrator.

No shotcrete shall be placed until all curing materials, and, in cold weather, all cold weather protection materials have been delivered to the site.

Shotcreting shall not be carried out when the air temperature or ~~the existing rock surface~~ surface temperature is ~~below~~ less than 10 °C, or is likely to ~~fall below~~ be less than 10 °C, or is ~~above~~ greater than 30 °C, or likely to ~~rise above~~ be greater than 30 °C throughout the duration of the shotcreting operation, unless cold weather protection is provided according to the Contractor's submitted plan.

Prior to shotcreting, the Contractor shall demonstrate to the Contract Administrator that the substrate temperatures meet the Contract requirements by measuring the substrate temperatures using a contact thermometer, and recording them.

Shotcrete shall not be placed against frozen surfaces. All surfaces against which shotcrete is to be placed shall be free of standing water. Shotcrete shall be protected from contact with rain or snow.

The air in contact with the shotcreted surfaces shall be maintained at temperatures greater than 10 °C for a minimum of 96 hours after the application of shotcrete. Unvented heaters shall not be used.

Shotcreting operations shall be suspended during weather conditions that may adversely affect the quality of the work. This includes but is not limited to wind causing segregation of ingredients, rain or snow.

203.07.02.02 Approval of Nozzle Operator

Prior to seasonal shutdown, operations shall be scheduled in such a manner as to ensure that the shotcreting operations are completed in all areas where surface preparation has commenced.

203.07.02.02 Surface Preparation

All

~~Shotcreting shall be carried out by a nozzle operator who has been certified by participation in the MTO Shotcrete Nozzleman Certification Program and who is on the list of approved nozzle operators for the current construction season.~~

203.07.02.03 Placing

~~To ensure that a full bond is developed with the shotcrete, all~~ rock surfaces against which shotcrete is to be placed shall be clean, solid and free from loose or partial-detached or unsound fragmentsrock, vegetation or other organic materials, and any foreign substances or other debris. All dust and loose material shall be removed using compressed air.

~~Immediately prior to wetting the rock surface, all dust and loose material shall be removed using compressed air.~~

Prior to the application of shotcrete:

- a) The area to be shotcreted shall be maintained in a wet condition for a minimum period of 2 hours; prior to the application of the shotcrete. ~~Prior to the shotcreting operation, excess~~
- b) Excess water shall be removed from the rock surface using compressed air to reach a saturated surface dry condition.

203.07.02.03 MTO Nozzleperson Certification Program

Shotcreting shall be carried out by a nozzleperson who has successfully participated in the MTO Shotcrete Nozzleperson Certification Program that is valid for the current construction season. Notwithstanding this prequalification, the nozzleperson shall be replaced when in the opinion of the Contract Administrator, acceptable quality of work is not achieved or maintained.

203.07.02.04 Placing

All necessary measures shall be taken during shotcrete application to guard against damage, including damage to passing vehicles which may be caused by excessive rebounding of shotcrete material.

~~Shotcrete~~The specified thickness of the shotcrete shall be placed to create a minimum 75 mm thick and an average of 100 mm thick layer to stabilize fractured rock and support rock overhangs at the locations as, unless otherwise specified in the Contract Documents.

During the application of the shotcrete, a steady continuous flow of shotcrete shall be maintained. ~~Any pre-dampened mixture that is not used within one half hour shall not be incorporated into the work.~~

For dry mix shotcrete, any predampened mixture which is not utilized within 30 minutes, shall be rejected and shall not be incorporated into the work. When wet mix shotcrete is transported to the site by means of agitating or mixing equipment, discharge of the shotcrete shall be completed within 1.5 hours after introduction of the mixing water to the cement and aggregates, except when the air temperature is greater than 28 °C and the concrete temperature is greater than 25 °C, the concrete shall be discharged within 1 hour after the introduction of the mixing water. Use of retarders does not change the specified concrete discharge time.

The total required depth of shotcrete shall be placed within the same Day once the shotcrete placement has commenced for an area.

Shotcrete shall be applied so that there is no sagging or separation of the material in place.

All rebound and overspray material shall be removed ~~from the work area~~ as the work proceeds. ~~Rebound, overspray~~ or waste material shall not be worked back into ~~construction the shotcrete~~ or salvaged and re-used.

The total required depth **203.07.02.05** Curing

Shotcrete shall be moist cured for a minimum period of 4 Days. Curing for at least the first 24 hours of the curing period shall be by fog mist.

Application of fog mist shall begin immediately after application of the final layer of shotcrete or, where hand finishing is specified, immediately after finishing of the shotcrete.

For the remainder of the moist curing period, moist curing shall be by means of fog mist or wet burlap.

When wet burlap is used, the burlap shall be placed within the same Day.

Immediately after placing shotcrete, in a manner that will ensure that it is in full contact with the surface of the shotcrete surface shall be coated with a curing compound for the full duration of the curing period. Curing with burlap and water shall be according to OPSS 904.

203.07.02.04 Testing of Rock Shotcrete **06** Cold Weather Protection

Testing of shotcrete Cold weather protection shall be according to ASTM C42. If necessary, thicknesses shall be confirmed by core drilling. The minimum number of cores taken will be 1 for every 50 square metres of shotcrete placed OPSS 931.

203.07.03 Material Sampling and Testing

203.07.03.01 Sampling for Acceptance Testing of Compressive Strength and Thickness of Shotcrete

Core samples for acceptance testing of 28-Day compressive strength and thickness shall be removed from the shotcrete at locations randomly selected by the Contract Administrator. Core samples shall be obtained for acceptance testing in the presence of the Contract Administrator.

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The lot size, subplot size and number of cores per subplot shall be according to the Quality Assurance section.

203.07.03.02 Coring

Coring shall be carried out according to CSA A23.2-14C when the shotcrete is between 7 to 10 Days of age. Cores shall be 75 mm in diameter and a minimum of 5 test panels shall be constructed during the work as directed by the Contract Administrator. Specimens from the panels 100 mm long.

To avoid cutting reinforcing steel, all embedded steel and rock drains in the area shall be located, using a covermeter, prior to taking any cores. Cores for compressive strength testing may contain welded steel wire reinforcement but shall not contain reinforcing steel.

Each core shall be marked legibly with durable ink immediately after removal with the following information:

- a) Contract number.
- b) Lot number.
- c) Sublot number.
- d) Location of each individual core.
- e) be tested by Date of shotcrete placement.
- f) Date of extraction.

Cores shall be placed in a plastic bag, sealed to prevent loss of moisture and provided to the Contract Administrator to determine compliance with this specification along with MTO Form PH-CC-433A, Concrete Mix Design Submission Form A, of the concrete mix design and the MTO form PH-CC-340, Field Sample Data Sheet – Concrete, on which the field data for the cores is recorded, for testing by the Owner.

When the shotcrete has gained sufficient strength and within 36 hours after its placement, all designated in-place shotcrete in both the initial and subsequent shotcreted layers shall be tested in the presence of the Contract Administrator. The testing shall consist of hammering at 300 mm centres to detect any hollow sounding areas.

Areas of shotcrete that are determined Core holes shall be filled according to OPSS 1350.

203.07.03.03 Preparation for Sounding Acceptance Testing

The Contract Administrator shall be notified in writing when the shotcrete is ready for the sounding acceptance testing. The sounding acceptance testing of the shotcrete shall be completed on the final shotcreted layer by the Contract Administrator to be inadequately bonded or cracked or any area of shotcrete where porous, rebound material, cracks, or sagging are present in cores that are taken within those areas shall be removed and replaced until adequate shotcrete quality and bonding has been achieved. Rehabilitation by other methods.

Provisions shall only be undertaken with made for access to the written approval site and to all areas of the shotcreted face for sounding acceptance testing.

203.07.04 Field Inspection for Cracks

The Contractor shall inspect all concrete to identify and document any cracks including, their location, width, and density. The results of the inspection shall be reported to the Contract Administrator.

Based on criteria in the Field Inspection of Completed Work clause, the Contractor shall identify areas requiring repair or replacement and shall identify the limits of such repair or replacement. This information shall be provided to the Contract Administrator along with a proposal for remedial action to be taken. No repairs shall proceed until the proposal has been accepted by the Contract Administrator in writing. Repair of cracks shall be according to OPSS 932 and shall be completed after the curing period has elapsed.

203.07.0305 Rock Drains

When rock drain holes are specified in the Contract Documents, the holes shall be drilled to depths of 3.0 m at an inclination of approximately 10 degrees above the horizontal and throughout the shotcrete layer at 2.0 to 3.0 m centres.

The drain holes shall then be lined with tightly-~~fitting~~fitted PVC pipe that protrudes approximately 25 to 75 mm outside of the shotcreted face.

~~203.07.04~~ 06 **Cast-in-place Concrete Buttress**

Rock cavities shall be filled with reinforced concrete at locations as specified in the Contract Documents.

~~All work~~Concrete buttress shall be according to OPSS 904.

~~Concrete shall be 30 MPa at 28 Days.~~

Dowels ~~into the rock~~ shall be installed into the existing rock baseface as specified in the Contract Documents on a grid pattern and to depths as specified in the Contract Drawings.

~~Reinforcing steel shall be according to OPSS 905.~~

The ~~resultant~~ concrete face shall behave a smooth surface.

~~203.07.05~~07 **Management of Excess Material**

Management of excess material shall be according to the Contract Documents.

203.08 **QUALITY ASSURANCE**

203.08.01 **Acceptance of Grout for Rock Bolting**

Grout for rock bolting shall be acceptable if all of the requirements of this specification are met, including:

- a) 7-Day compressive strength;
- b) 28-Day compressive strength;
- c) Mixing, handling and curing according to manufacturer's specifications; and
- d) There are no defects detected by inspection according to the Field Inspection subsection.

Unacceptable lots or sublots shall be deemed rejectable.

203.08.02 **Acceptance of Rock Shotcrete**

Shotcrete shall be acceptable if all of the requirements of this specification are met, including:

- a) 28-Day compressive strength;
- b) Thickness; and
- c) There are no defects detected by inspection according to the Field Inspection subsection.

Unacceptable lots or sublots shall be deemed rejectable.

203.08.03 **Field Inspection**

203.08.03.01 Field Inspection for Rock Bolting

The Contract Administrator will inspect the plastic grout or anchoring agent during the application process and will reject all or a portion of the work based on the presence of one or more of the defects and deficiencies identified below:

- a) Failure to mix, handle and cure of the grout according to manufacturer's specifications.
- b) Excessive bleeding of grout.
- c) Failure to completely fill the hole or rock bolts which protrude from the hole by an amount greater or less than the length specified.
- d) Improper cleaning of the drilled holes.

If plastic grout or anchoring agent is rejected by the Contract Administrator, the work shall stop and all necessary measures to correct deficiencies shall be taken.

203.08.03.02 Field Inspection for Rock Shotcreting

The Contract Administrator will inspect the plastic shotcrete during the application process and will reject all or a portion of the work based on the presence of one or more of the defects and deficiencies identified below:

- a) Failure to achieve specified surface profile.
- b) Failure to remove all loose and unsound material prior to pre-wetting.
- c) Failure to adequately pre-wet or achieve a saturated surface dry condition of the rock face prior to application of the shotcrete.
- d) Failure to properly control and remove build-up of shotcrete overspray and rebound.
- e) Incomplete consolidation around reinforcing steel, welded wire mesh, rock drains and anchors.
- f) Excessive shotcrete rebound.
- g) Incorporation of sand lenses, excessive voids, delaminations, sags, and sloughing.
- h) Failure to apply shotcrete to the required line, grade, and tolerance.

If plastic shotcrete is rejected by the Contract Administrator, the work shall stop and all necessary measures to correct deficiencies shall be taken.

203.08.03.03 Completed Work

The Contract Administrator will inspect the completed work and any cores removed from the work and will reject all or a portion of the work based on the presence of one or more of the defects and deficiencies identified below:

- a) Debonded or hollow-sounding areas.
- b) Porous or rebound material visible in cores or in the placed shotcrete.
- c) Areas which have visibly sagged in cores or in the placed shotcrete.

d) Cracks with a width greater than 0.3 mm where the linear measurement of the crack is 2 m or greater per square meter area.

Cracks greater than or equal to 0.3 mm in width shall be repaired according to this specification, if the linear measurement of the crack per square metre is less than 2 m.

203.08.04 Acceptance of Thickness and Compressive Strength of Rock Shotcrete

203.08.04.01 Lot Size

A lot shall consist of the total quantity of shotcrete in the Contract Documents. Each lot shall be divided into sublots of approximately equal size and no greater than 100 m².

The Contract Administrator will determine the subplot size prior to the commencement of the shotcreting operation.

203.08.04.02 Basis of Acceptance

203.08.04.02.01 General

The thickness and 28-Day compressive strength of shotcrete shall be determined based on the length of the three cores removed from each subplot.

203.08.04.02.02 Thickness

Each core shall be measured for length prior to trimming. Four measurements rounded to the nearest millimetre shall be made around the perimeter of each core to determine the actual shotcrete thickness. These measurements shall be taken at the ends of two perpendicular diameters.

The thickness of hardened shotcrete shall be determined according to LS-410. The thickness of a subplot shall be considered acceptable when it meets the following requirements:

- a) The average of the three thickness measurements shall be minimum of 100 mm.
- b) No individual thickness measurement shall be less than 75 mm.

203.08.04.02.03 Compressive Strength

The 28-Day compressive strength shall be determined according to LS-410. The 28-Day compressive strength of a subplot shall be considered acceptable when it meets the following requirements:

- a) The average of the three 28-Day compressive strength tests shall be greater than or equal to 35 MPa.
- b) No individual compressive strength test shall be less than 4.0 MPa below the specified strength.

Sublots with an average compressive strength greater than or equal to 31 MPa and less than 35 MPa shall be considered unacceptable but, with the agreement of the Owner, may be permitted to remain in the Work with a payment adjustment. The payment adjustment shall be calculated and applied according to the Basis of Payment section. Sublots with a compressive strength test less than 31 MPa shall be removed and replaced.

203.08.04.02.04 Referee Testing

Referee testing for a subplot may only be invoked by the Contractor within 2 Business Days of receiving the test results for that subplot.

Referee testing of 28-Day compressive strength or thickness for a subplot shall be done on a new set of three cores removed by the Contractor within 24 hours of invoking the referee testing. Cores for referee testing for each disputed subplot shall be taken in the presence of the Contract Administrator at a location no more than 1 metre from the location that each of the disputed acceptance cores were removed. The core size, and core extraction and timing of delivery to the referee laboratory shall be according to the Coring clause.

Referee testing shall be carried out according to the test method specified in the Acceptance Testing of Thickness and Compressive Strength of Rock Shotcrete clause.

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

Referee testing of 28-Day compressive strength or thickness for a subplot shall be done on a new set of three cores removed by the Contractor within 24 hours of invoking the referee testing. Cores for referee testing for each disputed subplot shall be taken in the presence of the Contract Administrator at a location no more than 1 m from the location that each of the disputed acceptance cores were removed. The core size, and core extraction shall be according to the Coring clause.

If the difference between the referee test result and the acceptance test result is less than or equal to the confirmation value, then the acceptance test result is confirmed, and the acceptance test result shall be used in the determination of acceptance and payment for the shotcrete. If the difference between the referee test result and the acceptance test result is greater than the confirmation value, the acceptance test result is not confirmed, and the acceptance test result shall be disregarded and not used in the determination of acceptance and payment.

The confirmation value for confirming the acceptance test result shall be the greater of 10% of the specified compressive strength or specified thickness or 10% of the compressive strength or thickness of the acceptance cores, expressed to one decimal place.

The cost of referee testing shall be as specified in the Contract Documents. When the referee result confirms the acceptance test results, the Contractor shall be charged the cost of referee testing. When the referee result does not confirm the acceptance test result, the Owner shall bear the cost.

203.08.05 Acceptance of Compressive Strength of Grout

203.08.05.01 Lot Size

The lot size shall represent all the grout produced during one day of production.

203.08.05.02 Basis of Acceptance

The 7-Day and 28-Day compressive strength shall be determined according to CSA A23.2-1B. The 7-Day and 28-Day compressive strength of a lot shall be considered acceptable when it meets the minimum requirements of this specification.

Lots with a compressive strength less than the minimum requirements of this specification shall be removed and replaced.

203.08.05.02.02 Referee Testing

Referee testing for a lot may only be invoked by the Contractor within 2 Business Days of receiving the test results for that lot.

The referee testing process for grout compressive strength is based on duplicate grout cubes cast at the

same time as the acceptance grout cubes.

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

If the difference between the referee test result and the acceptance test result is less than or equal to the confirmation value, then the acceptance test result is confirmed, and the acceptance test result shall be used in the determination of acceptance and payment for the concrete. If the difference between the referee test result and the acceptance test result is greater than the confirmation value, the acceptance test result is not confirmed, and the acceptance test result shall be disregarded and not used in the determination of acceptance and payment.

The confirmation value for confirming the acceptance test result shall be the greater of 10% of the specified strength or 10% of the strength of the acceptance grout cubes, expressed to one decimal place.

The cost of referee testing shall be as specified in the Contract Documents. When the referee result confirms the acceptance test results, the Contractor shall be charged the cost of referee testing. When the referee result does not confirm the acceptance test result, the Owner shall bear the cost.

203.08.06 Sounding Acceptance Testing

The sounding acceptance testing shall consist of hammering at 300 mm centres and any areas of concern, to detect any hollow sounding or debonded areas.

Areas of shotcrete that are determined by the Contract Administrator to be inadequately bonded shall be removed and replaced.

203.09 MEASUREMENT FOR PAYMENT

203.09.01 Actual Measurement

203.09.01.01 Rock Bolting

For measurement purposes, a count shall be made by the Contract Administrator of the number of rock bolts installed.

203.09.01.02 Rock Shotcrete

Measurement shall be by area in square metres of shotcrete ~~and shall only include those areas that have an average thickness of 100 mm and a minimum thickness of 75 mm.~~

203.09.01.03 Rock Drains

For measurement purposes, a count shall be made by the Contract Administrator of the number of rock drains installed.

203.09.01.04 Concrete Buttress

Measurement shall be by volume in cubic metres of the reinforced concrete placed.

203.09.02 Plan Quantity Measurement

When measurement is by Plan Quantity, such measurement shall be based on the units shown in the clauses under Actual Measurement.

203.10 BASIS OF PAYMENT

203.10.01 ~~Rock Drains - Items~~ Bolting - Item
Rock Shotcreting - Item
~~Rock Drains - Items~~
Concrete Buttress - 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~~

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~~203.10.02~~ ~~Rock Shotcreting - Item~~
~~Rock Bolting - 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.

Replacement of unacceptable rock bolts and rock shotcreting shall be carried out at no additional cost to the Owner.

203.10.01.01 Payment Adjustment for Shotcrete

The payment adjustment factor (Pr_i) for the compressive strength of each shotcrete subplot will be calculated by the following equation:

$$Pr_i = 1.0 - ((0.525 - 0.015S))$$

Where:

S = The average 28-Day compressive strength (MPa) for each shotcrete subplot. (For the purpose of calculating the payment adjustment for shotcrete, a value of 35 MPa shall be used for "S" when the average compressive strength is greater than or equal to 35 MPa.)

The payment adjustment factor for the lot (Pr) is calculated by the following equation:

$$Pr = \frac{(Pr_1 \times LQ_1) + (Pr_2 \times LQ_2) \dots (Pr_n \times LQ_n)}{(LQ_1 + LQ_2 \dots LQ_n)}$$

Where:

Pr_i = Payment adjustment factor for subplot i.

LQ_i = Quantity of subplot i (m³)

n = The total number of sublots.

The total payment adjustment (Pa) for the lot is calculated by the equation:

Pa = Quantity x Tender Unit Price x Pr