TENDER DOCUMENTS

SUBSECTION 6.34
SHOTCRETE

TABLE OF CONTENTS

PAGE

SUBSECTION 6.34 SHOTCRETE

6.34.1 GENERAL

6.34.1.1 This subsection sets out the requirements for the rehabilitation of structures with shotcrete as part of the rehabilitation of existing structures under this Contract.

6.34.1.2 Any specific requirements pertaining to repair work of structures with shotcrete under this Contract are set out ion the plans and in Section 4 *Special Technical Conditions.*

6.34.1.3 The requirements relating to concrete demolition are described in subsection 6.21 *Demolition and Removal.*

6.34.1.4 The requirements relating to reinforcing steel and anchors are described in subsection 6.31 *Reinforcing Steel for Concrete.*

6.34.2 MEASUREMENT UNITS

6.34.2.1 The measurement units and respective symbols thereof used in this subsection are described as follows:

Measurement Unit	**Designation**	**Symbol**
length	meter	m
length	millimeter	mm
length	micrometer	µm
volume	cubic meter	m^3
volume	liter	L
basis weight	gram per square meter	g/m^2
density	kilogram per cubic meter	kg/m^3
mass	kilogram	kg
stress, pressure	kilopascal	kPa
stress, pressure	megapascal	MPa
time	hour	h
temperature	Celsius degree	°C

6.34.3 REFERENCE STANDARDS

6.34.3.1 The Contractor shall perform all shotcrete work in accordance with the requirement of the following standards and documents, to which the provisions of this Contract are added:

6.34.3.1.1 (AASHTO) American Association of State Highway and Transportation Officials:

- AASHTO M182-05-UL *Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats*;

- AASHTO T026-79-UL *Standard Method of Test for Quality of Water to be used in Concrete*.

6.34.3.1.2 (ACI) American Concrete Institute:

- ACI 304.2R *Placing Concrete by Pumping Methods*;
- ACI 306R *Guide to Cold Weather Concreting*;
- ACI 506R *Guide to Shotcrete*;
- ACI 506.2 *Specification for Shotcrete*;
- ACI 506-3R *Guide to Certification of Shotcrete Nozzelman*.

6.34.3.1.3 (ASTM) ASTM International:

- ASTM C109/C109M *Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)*;
- ASTM C157/C157M *Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete*;
- ASTM C171 *Standard Specification for Sheet Materials for Curing Concrete*;
- ASTM C260 *Standard Specification for Air-Entraining Admixtures for Concrete*;
- ASTM C295/C295M *Standard Guide for Petrographic Examination of Aggregates for Concrete*;
- ASTM C309 *Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete*;
- ASTM C348 *Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars;*
- ASTM C387/C387M *Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete*;
- ASTM C457/C457M *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete*;
- ASTM C494/C494M *Standard Specification for Chemical Admixtures for Concrete*;
- ASTM C642 *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete*;
- ASTM C666/C666M *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*;
- ASTM C672/C672M *Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals*;
- ASTM C685/C685M *Standard Specification for Concrete Made By Volumetric Batching and Continuous Mixing*;
- ASTM C881/C881M *Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete*;

- ASTM C882/C882M *Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear*;
- ASTM C1017/C1017M *Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete*;
- ASTM C1116/C1116M *Standard Specification for Fiber-Reinforced Concrete*;
- ASTM C1140/1140M *Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels*;
- ASTM C1152/C1152M *Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete*;
- ASTM C1202 *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*;
- ASTM D512 *Standard Test Methods for Chloride Ion In Water*;
- ASTM D516 *Standard Test Method for Sulfate Ion in Water*;
- ASTM D4191 *Standard Test Method for Sodium in Water by Atomic Absorption Spectrophotometry*;
- ASTM D4192 *Standard Test Method for Potassium in Water by Atomic Absorption Spectrophotometry*;
- ASTM D5095 *Standard Test Method for Determination of the Nonvolatile Content in Silanes, Siloxanes and Silane-Siloxane Blends Used in Masonry Water Repellent Treatments*;
- ASTM D5167 *Standard Practice for Melting of Hot-Applied Joint and Crack Sealant and Filler for Evaluation*;
- ASTM D5329 *Standard Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements*.

6.34.3.1.4 CSA Group (Canadian Standard Association):

- CAN/CSA-A23.1/A23.2 *Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete;*
- CAN/CSA-A23.3 *Design of Concrete Structures*;
- CAN/CSA-A3000 *Cementitious Materials Compendium (Consists of A3001, A3002, A3003, A3004 and A3005)*;
- CSA S6-F14 *Canadian Highway Bridge Design Code*.

6.34.3.1.5 (BNQ) Bureau de normalisation du Québec:

- BNQ 2501-025 *Sols – Analyse granulométrique des sols inorganiques;*
- BNQ 2560-114 *Travaux de génie civil – Granulats,* Partie IV : *Béton de masse volumique normale*;
- BNQ 2621-905 *Béton prêt à l'emploi (Ready-Mix Concrete).*

6.34.3.1.6 (MTQ) Ministère des Transports du Québec:

- MTQ – *Cahier des charges et devis généraux* (CCDG);
- MTQ – *Normes – Ouvrages routiers* – Tome VII *Matériaux*, Chapitre 3 *Béton de ciment et produits connexes,* Norme 3201 *Béton projeté par procédé à sec;*
- MTQ – *Normes – Ouvrages routiers* – Tome VII *Matériaux*, Chapitre 3 *Béton de ciment et produits connexes,* Norme 3301 *Béton projeté par procédé humide.*

6.34.4 MATERIALS

6.34.4.1 CEMENT AND CEMENT ADDITIVES

6.34.4.1.1 Hydraulic cements shall comply with standards CAN/CSA-A23.1 and CAN/CSA-A3000.

6.34.4.1.2 The cementitious binder used shall be a general use GU Portland hydraulic cement or a GUb-SF, GUb-S/SF or GUb-F/SF hydraulic compound cement.

6.34.4.1.3 The total mass of cement additives (fly ash, finely ground granulated blast furnace slag and silica fume) shall not exceed 30 % of the total mass of the binder.

6.34.4.1.4 Silica fume shall comply with standard CAN/CSA-A3000, Type U in a ratio of 6 % to 8 % by cement mass.

6.34.4.1.5 Fly ash, where required, shall meet the requirements for Type F of standard CAN/CSA-A3000 and, more specifically, the section of the standard entitled A3001 – *Binders used in Concrete*.

6.34.4.1.6 Unless otherwise indicated, the use of ternary cements is prohibited between October 15 and March 31.

6.34.4.2 WATER

6.34.4.2.1 All water used in the manufacturing of concrete, including the water added to the pre-dampener and shotcrete nozzle and the water used for curing, shall be fresh, clean, potable and free of oil and chemical or organic impurities and shall comply with the provisions of standard CAN/CSA-A23.1.

6.34.4.2.2 Raw water used as mixing water shall meet the following properties (from Article 4.2.2 of standard CAN/CSA-A23.1):

Parameter	Maximum Concentration in Mixing Water (mg/l)	Standard
Chlorides	500 (for Prestressed Concrete) 1,000 (for Other Reinforced Concrete)	ASTM D512
Sulphates (SO_4)	3,000	ASTM D516
Alkali ($Na_2O + 0.658\ K_2O$)	500 600	ASTM D4191 ASTM D4192
Total Solids	50,000	AASHTO T26

6.34.4.3 AGGREGATE

6.34.4.3.1 All aggregate shall be clean, resistant and free of deleterious materials and shall comply with standard CAN/CSA-A23.1 applicable to the appropriate exposure class.

6.34.4.3.2 The Contractor shall submit to the Engineer, for review, a statement signed by the qualified person who conducted the petrographic examination of the fine and coarse aggregate (in accordance with standard ASTM C295/C295M) certifying that the aggregate used in the concrete will not lead to excessive expansion of and cracks in the concrete caused by the alkali-aggregate reaction or any other adverse reaction, as prescribed in standard CAN/CSA-A23.1.

6.34.4.3.3 Aggregate shall consist of natural sand, gravel or crushed stone in accordance with standard CAN/CSA-A23.1 as to the grading, strength and durability.

6.34.4.3.4 Aggregate used for mixing shotcrete on site shall be stored and handled so as to eliminate any risk of segregation and shall be maintained at a moisture content ranging from 3 % to 7 %. The Contractor shall use shelters or tarpaulins to protect the aggregate stockpiles from damp weather, rain or other adverse conditions.

6.34.4.3.5 Normal-density fine aggregate

6.34.4.3.5.1 Normal-density fine aggregate shall consist of natural sand, manufactured sand or a combination thereof.

6.34.4.3.5.2 Fine aggregate shall be graded as follows:

Sieve Size (mm)	Total Passing Each Sieve, Percentage by Mass							
	10 mm	**5 mm**	**2.5 mm**	**1.25 mm**	630 µm	315 µm	160 µm	80 µm
10 to 2.5	100	95 to 100	80 to 100	50 to 90	25 to 65	10 to 35	2 to 10	0 to 3

6.34.4.3.6 Normal-density coarse aggregate

6.34.4.3.6.1 The 10 to 2.5 mm coarse aggregate shall be stored and added separately from the fine aggregate (maximum nominal size of 5 mm) during mixing operations. The particle size distribution of the 10 to 2.5 mm coarse aggregate used shall meet the requirements set out in Table 11 of standard CAN/CSA-A23.1.

6.34.4.3.6.2 Coarse aggregate shall be graded as follows:

Sieve Size (mm)	Total Passing Each Sieve, Percentage by Mass						
	28 mm	20 mm	14 mm	10 mm	5 mm	2.5 mm	1.25 mm
10 to 2,5	-	-	100	85 to 100	10 to 30	0 to 10	0 to 5

6.34.4.3.7 Alkali-aggregate reactivity

6.34.4.3.7.1 Aggregate used in the concrete shall not react on contact with the alkalis contained in the concrete to an extent that results in excessive expansion of the concrete, cracking or both.

6.34.4.3.7.2 The assessment of the potential reactivity of an aggregate shall be tested in accordance with standard CAN/CSA-A23.2-14A.

6.34.4.3.7.3 The classification of the degree of reactivity of the aggregate is based on Table 2 of standard CAN/CSA-A23.2-27A. Results obtained using the accelerated test will not be considered.

6.34.4.3.7.4 Aggregate classified as “highly reactive” shall not be used. Aggregate classified as “moderately reactive” may be used in combination with the following preventive measure:

6.34.4.3.7.4.1 the addition of alkali from Portland cement to the concrete shall be limited to a maximum of 2.4 kg/m³ of equivalent Na_2O as prescribed in Table 5 *Preventive Measures* of standard CAN/CSA-A23.2-27A.

6.34.4.3.7.5 Aggregate presenting alkali-carbonate reactivity shall not be used.

6.34.4.4 ADMIXTURES

6.34.4.4.1 The Contractor shall not add any admixtures to the concrete mix without prior authorization from the Engineer. The Contractor shall not use any admixture containing chlorides.

6.34.4.4.2 Air-entraining agent

6.34.4.4.2.1 The Contractor shall add air-entraining agents to the mix water. Air-entraining agents shall comply with standard ASTM C260. The Contractor may, subject to prior approval from the Engineer, use a powdered air-entraining agent for pre-packaged mixes.

6.34.4.4.2.2 Characteristics of air bubble network in hardened concrete:

Shotcrete Method	Minimum Air Content, %	Spacing Factor □m	
		Maximum Individual Result	Maximum Average Result
Dry Process	--	320	300
Wet Process	≥ 3.0	260	230

6.34.4.4.3 Chemical admixtures

6.34.4.4.3.1 Chemical admixtures shall comply with standard ASTM C494/C494M or ASTM C1017/C1017M.

6.34.4.4.3.2 Only the aluminate-based set accelerator admixture is permitted.

6.34.4.4.3.2.1 Set accelerator admixtures shall be the product *Eucon DSC* manufactured by Euclid Canada or an equivalent authorized by the Engineer.

6.34.4.4.3.3 The chemical admixtures used shall not contain any chlorides. Furthermore, Type C or E admixtures, set accelerators, are prohibited unless specifically authorized by the Engineer.

6.34.4.4.3.4 Unless otherwise indicated on the plans, only Type A water reducers shall be used. They shall produce a water reduction greater than 5 % compared with the control mix that also contains entrained air.

6.34.4.4.3.5 If the use of a superplasticizer, high-range water reducer, is indicated on the plans, the following special measures shall be taken by the Contractor when mixing the concrete:

6.34.4.4.3.5.1 before the superplasticizer is added, the slump of the concrete shall be within the prescribed limits;

6.34.4.4.3.5.2 at the time it is incorporated into the structure, the concrete shall have an air content within the prescribed limits.

6.34.4.4.3.6 Where a superplasticizer is used, the slump measured after mixing on site shall be maintained at a maximum value of 130 mm unless otherwise indicated by the Engineer.

6.34.4.5 FIBRES

6.34.4.5.1 Shotcrete shall only contain polypropylene fibres that have the following properties:

- virgin polypropylene homopolymer-based composition;
- tensile strength: 275 to 425 MPa;
- water absorption: zero;
- density: 0.90 to 0.92;
- length: 12 to 20 mm;
- moisture resistant and resistant to the alkalis contained in the concrete.

6.34.4.5.2 If a mobile concrete mixer is used to manufacture the dry shotcrete, the polypropylene fibres shall first be mixed with the fine aggregate at the plant and the air-entraining agent shall be added to the water in the tank of the agitator-equipped mobile concrete mixer.

6.34.4.6 CURING AGENTS

6.34.4.6.1 The materials used in the curing of concrete shall comply with standards ASTM C171, ASTM C309 and AASHTO M182-05-UL.

6.34.4.6.2 Membrane-forming curing compound

6.34.4.6.2.1 Chemical curing compound may not be used unless specifically permitted on the plans or authorized by the Engineer as a temporary curing measure when, in his opinion, wet curing will be difficult to achieve.

6.34.4.6.2.2 The membrane-forming curing compound used shall comply with standard ASTM C309 and shall be translucent with a fugitive dye (Type 1-D).

6.34.4.6.3 Absorbent fabric

6.34.4.6.3.1 The absorbent fabric made of unwoven needle-punched synthetic polyester or polypropylene fibres shall have a minimum mass density of 300 g/m^2 and shall be white.

6.34.4.6.3.2 The absorbent fabric shall be at least 1 m wide and shall not contain any substances that might be deleterious to the concrete. New fabric shall be flushed out thoroughly with water in order to make it more absorbent and remove any soluble materials.

6.34.4.6.4 Waterproof sheet

6.34.4.6.4.1 The waterproof sheet shall comply with standard ASTM C171.

6.34.4.6.4.2 The waterproof sheet may be:

6.34.4.6.4.2.1 a transparent or opaque white polyethylene film of a minimum thickness of 0.1 mm; or

6.34.4.6.4.2.2 a fabric with a minimum mass density of 305 g/m^2 covered on one side with an opaque white polyethylene film of a minimum thickness of 0.1 mm.

6.34.4.6.4.3 The waterproof sheet shall be at least 1 m wide, shall have no tears and shall not contain any substances that might be deleterious to the concrete.

6.34.4.7 CALCIUM CHLORIDE

6.34.4.7.1 The use of calcium chloride is prohibited.

6.34.4.8 SHOTCRETE

6.34.4.8.1 Shotcrete shall have the following properties:

Specified Shotcrete Method	Minimum Compressive Strength at 28 Days (MPa) (1)	Type and Quantity of Cement (kg/m^3)		Max. Water/ Cementitious Binder Ratio	Coarse Aggregate (Min. %)	Air Content of Fresh Concrete (%)	Slump (mm)	Min. Fibre Mass (kg/m^3)
		Blended Cement(2)	HE (3)					
Dry Process	35	450	460	0.40	10	5 – 8(4)	---	0.9
Wet Process	35	410	---	0.40	25	10 – 15(5)	100±30(5)	0.9

Notes:
(1) The minimum compressive strength at six (6) hours shall be 8MPa.
(2) GUb-SF, GUb-F/SF or GUb-S/SF hydraulic blended cement.
(3) Overhanging use.
(4) Air content measured after projection into the air meter prior to placement.
(5) Slump and air content properties measured at the outlet of the mixer truck following the addition of superplasticizer, where applicable.

6.34.4.8.2 The work shall be carried out using shotcrete applied by dry-mix or wet-mix process. For overhanging surfaces, the repair shall be performed using shotcrete applied by dry-mix process.

6.34.5 EQUIPMENT AND TOOLS

6.34.5.1 MOBILE CONCRETE MIXER

6.34.5.1.1 For spraying concrete in small quantities, the concrete may, unless otherwise specified by the Engineer, be proportioned and mixed on site in a mobile concrete mixer in accordance with standard ASTM C685/C685M.

6.34.5.1.2 If the Contractor elects to supply the concrete from floating facilities, a barge-mounted mobile plant is permitted if it complies with standard ASTM C685/C685M. Mixing tests shall then be conducted by the Contractor, as well as tests to determine the mixing sequence and time for each ingredient of the mix.

6.34.5.1.3 The mobile concrete mixer and operator thereof shall be identified and only that mixer and that operator will be authorized to supply the concrete during the work. The tests results shall be recorded in writing and a copy given to the Engineer before shotcreting begins. The storage areas for materials shall comply with standard CAN/CSA-A23.1 and shall be set up so as to protect the materials from dampness and other weather conditions.

6.34.5.1.4 The first 0.25 m^3 of concrete used to prepare and calibrate the equipment may not be used and shall be discarded.

6.34.5.2 MIXER OR PRE-DAMPENER (SHOTCRETE APPLIED BY DRY-MIX PROCESS)

6.34.5.2.1 The mixer or pre-dampener used for pre-damping the pre-mixed ingredients shall have sufficient capacity to steadily produce a uniform mix having a water content ranging from 3 % to 6 % of the total mass of the mix and shall have sufficient capacity to ensure that there are no delays in the performance of the work. The materials shall be discharged without segregating. It is not permitted to discharge materials that are completely dry into the shotcrete nozzle.

6.34.5.2.2 For materials that are mixed on site, if the moisture content in the sand is too low to provide a moisture content of the mixed shotcrete materials within the range of 3 % to 6 %, the Contractor shall pre-dampened the shotcrete in a pre-dampener prior to discharge into the shotcrete nozzle.

6.34.5.3 PUMP (SHOTCRETE APPLIED BY DRY-MIX PROCESS)

6.34.5.3.1 The pump shall consist of a tank into which the mix from the mixer is poured. An air pressure shall be established inside the tank so that the hose and nozzle are continuously fed at the required velocity to provide a steady flow of uniformly mixed material.

6.34.5.4 HOSES AND NOZZLE

6.34.5.4.1 The hoses shall be flexible, be at least 38 mm in diameter, be capable of withstanding the required pressures and be fitted with seal to interconnect the hose sections.

6.34.5.4.2 For shotcrete applied by dry-mix process, the nozzle shall be equipped with a branching connection fitted with an adjustable valve to connect the water supply hose. When it reaches the nozzle, the water shall pass through a perforated ring that ensures that the mix is uniformly hydrated at the outlet of the nozzle. The inner lining of that shotcrete nozzle shall be replaced as needed. The water inlet shall be adjustable as needed.

6.34.5.4.2.1 The water supply ring shall be checked during the operation to detect any sign of clogging of the individual water spray holes. If, in the opinion of the Engineer, the shotcrete discharged is not uniformly moistened, the Contractor shall stop the concrete spraying and clean the water supply ring or take any other corrective measures.

6.34.5.5 WATER PUMP (SHOTCRETE APPLIED BY DRY-MIX PROCESS)

6.34.5.5.1 The water pump shall have the capacity to provide a water pressure that is 105 kPa higher than the air pressure required for the water to be mixed with the pre-mixed concrete materials. If the pressure of the water supply line is inadequate, the Contractor shall install, on the water supply line, a booster pump in order to provide a steady water pressure.

6.34.5.6 COMPRESSOR

6.34.5.6.1 The compressor shall have the capacity to provide sufficient quantity of clean, dry air at the required pressure (minimum 310 kPa) for 45 m of hose in order to prevent any pressure fluctuation and to maintain sufficient nozzle velocity of the mix.

6.34.5.6.2 The minimum pressure shall be increased by 35 kPa for every additional 15 m of hose. In addition, the operating pressure shall be increased by 35 kPa for every additional 8 m of drop between the compressor and the nozzle.

6.34.5.6.3 The minimum pressures shall be respected, taking into account the use of auxiliary devices such as, without limitation, air blasting cleaning and/or a pre-dampening hose.

6.34.5.6.4 The air supply system shall contain a moisture and oil trap to prevent contamination of the shotcrete.

6.34.5.7 AUXILIARY EQUIPMENT

6.34.5.7.1 The auxiliary equipment for shotcrete such as the discharge hose, water hose, booster pumps, air blasting cleaning hoses, fittings, admixture dispensers and fibre feeders shall comply with standard ACI 506R.

6.34.5.8 CONCRETE PUMP (SHOTCRETE APPLIED BY WET-MIX PROCESS)

6.34.5.8.1 The pumping equipment shall comply with standard CAN/CSA-A23.1.

6.34.5.8.2 The concrete pump used shall be capable of pumping the concrete through the specified lengths of pipe at the required flow rates without any changes to the proportioning of the ingredients in the mix.

6.34.5.8.3 No adjustments of proportions to obtain a mix with a higher cement content, a higher sand/stone ratio or a higher slump than indicated on the plans are permitted to meet the requirements of specific models of pumps.

6.34.6 EXECUTION OF WORK

6.34.6.1 PRE-WORK MEETING

6.34.6.1.1 The Contractor shall hold a pre-work meeting at least fourteen (14) days prior to the start of the shotcreting work. The Contractor shall, at that time, have the Engineer validate the following:

6.34.6.1.1.1 the concrete placement method proposed for each type of repair based on the plans and specifications;

6.34.6.1.1.2 the repair materials proposed on the basis of the requirements of these specifications, including any adjustments made as a result of the suitability tests;

6.34.6.1.1.3 the Contractor’s quality control program.

6.34.6.2 CONCRETE MIX

6.34.6.2.1 The Contractor is responsible for proportioning the ingredients in the proposed concrete mix and shall, at least fourteen (14) days before concreting begins, provide the Engineer, for review, with the proposed shotcreting operations and placement methods. The component compatibility defined in standard CAN/CSA A23.1 shall be checked by the Contractor at the time of establishing the mixing proportions.

6.34.6.2.2 The Contractor shall provide a technical data sheet on the cement concrete mix dated and signed by the person in charge of manufacturer’s quality control. The technical data sheet shall not be more than one (1) year old.

6.34.6.2.3 Concrete mix – Wet-mix process

6.34.6.2.3.1 The technical data sheet on the concrete mix shall include the following information:

6.34.6.2.3.1.1 a mix designator, number or code;

6.34.6.2.3.1.2 the concrete density of the fresh mix in kg/m³ for the specified air content and slump;

6.34.6.2.3.1.3 the cement mass of the mix in kg/m³;

6.34.6.2.3.1.4 the quantity of water in the mix in L/m³;

6.34.6.2.3.1.5 the mass of fine aggregate and coarse aggregate in the mix (saturated-surface dry (SSD) condition) in kg/m³;

6.34.6.2.3.1.6 the water/cementitious binder ratio in SSD condition;

6.34.6.2.3.1.7 the specified compressive strength;

6.34.6.2.3.1.8 the air content and slump limits;

6.34.6.2.3.1.9 the types of admixture, product names and manufacturers as well as the proposed quantities;

6.34.6.2.3.1.10 the type and origin of the cement and identification of the cement plant;

6.34.6.2.3.1.11 a report from a laboratory member of Association des firmes de génie-conseil – Québec (AFG) issued within the previous three (3) years establishing, for the mix supplied, the properties of the air-entrained bubble network, namely the air content, the air bubble spacing factor and the specific surface;

6.34.6.2.3.1.12 the intrinsic, manufacturing and complementary properties of the fine and coarse aggregate as well as their origin thereof for each calendar year;

6.34.6.2.3.1.13 the grading, dry rodded density, gross relative density (SSD condition), percentage of absorption of the fine and coarse aggregate and the fineness modulus and colour indicator of the fine aggregate;

6.34.6.2.3.1.14 a report from a laboratory member of AFG issued within the previous three (3) years establishing the potential alkali-aggregate reactivity;

6.34.6.2.3.1.15 if indicated on the plans, the results of the performance and suitability tests.

6.34.6.2.4 Concrete mix – Dry-mix process

6.34.6.2.4.1 The technical data sheet on the bagged concrete mix shall include, in addition to the information required in Article 6.34.6.2.3.1, the following:

6.34.6.2.4.1.1 the recommended use;

6.34.6.2.4.1.2 the precautions and limitations;

6.34.6.2.4.1.3 the name, quantity and properties of the fibre.

6.34.6.2.5 The mix formulas shall be reviewed and verified by the Owner's Laboratory. The Owner reserves the right to request changes to the formula in order for it to comply with the plans.

6.34.6.2.6 The Engineer may request that the Contractor submit samples of the admixtures it plans to use.

6.34.6.2.7 A manufacturer's certificate shall accompany all admixture samples, guaranteeing that they are the same in composition as those which will be supplied by the Contractor to be used.

6.34.6.3 MIX PROPORTIONS AND MANUFACTURING OF CONCRETE

6.34.6.3.1 The Contractor shall obtain its supply from a manufacturer capable of guaranteeing that the facilities, equipment and materials used in the manufacturing of concrete and all operations related thereto comply with standard CAN/CSA-A23.1.

6.34.6.3.2 The concrete manufacturer's plant shall hold a compliance certificate issued by the BNQ pursuant to certification protocol NQ 2621-905.

6.34.6.4 DELIVERY SLIP

6.34.6.4.1 For the wet-mix process, the Contractor shall, prior to discharging the concrete, submit to the Engineer a delivery slip containing the following information:

6.34.6.4.1.1 corporate name of the concrete manufacturer and the identification of the batch plant;

6.34.6.4.1.2 date and identification number of the slip;

6.34.6.4.1.3 name of the Contractor to which the concrete is to be delivered;

6.34.6.4.1.4 designation of the structure or structural element;

6.34.6.4.1.5 grade of concrete;

6.34.6.4.1.6 mixing formula number, comprising the quantities of the cement, water, coarse aggregate, fine aggregate and admixtures actually incorporated into the mix;

6.34.6.4.1.7 admixtures used;

6.34.6.4.1.8 temperature limits specified for fresh concrete;

6.34.6.4.1.9 air content limits;

6.34.6.4.1.10 slump limits;

6.34.6.4.1.11 quantity of concrete in cubic meters;

6.34.6.4.1.12 number of the truck, cumulative total for the pour and load number;

6.34.6.4.1.13 loading time;

6.34.6.4.1.14 time of arrival on site;

6.34.6.4.1.15 start time of unloading;

6.34.6.4.1.16 quantity of water added after mixing and the signature of the Engineer who authorized that addition.

6.34.6.4.2 For the dry-mix process, the following information shall appear on the bags:

6.34.6.4.2.1 manufacturer’s name;

6.34.6.4.2.2 product name;

6.34.6.4.2.3 dry mass;

6.34.6.4.2.4 air-entraining agent;

6.34.6.4.2.5 set accelerator;

6.34.6.4.2.6 yield;

6.34.6.4.2.7 recommendations for application;

6.34.6.4.2.8 storage time;

6.34.6.4.2.9 batch number.

6.34.6.5 QUALITY CONTROL

6.34.6.5.1 The Contractor shall establish, maintain and pay the cost of a quality control program for the shotcrete work in order to ensure that the work meets the Contract requirements. Such program shall include, without however being limited to:

6.34.6.5.1.1 keeping of test records for all quality control operations, including the following:

6.34.6.5.1.1.1 for all materials mixed on site, if any, monitoring of the aggregate grading and moisture content. To that effect, the Contractor shall check the moisture content at the beginning of each shotcrete application and whenever the moisture content of the aggregate changes;

6.34.6.5.1.1.2 for pre-mixed and pre-bagged materials, conduct of leaching tests, at the frequency prescribed by the Engineer, to check the cement content, the particle size distribution for the aggregate, and in the case of fibre-reinforced shotcrete, the fibre content;

6.34.6.5.1.1.3 for volume-proportioned concrete, verifications, at the prescribed frequency, of the mix by the proportion of moisture, and of ingredients.

6.34.6.6 SUITABILITY TEST

6.34.6.6.1 The Contractor shall conduct a suitability test in order to enable the Engineer to assess the compliance of the proposed materials, shotcrete mix, equipment and personnel with the requirements of this Contract.

6.34.6.6.2 Every nozzleman shall prepare suitability test panels. The test panels shall be produced in accordance with standard ASTM C1140 and be at least 750 mm x 750 mm by 125 mm deep. The test panels shall be made of plywood or sealed steel and have 45 degree angle edges to allow rebound materials to be released.

6.34.6.6.3 Half the test panels shall contain reinforcing steel and anchors that are representative of the sizes and spacings required for the work. The other half of the panels shall not contain any reinforcement (other than reinforcing fibres) so that shotcrete samples may be extracted for the suitability tests.

6.34.6.6.4 The Contractor shall have a test panel prepared for every nozzleman proposed for this Contract and for each mix used, according to each spray direction anticipated.

6.34.6.6.5 For shotcrete applied by dry-mix process, the Engineer establishes the concrete consistency value with a needle penetrometer to which the Contractor shall add a nozzle designed specifically for shotcrete. The value obtained as a result of the suitability test will be used as reference for acceptance of the work.

6.34.6.6.6 At each testing age, the Owner's Laboratory will extract three (3) samples of the unreinforced shotcrete in order to check the performance parameters indicated on the plans, with the exception of the measurement of chloride ion penetration, ASTM C1202 test, for which two (2) samples will suffice.

6.34.6.6.7 The Owner's Laboratory will extract three (3) 100 mm diameter core samples at the locations where reinforcing steel bars and mesh intersect and another one at the location of an anchor to check whether the shotcrete is sufficiently consolidated around the reinforcing steel.

6.34.6.6.8 The Engineer will assess the quality of the core samples and test panels. When a test panel is rejected, the nozzleman will be allowed to prepare another one. If the second test panel is also rejected, the nozzleman will not be permitted to perform work under this Contract unless otherwise agreed or indicated by the Engineer.

6.34.6.6.9 The suitability test panels shall be wet cured on site with polyethylene films at a temperature ranging between 15°C and 30°C for a minimum period of twenty-four (24) hours and shall not be moved.

6.34.6.6.10 If the suitability test samples fail to meet the performance indicated on the plans, the Contractor shall make the necessary adjustments and prepare new test panels. Shotcrete work may not begin until the performance requirements are met.

6.34.6.7 PERSONNEL QUALIFICATIONS, METHODS AND EQUIPMENT

6.34.6.7.1 At least fourteen (14) days prior to the start of shotcrete work, the Contractor shall submit to the Engineer a document demonstrating:

6.34.6.7.1.1 the qualifications and experience of the work crew. Shotcrete work shall be performed by fully qualified specialists only. To this end, the shotcrete nozzlemen shall have obtained the ACI 506.3R certification;

6.34.6.7.1.1.1 the concrete shall be sprayed by a nozzleman who is qualified in accordance with Article 15.5.2.1.2 *Certification des opérateurs de lance de projection* of CCDG. Before the beginning of the work, the Contractor shall provide the Engineer, for review, with a copy of the competency card or certificate of the nozzleman who will perform the work. The nozzleman shall present his competency card or certificate at the request of the Engineer.

6.34.6.7.1.2 a list of the proposed shotcreting equipment, including the brand name, model and capacity of the shotcrete nozzle, pre-dampener and air compressor;

6.34.6.7.1.3 the curing and protection method proposed by the Contractor for the shotcrete.

6.34.6.8 PREPARATION OF EXISTING SURFACES BEFORE SHOTCRETING

6.34.6.8.1 Existing surfaces (concrete or rock)

6.34.6.8.1.1 All surfaces shall be clean, solid and free of loose or broken fragments, sawdust, ice, snow and any other foreign matter or debris and shall be sufficiently rough to ensure a complete bond with the new concrete.

6.34.6.8.1.2 In the case of hardened concrete surfaces, the laitance shall be removed and the aggregate partially exposed.

6.34.6.8.1.3 Rock surfaces may be cleaned using air blasting, water blasting, abrasive blasting or vigorous brushing.

6.34.6.8.1.4 Surfaces shall be rough, and the roughness of a treated surface shall have an amplitude of at least 5 mm.

6.34.6.8.1.5 The Contractor shall subsequently remove any excess water from the surfaces using air blasting alone.

6.34.6.8.1.6 The Contractor shall monitor and eliminate any water that may have infiltrated as well as any accumulations that have formed in depressions, to the satisfaction of the Engineer.

6.34.6.8.2 Demolished concrete surfaces

6.34.6.8.2.1 The Contractor shall demolish any deteriorated concrete and prepare the surfaces in accordance with subsection 6.21 *Demolition and Removal*.

6.34.6.8.2.2 After having been cleaned by means of water blasting, the Contractor shall remove any excess water from the surfaces using air blasting alone.

6.34.6.8.2.3 Prior to shotcreting, the work area shall be checked for water that may have infiltrated, and any accumulations of water in depressions shall be removed to the satisfaction of the Engineer.

6.34.6.8.2.4 At least three (3) hours before the new concrete is sprayed, the Contractor shall thoroughly dampen the surfaces to be repaired so that they are in SSD condition. Any excess water shall be removed by means of air blasting fifteen (15) minutes prior to placement of the concrete so that the concrete is in SSD condition at the time of placement.

6.34.6.9 SHOTCRETE APPLICATION

6.34.6.9.1 Conditions of application

6.34.6.9.1.1 All areas prepared for repair by means of shotcreting shall be authorized by the Engineer before the shotcrete is applied.

6.34.6.9.1.1.1 The Contractor shall protect existing mechanical and electrical installations, if any.

6.34.6.9.1.2 The Contractor shall not apply shotcrete during periods of rain or strong wind that could adversely affect the shotcrete spray unless appropriate protective covers, enclosures or windbreaks are installed. Shotcrete work shall not be undertaken or pursued if the surfaces to be covered are exposed to rain or runoff.

6.34.6.9.1.3 Temperature control

6.34.6.9.1.3.1 The temperature of the concrete delivered to the site shall comply with standard CAN/CSA-A23.1 and be measured at the outlet of the mixer truck in accordance with standard ASTM C1064/C1064M.

6.34.6.9.1.3.2 The temperature of the shotcrete applied shall range between 10°C and 20°C.

6.34.6.9.1.4 If the ambient conditions (relative humidity, wind speed, air temperature and direct exposure to sunlight) are such that the shotcrete develops plastic shrinkage or shrinkage cracking during the initial set period, the Contractor shall stop the shotcrete application and postpone the work until the ambient conditions are more favorable, or take corrective measures.

6.34.6.9.1.5 Shotcreting in hot weather

6.34.6.9.1.5.1 In severely dry conditions, the formwork, reinforcing steel and shotcreting equipment shall be protected from direct sunlight or cooled by means of misting and evaporation.

6.34.6.9.1.5.2 The Contractor shall take such measures as are needed to ensure that the evaporation rate is less than 1.0 kg/m^2h, as prescribed in Appendix D of standard CAN/CSA-A23.1.

6.34.6.9.1.5.3 If the evaporation rate exceeds or is likely to exceed the limit described above, the Contractor shall take the necessary measures, including one of the following:

6.34.6.9.1.5.3.1 erect wind screens around concrete surfaces;

6.34.6.9.1.5.3.2 dampen the substrate prior to concrete placement;

6.34.6.9.1.5.3.3 place sun shades over the concrete during finishing;

6.34.6.9.1.5.3.4 lower the concrete temperature;

6.34.6.9.1.5.3.5 cover the concrete surface with a polyethylene film between finishing operations;

6.34.6.9.1.5.3.6 undertake curing immediately after trowel finishing;

6.34.6.9.1.5.3.7 place and finish the concrete at night.

6.34.6.9.1.5.4 The Contractor shall stop shotcreting if the air temperature rises above 30°C, unless the Contractor adopts special methods for shotcreting in hot weather, which shall be authorized in advance by the Engineer.

6.34.6.9.1.6 Shotcreting in cold weather

6.34.6.9.1.6.1 When the air temperature is at or below 5°C or that there is a possibility of it falling below 5°C within twenty-four (24) hours of placement (according to the forecasts from the Environment and Climate Change Canada weather station closest to the worksite), all equipment and materials needed to protect and cure the concrete shall be available and ready for use prior to the start of concreting.

6.34.6.9.1.6.2 Snow and ice shall be removed before shotcrete is placed on any surface. The Contractor shall not use calcium chloride or other salts to de-ice the formwork or substrate.

6.34.6.9.1.6.3 All surfaces with which fresh concrete comes into contact shall be heated to a minimum temperature of 10°C and maintained at that temperature for a minimum period of twelve (12) consecutive hours before shotcreting. The concrete shall not be sprayed onto a surface whose temperature would help lower the temperature of the concrete.

6.34.6.9.1.6.4 In cold weather, the Contractor shall provide appropriate protection for the concrete throughout the duration of the placement and curing process. Such protection shall be provided by means of heated shelters, tarpaulins, insulation or a combination thereof.

6.34.6.9.1.6.4.1 The shelter may be heated with live steam, forced hot air or stationary heaters.

6.34.6.9.1.6.4.2 Where heaters that produce carbon dioxide are used, the Contractor shall ensure that the gas is exhausted from the shelter. Under no circumstances shall carbon dioxide be allowed to come into contact with the concrete.

6.34.6.9.1.7 Specified time between mixing and placement

6.34.6.9.1.7.1 At no time shall the time elapsed between the manufacturing and discharge exceed one hundred and twenty (120) minutes after the initial addition of mixing water. Any derogation from this requirement shall be authorized by the Engineer before the concrete is placed.

6.34.6.9.1.7.2 If more than ninety (90) minutes have elapsed since mixing, the air content and temperature of the concrete shall be rechecked by the Contractor.

6.34.6.9.1.7.3 Shotcrete that is not placed within the prescribed time cannot be used.

6.34.6.9.2 Application

6.34.9.2.1 Prior to any placement of shotcrete, the Contractor shall ensure that the following elements comply with the plans:

6.34.6.9.2.1.1 technical data sheets of concrete mixes;

6.34.6.9.2.1.2 solidification of existing reinforcing steel and placement of the wire mesh are completed;

6.34.6.9.2.1.3 25 mm clearance under the mesh;

6.34.6.9.2.1.4 quantity of tightened wires in place;

6.34.6.9.2.1.5 coating above the mesh;

6.34.6.9.2.1.6 preparation of the surfaces to cover;

6.34.6.9.2.1.7 equipment and materials required for the placement and curing, notably that the synthetic fibre sheets that must be fixed above the vertical surfaces to be covered are in place;

6.34.6.9.2.1.8 equipment necessary for concrete finishing is in place;

6.34.6.9.2.1.9 lighting plan for evening or night work has been submitted to the Engineer for review;

6.34.6.9.2.1.10 nozzlemen present at the site are certified.

6.34.6.9.2.2 The application of shotcrete onto vertical surfaces shall begin at the bottom of the repair and from the corners.

6.34.6.9.2.3 Shotcrete work shall comply with standards ACI 506R and ACI 506.2. Wherever possible, the Contractor shall apply the shotcrete over the full thickness in a single layer. Otherwise, the Contractor shall use the minimum number of layers required to obtain the full thickness of shotcrete without slump, separation or ripple. This shall be completed within the one hundred and twenty (120) minutes period from the manufacturing of the mix. The maximum time allowed between two (2) applications is sixty (60) minutes.

6.34.6.9.2.4 Shotcrete nozzles shall be used in the proper manner and as prescribed in standard ACI 506R, notably in that:

6.34.6.9.2.4.1 the Contractor shall direct the nozzle at a right angle to and approximately 1 m away from the receiving surface, except to fill corners, finish edges and coat large-diameter reinforcing steel;

6.34.6.9.2.4.2 the combination of the air pressure in the nozzle, moisture content of the shotcrete and distance between the nozzle and the receiving surface shall be optimized in order to achieve maximum consolidation of the shotcrete;

6.34.6.9.2.4.3 care shall be taken by the Contractor, when coating the steel and reinforcing mesh, to maintain the front side of the reinforcing steel clean during shotcreting, so that the shotcrete accumulates and the reinforcing steel is coated from behind so as to prevent the formation of voids and sand pockets;

6.34.6.9.2.4.4 the Contractor shall interrupt shotcreting when the concrete at the outlet of the nozzle is not homogeneous or when the malfunction of equipment alters the mix.

6.34.6.9.2.5 Where the Contractor applies the concrete in multiple layers, the first layer shall be prepared, prior to the application of the next layer, by one of the following methods:

6.34.6.9.2.5.1 either by sweeping the previous layer with a stiff straight-bristle broom to remove any loose materials, splatters or residues of rebound materials before the concrete has reached its initial set, or;

6.34.6.9.2.5.2 if the concrete has reached its initial set, the Contractor shall wait at least twenty-four (24) hours to prepare the surface, after which the surface shall be prepared by sandblasting or high-pressure water blasting to remove any loose materials, splatters, hardened residues of rebound materials or any other materials deleterious to proper adhesion of the concrete.

6.34.6.9.2.6 Where successive layers of concrete are required to reach the full thickness of shotcrete, the Contractor shall, by means of misting or watering, prevent the first layer from drying. Curing compounds may not be used without the prior written authorization of the Engineer. If the Contractor uses a curing compound, it shall remove it by abrasive blasting or high-pressure water blasting before applying the next layer. The underlying layer shall be free of surface water and shall be in SSD condition when the next layer is applied.

6.34.6.9.2.6.1 The Contractor shall install tarps or any other waterproof system to recover shotcrete rebound materials and prevent them from polluting the environment.

6.34.6.9.2.7 Care shall be taken by the Contractor to protect adjacent surfaces from accumulations of rebound materials and splatters. The Contractor shall remove any rebound materials and splatters from the surfaces to receive the shotcrete, which is best achieved when the material is still plastic, by means of compressed air, scrapers, wire brushes or other appropriate tools. Hardened rebound materials and splatters shall be removed by means of abrasive blasting, jackhammers, high-pressure water blasting or other appropriate techniques before more shotcrete is applied.

6.34.6.9.2.8 Rebound materials and splatters cannot be used for the work and shall be removed from the worksite.

6.34.6.9.2.9 The Contractor shall apply shotcrete according to the required limits, slopes and tolerances indicated on the plans, by means of alignment wires, depth gauges, guide strips, formwork or other appropriate devices. The Contractor shall apply the shotcrete so as to provide the minimum cover required on the plans.

6.34.6.9.2.10 The Contractor shall cut all metal depth gauges to 5 mm underneath the shotcrete surface in order to prevent soiling of the surface by corrosion.

6.34.6.9.2.11 For shotcrete containing aggregate no bigger than 10 mm or fibre-reinforced shotcrete, the application of a final 5 mm to 20 mm-thick layer of shotcrete containing aggregate no bigger than 5 mm is permitted.

6.34.6.9.2.12 Shotcreting is not allowed from November 1 to March 31. Concreting may however, with the permission of the Engineer, be performed during that period provided the Contractor uses the Type 1 protection defined Article 15.4.3.8.2 *Types de protection* of the CCDG and complies at all times with the temperature ranges therein prescribed for the application of shotcrete.

6.34.6.9.2.13 The Contractor shall give the Engineer a twenty-four (24) hour written notice prior to any concrete placement. The notice shall specify the date and the time when concreting is scheduled to begin as well as the sequence of work.

6.34.6.10 SURFACE FINISH

6.34.6.10.1 Prior to proceeding with the surface finish, the Contractor shall cut the shotcrete to the prescribed limits and slopes using sharp tools or other devices. The Contractor shall allow the shotcrete to sufficiently harden before cutting and thinning in order to prevent the tears, cracks, delamination and scaling from forming. The Contractor shall remove the alignment wires once cutting and thinning are completed. The surface profile shall be checked and corrected using a 3 m rule. Any depressions deeper than 15 mm over a length of 3 m shall be corrected.

6.34.6.10.1.1 Leveling of vertical surfaces shall be carried out with of a rotary power trowel equipped with a high-density rubber disc.

6.34.6.10.2 Unless otherwise indicated on the plans, the Contractor shall provide a finishing texture comparable to that of existing surfaces, either by leaving the shotcrete in its natural finished state if the texture is adequate or by using one of the following methods:

6.34.6.10.2.1 wood float finish: either as preliminary finish for other surface treatments or as granular textured finish;

6.34.6.10.2.2 rubber float finish: in order to produce a finer granular textured finish;

6.34.6.10.2.3 fine metal brush finish: leaving a fine, sandy textured finish;

6.34.6.10.2.4 magnesium trowel finish: leaving a dense, soft and hard finish.

6.34.6.11 CLEAN-UP

6.34.6.11.1 The Contractor shall remove all debris, abrasives from abrasive blasting and removed splatters and rebound materials in accordance with subsection 6.13 *Environmental Protection*.

6.34.6.12 CONSTRUCTION JOINTS

6.34.6.12.1 Construction joints represent breaks in the work and are permitted only in the locations indicated on the plans.

6.34.6.12.2 Construction joints that are not indicated on the plans are subject to authorization by the Engineer and shall be located and designed so that the strength of the concrete and appearance of the structure are impaired as little as possible.

6.34.6.12.3 Where a construction joint must be made, the surface of the set concrete shall be suitably roughened, thoroughly cleaned of any foreign materials and laitance, saturated with water and kept in a damp condition with no excess water on the surface, until concreting resumes, all in accordance with Article 6.33.5.5.1 *Existing Surfaces* (*Concrete or Rock*) of subsection 6.33 *Cast-in-Place Concrete*.

6.34.6.12.4 When formwork is being installed, chamfer strips shall be placed along the joints so that the exposed edge has a uniform finish.

6.34.6.13 SEALING OF CONSTRUCTION JOINTS

6.34.6.13.1 Contraction joints

6.34.6.13.1.1 For contraction joints, the Contractor, in addition to the requirements of standard CAN/CSA-A23.1, shall meet the following requirements:

6.34.6.13.1.1.1 contraction joints, also called “control joints” shall be made by sawing, manual shaping or inserting pre-formed crack-inducing strips into the concrete surface;

6.34.6.13.1.1.2 the only contraction joints permitted are those indicated on the plans, if any;

6.34.6.13.1.1.3 unless otherwise indicated on the plans, joints shall be spaced according to a grid whose axes shall be no farther than 4.5 m apart;

6.34.6.13.1.1.4 shaped joints and pre-formed strips shall sink into the concrete to a minimum depth of 25 mm.

6.34.6.13.2 Joint rustication

6.34.6.13.2.1 Unless otherwise indicated on the plans, all horizontal and vertical construction joints and contraction joints shall be rusticated by means of 20 mm chamfer strips placed in the formwork.

6.34.6.13.2.2 The chamfer strips shall consist of the same material as that of the formwork.

6.34.6.13.2.3 The chamfer strips shall be placed so as to leave a neat regular groove in the concrete at all construction joints, along the exposed vertical edges of contraction joints and at all exposed edges and corners of the concrete.

6.34.6.13.2.4 All chamfer strips shall be of equal section, level and aligned correctly.

6.34.6.14 CURING OF CONCRETE

6.34.6.14.1 Curing method

6.34.6.14.1.1 As soon as finishing is complete, the Contractor shall apply a chemical curing compound to temporarily prevent the shotcrete from drying. Wet curing shall begin within sixty (60) minutes after the surface is finished and the curing compound is applied. The Engineer reserves the right to require the Contractor to slow the rate of concreting, at no additional cost to the Owner, if this requirement is not met.

6.34.6.14.1.1.1 Overhanging surfaces shall be covered with a translucent curing compound. The curing compound shall be applied, at the rate recommended by the manufacturer, so as to form a continuous, sufficiently thick film over the entire surface that is exposed to the ambient air.

6.34.6.14.1.2 When the concrete has fully set, the Contractor shall, unless otherwise indicated on the plans, keep it wet on a continuous basis for a period of seven (7) days. The Contractor shall carry out wet curing using one or more of the following methods:

6.34.6.14.1.2.1 wrap the concrete elements in wet burlap cloth covered with a waterproof polyethylene sheet to slow the drying rate of the burlap cloth and keep the wrapping continuously wet with a water system;

6.34.6.14.1.2.2 install sprinklers, watering hoses or other devices that keep the shotcrete repairs wet on a continuous basis and ensure that no damage is caused to the concrete surface. The use of intermittent moistening methods that allow the shotcrete to cycle through wet and dry periods while curing is prohibited.

6.34.6.14.1.3 Payment will not be made for concrete work performed that is not cured in accordance with the plans or as directed by the Engineer. Furthermore, the Owner reserves the right to have the shortcrete work redone at the Contractor's expense if, in the opinion of the Engineer, the quality of the work has suffered a loss of quality as a result of improper curing.

6.34.6.14.1.4 Cold-weather curing

6.34.6.14.1.4.1 Concrete shall be maintained at a temperature of at least 10°C for the minimum seven (7) days curing period.

6.34.6.14.1.4.2 Wet curing shall be completed twelve (12) hours before the end of the protection period.

6.34.6.14.1.4.3 This minimum period of concrete protection shall be extended as long as the concrete has not reached 70 % of the required strength at twenty-eight (28) days or according to the strength indicated on the plans.

6.34.6.14.1.4.4 The capacity and number of heaters shall be sufficient to maintain the concrete at the required temperature.

6.34.6.14.1.4.5 Where heaters that produce carbon dioxide are used, the Contractor shall ensure that the gas is exhausted from the shelter. Under no circumstances shall carbon dioxide be allowed to come into contact with the concrete.

6.34.6.14.1.4.6 Following the protection period, the temperature of the concrete shall be gradually lowered over the first twenty-four (24) hours. The rate of decrease shall not exceed 10°C/h. The concrete shall not be exposed to outdoor air if the difference between the temperature of the concrete surface and that of the outdoor air is more than 20°C.

6.34.6.14.1.4.7 Throughout the duration of the protection period, the Contractor shall supply and install a sufficient number of thermometers that record the low and high temperatures to check the temperature of the concrete in place and a thermometer to check the temperature of the outdoor air.

6.34.6.14.1.4.8 Any concrete damaged by freezing, inadequate protection or improper curing shall be removed and replaced by the Contractor at no additional cost to the Owner.

6.34.6.15 ACCEPTANCE OF SHOTCRETE

6.34.6.15.1 The Engineer has the authority to accept or reject shotcrete work under, without however being limited to, paragraph 6.34.6.15.2. The Contractor shall permit the Engineer to have access at all times to the repaired area for verification purposes. Shotcrete that does not comply with the requirements of this Contract will be rejected on the basis of the results of the tests conducted on the test panels during shotcreting or on the basis of the shortcreting work.

6.34.6.15.2 Defects that constitute sufficient grounds for the Engineer to reject plastic shotcrete include, without however being limited to, the following:

6.34.6.15.2.1 lack in the adequate control and removal of the accumulation of splatters and rebound materials;

6.34.6.15.2.2 incomplete consolidation around reinforcing steel, mesh and anchors;

6.34.6.15.2.3 excess shotcrete rebound or, in the case of fibre-reinforced shotcrete, excess fibre rebound;

6.34.6.15.2.4 incorporation of sand pockets, excessive voids, delamination, slumps and ripples;

6.34.6.15.2.5 failure in the application of shotcrete within the required limits, slopes and tolerances;

6.34.6.15.2.6 variance between the consistency measured during the suitability test for the shotcrete applied by dry-mix process and the consistency measured during application.

6.34.6.15.3 Repair of defects

6.34.6.15.3.1 Concrete that is deemed to be defective by the Engineer while it is still plastic shall be removed by means of picks, scrapers or other appropriate mechanical devices. The Contractor may use high-pressure water blasting provided that the removal and means used by the Contractor to manage the removal of the shotcrete and sludge are acceptable to the Engineer.

6.34.6.15.3.2 Once curing is complete, the Contractor and the Engineer shall verify the adhesion of the new concrete using a geological hammer.

6.34.6.15.3.3 Hardened concrete that is deemed to be defective shall be removed and redone at no cost to the Owner. During these operations, the Contractor shall be careful not to damage the reinforcing steel, wire mesh or anchors. The Contractor shall replace, at no cost to the Owner, any embedded element damaged in the course of the shotcrete removal operations.

6.34.7 APPLICABLE PENALTIES

6.34.7.1 In the event that the actual strength of the concrete at twenty-eight (28) days is less than the strength prescribed in the table below, the concrete will be deemed non-compliant, and the following penalties shall be applicable:

Prescribed Strength 35 Mpa	
Strength at 28 days (MPa)	**Penalty (%) [(1)]**
34.0 to 34.9	2%
33.0 to 33.9	4%
32.0 to 32.9	6%
31.0 to 31.9	8%
30.0 to 30.9	10%
29.0 to 29.9	25%
28.0 to 28.9	40%
27.0 to 27.9	55%
26.0 to 26.9	70%
25.0 to 25.9	85%
< 25.0	See Article 6.34.6.2

(1): % of the unit price tendered under the relevant pay item of the Price Table for defects quantities.

6.34.7.2 If the strength of the concrete at twenty-eight (28) days is less than the lower limit indicated in the table contained in paragraph 6.34.7.1, the Owner reserves the right to have the non-compliant work resumed at the Contractor's expense.

6.34.7.3 No penalty is applicable where the strength is greater than that prescribed. However, the Owner reserves the right to request that the Contractor, at its expense, change its mix or modify its quality control measures, notably with regard to the proportioning of cement and water content of the aggregate, if the strengths are 20 % greater than those indicated on the plans and that these strength values are, in the opinion of the Engineer, detrimental to the quality of the work, particularly in terms of excessive cracking.

END OF SUBSECTION