

SECTION 7 - CAST IN PLACE CONCRETE

1.0 DESCRIPTION

This section details the requirements for materials and methods in the proportioning, mixing, transport, placement, finishing, curing, and inspection of cast in place Portland Cement Concrete (PCC).

2.0 REFERENCES

All reference standards shall be current issue or latest revision at the first date of tender advertisement. This specification refers to the following standards, specifications, or publications:

- ANSI/ACI 117, Tolerances for Concrete Construction and Materials
- ASTM C114, Chemical Analysis of Hydraulic Cement
- ASTM C260, Air-Entraining Admixtures for Concrete
- ASTM C309, Specification for Liquid Membrane-Forming Compounds for Curing Concrete
- ASTM C457, Air Void Parameters
- ASTM C494, Chemical Admixtures for Concrete
- ASTM C1152, Acid-Soluble Chloride in Mortar and Concrete
- ASTM C 1524, Water-Extractable Chloride in Aggregate (Soxhlet Method)
- ASTM D244, Standard Test Methods and Practices for Emulsified Asphalts (testing for relative density of curing compound)
- ASTM D1309, Settling Properties of Traffic Paints During Storage
- ASTM D1644, Non-volatile Content of Varnishes
- ASTM D1751, Preformed Expansion Joint Filler for Concrete Paving and Structural Construction
- ACI 214R-11, Guide to Evaluation of Strength Test Results of Concrete
- CGSB 37.2-M, Emulsified Asphalt Mineral Colloid Type Unfilled for Damp-Proofing, Water-Proofing and for Roof Coatings
- CGSB 37.3-M, Application of Emulsified Asphalts for Damp-Proofing or Water-Proofing
- CSA A3000-18, Cementitious Materials Compendium
- CSA A23.1:19, Concrete Materials and Methods of Concrete Construction
- CSA A23.2:19, Methods of Test and Standard Practices for Concrete
- CSA A283:19, Qualification Code for Concrete Testing Laboratories
- CSA S269.1, Falsework and Formwork
- NRC NBC, National Building Code of Canada 2015 – 14th Edition
- Drawing S-2009-019
- Drawing S-2009-021
- Drawing S-2009-051
- Drawing S-2009-022

3.0 SUBMISSIONS AND DESIGN REQUIREMENTS

3.1 Formwork and Falsework. One copy of drawings and design calculations for Formwork and related Work bearing a Professional Engineer's seal shall be submitted by the Contractor to the Engineer for review at least four (4) weeks before construction. The Professional Engineer sealing the work shall be registered and in good standing in the province of Nova Scotia. The submission is intended for information purposes only and shall in no way relieve the Contractor of full responsibility to carry out work related in accordance with CSA S269.1 for Falsework and Formwork.

3.2 Notification of Concrete Supplier. At least two weeks in advance, the Contractor shall advise the Engineer of the qualified Concrete Supplier which they propose to use. The Engineer will verify the acceptability of the Concrete Supplier and the mixture designs. Acceptance of the Concrete Supplier and the mixture designs by the Engineer does not relieve or reduce the responsibility of the Contractor or Supplier from the requirements of the specification.

In the event that the Contractor selects a Concrete Supplier not qualified in advance by the Department, the Contractor shall, no later than four (4) weeks prior to starting concrete work, submit to the Engineer all of the required information detailed in Section 3.3 of this specification. The Engineer will verify the acceptability of the Concrete Supplier and the mixture designs.

3.3 Advance Qualification of Concrete Suppliers. The Contractor shall recognize that the Department of Public Works (the Department) may qualify in advance, as detailed below, Concrete Suppliers, however, the Department bears no responsibility for said advance qualification. Liability for the product supplied shall be the sole responsibility of the Contractor.

Concrete Suppliers may get qualified in advance to supply concrete to Department projects. Advanced qualification may be obtained by submitting required test information as identified in Section 3.3.1 and concrete mixture designs, typically specified for Cast in Place Concrete, to the Department for review prior to the first day of March. The Department will review the provided test information and mix designs in March and will prepare a list of qualified Concrete Suppliers by the last day of March. Concrete Suppliers who submit the required test information and acceptable mix designs before the first day of March become qualified on the first day of April and shall remain qualified to the thirty first day of March of the following year. The list of qualified Concrete Suppliers will not be updated throughout the year. Concrete Suppliers that are not qualified in advance will have to submit required test information and mix designs for each contract.

Mix designs submitted to the Department shall contain a unique mix design code which is to be constructed from the following criteria:

- two digits displaying the specified compressive strength of the concrete, followed by,
- two or three digits displaying the class of the concrete. For example, class C-2 would be noted as C2, and C-XL would be CXL, followed by,
- two digits indicating the submission number for that contract. For example, 01 would be the first mix design submission, 02 would be the second mix design submission, etc. Followed by,
- one digit indicating the plant source. A legend identifying which plant locations correspond to what number shall be documented on the mix design submission.

3.3.1 Required Test Information. The Concrete Supplier shall provide relevant test data for all materials indicating conformance to the requirements of CSA-A23.2-24C and this specification. The sources and test results of all materials shall be clearly identified. The aggregate tests shall be conducted by a testing laboratory certified by the Canadian Council of Independent Laboratories (CCIL) for concrete aggregate tests in accordance with CSA A283, under the direction of a Professional Engineer registered to practice in Nova Scotia and meeting the requirements of CSA A23.1:19 Clause 4.4.1.6.

Test data reports required shall include, but not be limited to:

- Cementitious materials report in accordance with CSA A3004-A1.
- Water quality test in accordance with CSA A23.1:19 Clause 4.2.2 or declaration of potability.
- Admixture product data with certification by the manufacturer that the requirements of CSA A23.1:19 Clause 4.2.4 will be met.
- Aggregate report in accordance with CSA A23.2:19-30A. Sampling, testing, and acceptance of aggregates used in concrete shall be conducted in accordance with CSA A23.2:19-30A.
- Documentation demonstrating that the concrete complies with the requirements of this standard.

Aggregate testing shall be in accordance with CSA A23.2:19-30A as follows:

- CSA A23.2:19-2A - Sieve Analysis⁽¹⁾ of Fine and Coarse aggregate (including Fineness Modulus⁽¹⁾ of Fine Aggregate)
- CSA A23.2:19-5A - Amount of Material Finer⁽¹⁾ Than 80 µm in Aggregate
- CSA A23.2:19-6A/12A - Bulk Relative Density and Absorption of Fine and Coarse Aggregate (SSD basis)
- CSA A23.2:19-3A/4A - Clay Lumps and Low Density Materials in Aggregate
- CSA A23.2:19-7A - Test for Organic Impurities in Fine Aggregate
- CSA A23.2:19-13A - Flat and Elongated Particles in Coarse Aggregates
- CSA A23.2:19-15A - Petrographic Analysis of Coarse Aggregate (A23.2:19 Clause 6.3)
- CSA A23.2:19-16A/17A - Resistance to Degradation of Coarse Aggregate by Abrasion and Impact in the Los Angeles machine
- CSA A23.2:19-29A/23A - Micro-Deval test for Coarse and Fine Aggregate
- CSA A23.2:19-9A - Soundness of Coarse & Fine Aggregate by Use of Magnesium Sulphate
- CSA A23.2-14A:19 - Test for Potential Expansivity of Aggregates (Procedure for Length Change due to Alkali-

Aggregate Reaction in concrete Prisms at 38 Degrees Celsius)

- CSA A23.2-25A:19 - Test Method for Detection of Alkali-Silica Reactive Aggregate by Accelerated Expansion of Mortar Bars⁽²⁾
- CSA A23.2-27A:19 - Standard Practice to Identify Degree of Alkali-Reactivity of Aggregates and to Identify Measures to Avoid Deleterious Expansion in Concrete.
- CSA A23.2-28A:19 - Demonstrate the Effectiveness of Supplementary Cementitious Materials and Lithium-based Admixtures to Prevent Alkali-Silica Reaction in Concrete.
- CSA A23.2-24A:19 - Unconfined Freeze Thaw test.

⁽¹⁾ Prior to the first concrete placement for each contract, a washed sieve analysis shall be conducted on each proposed stockpiled aggregate at the plant, representative of the materials to be used in the work and the results submitted to the Engineer by the Contractor.

⁽²⁾ CSA A23.2-25A:19 may only be necessary as described in the sections below.

All submitted test results shall be from tests completed within one (1) calendar year of submission to the Department, apart from those modified below.

When tested in accordance with CSA A23.2-14A:19, the expansion of test samples incorporating the aggregate source shall not exceed 0.04 percent at one year. In the absence of current test data developed using the test method of CSA A23.2-14A:19, test samples incorporating aggregate sources having a satisfactory history of conformance and exhibiting expansions not exceeding 0.150 percent when tested in accordance with CSA A23.2-25A:19 shall be deemed acceptable. If the aggregate does not meet this requirement, preventative measures shall be identified in accordance with procedures illustrated in CSA A23.2-27A:19. The supplier shall provide evidence to the Department demonstrating the effectiveness of the preventative measures selected in accordance with CSA A23.2-28A:19.

A satisfactory history of non-reactive AAR conformance shall consist of at least five (5) consecutive passing tests performed in accordance with CSA A23.2-14A:19 over a period not to exceed ten (10) years and not less than five (5) years. Failure to invalidate CSA A23.2-25A:19 test results which indicate reactive aggregates through concurrent CSA A23.2-14A:19 testing initiated at the same time as the CSA A23.2-25A:19 testing will establish an unsatisfactory history of conformance for the aggregate source.

Where supplementary cementing materials are used to mitigate deleterious expansions due to AAR in mix designs incorporating reactive aggregate, results of tests in accordance with CSA A23.2-14A:19 following CSA Standard Practice A23.2-28A:19 shall not exceed 0.04 percent at two years. In the absence of current CSA A23.2-28A:19 test data developed in accordance with CSA A23.2-14A:19, the expansion of the test samples incorporating the supplementary materials and reactive aggregate source(s) tested in accordance with CSA A23.2-25A:19 shall not exceed 0.100 percent at 14 days. As per Clause 7.1 of CSA A23.2-28A:19, if CSA A23.2-25A:19 is used, then CSA A23.2-14A:19 testing shall be started at the same time to validate the results of CSA A23.2-25A:19. If the results of CSA A23.2-14A:19 and CSA A23.2-25A:19 contradict each other, the result from CSA A23.2-14A:19 shall govern as per CSA A23.2-28A:19 Clause 9. Testing in accordance with CSA A23.2-25A:19 is not applicable for material intended for use in controlling alkali-aggregate reaction that does not meet the requirements of CSA A3001, when evaluating the effectiveness of fly ash with total alkalis greater than 4.5%, or for a lithium-based mixture. In these cases, CSA A23.2-14A:19 shall be used.

In the case where a new aggregate source is used and a satisfactory history of compliance is not provided, the aggregate is assumed to be extremely reactive as defined in CSA A23.2-27A:19. The supplier must adhere to the preventative measures outlined in CSA A23.2-27A:19 for extremely reactive aggregate and shall provide evidence of the effectiveness of the preventative measures selected in accordance with CSA A23.2-28A:19.

In accordance with CSA A23.2-24C:19 Clause 8.2.1, except where modified below, documentation demonstrating that the concrete complies with the requirements of this standard, project specifications, and the specified exposure class shall consist of, but not be limited to:

- Compressive strength of concrete. Specimens used for the basis of acceptance of concrete shall be made and cured in accordance with CSA A23.2-3C:19 and standard tests shall be carried out in accordance with CSA A23.2-9C:19.
- Slump tests in accordance with CSA A23.2-5C:19 or slump flow tests in accordance with CSA A23.2-19C:19.
- Plastic air content in accordance with CSA A23.2-4C:19 or A23.2-7C. Where low-density aggregate concrete is used, air content determinations shall be made in accordance with CSA A23.2-7C:19, except that CSA

- A23.2-4C:19 may be used if comparative conditions are established and are frequently checked.
- Air void system parameters from tests performed in accordance with ASTM C457 where concrete is subject to the exposures requiring Category 1 air entrainment as described in Tables 1 and 2 of CSA A23.1:19. Testing shall be carried out in accordance with ASTM C457, using a magnification between 100 and 125.
 - Chloride ion penetrability for steel reinforced or pre-stressed concrete or as described in CSA A23.1:19 Table 1, or as specified. Test specimens shall be moulded in accordance with CSA A23.2-3C:19 and tested in accordance with CSA A23.2-23C:19.
 - Density of plastic concrete measured in accordance with CSA A23.2-6C:19 if specified when a non-standard density of concrete is specified. When tests are performed on low-density and semi-low-density concrete, the air-dry density shall be measured in accordance with CSA A23.2-11C:19.
 - Flexural strength of concrete measured in accordance with CSA A23.2-8C:19, where limits are specified in the contract documents.
 - Chloride ion content in accordance with CSA A23.1:19 Clause 4.1.1.2. The acid-soluble chloride content of hardened concrete shall be determined in accordance with ASTM C1152 on the proposed mix, prior to commencement of work. The water-soluble chloride ion content of hardened concrete shall be determined in accordance with CSA A23.2-4B:19 on the proposed mix, prior to the commencement of work. Tests shall be carried out at a minimum concrete age of 28 days. When measurement of the water-soluble chloride ion content is made on separate constituents, the following test methods shall be used:
 - Cementitious materials: ASTM C114
 - Coarse Aggregate: ASTM C1524
 - Fine Aggregate: ASTM C1524
 - Chemical admixtures: as stated in ASTM C494/494M, the manufacturer shall state in writing the chloride content of each admixture and whether chloride has been added during its manufacturing.

If test data within one (1) calendar year of submission is not available for the proposed mix design (for example, a mix design that has not been used before or contains new material), a trial batch of this concrete shall be performed to obtain test data so a qualification assessment can be made. The trial batch shall be completed by producing concrete at a Ready-Mix plant with a minimum batch size of 3 m³ to cast the necessary specimens to test to the above required standards. The test results shall be submitted to the Department upon completion as part of the qualification evaluation and must be completed by a CCIL certified laboratory in accordance with CSA A283. Additionally, proof of concrete control must be displayed during the trial. To do this, a minimum of 10 compressive strength tests must be conducted to provide sufficient data to evaluate the variation of the concrete. Each compressive strength test shall be the average of two, three, or four compressive strength specimens, all of which shall be cast on the same batch of concrete. The variation shall be calculated as described in Section 4.3.1 of ACI 214R-11. As per the requirements of ACI 214R-11 Tables 4.3 and 4.4, the within-batch variation shall be less than 4.0 to be considered "good".

3.3.2 Certification and Membership. The Concrete Supplier shall provide current plant certification and membership certificates issued by the Atlantic Concrete Association (ACA) to comply with CSA A23.1:19 Clause 5.2.1.

Concrete Suppliers shall accommodate randomized inspections during any period that concrete is being produced for the Department. Randomized inspections will be coordinated through the Contractor. The Engineer will advise the Contractor a minimum of 48 hours in advance of any planned inspection. Documentation verifying the calibration of all scales used in production and documentation of moisture content checks on aggregate may be requested. Raw materials (aggregate, cement, SCM, etc.) may be sampled during the inspection. Any non-conformances identified during an inspection will be provided in writing to the Contractor from the Engineer no more than 24 hours after the end of an inspection. Contractors are required to respond in writing to the Engineer no more than 24 hours after being notified of a non-conformance. The written response from the Contractor will identify immediate actions taken to eliminate the non-conformance and actions taken to make sure the non-conformance does not reoccur in the future.

3.4 Use of Proprietary Products. In the event a proprietary product is selected as the repair material, the product shall be reviewed and accepted by the Department in advance.

Submissions shall be made to the Department prior to the first day of March. The Department will review the submission in March and will respond to the submitter indicating acceptance or rejection of the products proposed by March 31. Proprietary products approved in March shall remain approved to the thirty first day of March of the following year. Proprietary products not approved in March will need to be approved for each contract.

Products will be reviewed for the following application types: vertical, horizontal, and overhead. The submitter shall indicate the intended application for each product submitted. A maximum of four (4) products can be submitted for each of the above applications. The submission shall be in the form of a letter stamped by a professional engineer licensed to practice in Nova Scotia. The letter shall include:

- Submission date,
- Verification of application types for each product proposed, and of specialized or unique applications,
- Manufacturer's technical data sheet and material safety data sheet (MSDS) for each proposed product as an appendix; verification of temperature range for application and curing period, list of at least three (3) different projects where the proposed product, with current formulation, has been successfully used in similar applications within the last 5 years in a similar environment, complete with contact names, and telephone numbers.

Technical data sheets shall include technical attributes for the intended application such as, but not limited to, plastic properties to suit placing conditions, shrinkage characteristics, compressive strength, and freeze thaw durability.

On each project, prior to the use of a propriety product, the contractor shall submit to the Project Engineer a current copy of the Department's acceptance letter for the proposed products and application. The submittal to the Project Engineer shall be accompanied by a current technical data sheet and MSDS for each product intended for use on the project. Application to the Engineer shall be made a minimum of five (5) days prior to the use of the product. The Engineer will review and verify the submission prior to the product use.

In the event a contractor proposes a product that has not been accepted, the contractor shall submit the proposed product in the manner described above to the Project Engineer at least four (4) weeks prior to the scheduled use on a project. Proprietary products not reviewed and accepted shall not be used on the Department's projects.

Acceptance for the use of a propriety product shall not relieve the Contractor of any performance or warranty responsibilities for the performance of the product. the Department is not obligated to accept any or all proposed products. In the opinion of the Department, demonstrated unsatisfactory performance of a product could result in removal of the product from the acceptance process.

4.0 MATERIALS

4.1 General. All materials used in the production of concrete shall conform to the referenced standards.

4.1.1. Aggregates. The fine and coarse aggregates shall be normal density and conform to the requirements of CSA A23.1:19 Clause 4.2.3, except as modified herein. Upon acceptance of the aggregates, the source and method of manufacture shall not be altered for the duration of the contract. Aggregates shall be stored and maintained in such a manner to avoid the inclusion of foreign materials in the concrete and such that no equipment will be operated on the storage piles. The stockpiles shall be constructed to prevent segregation or contamination. The ready-mix concrete supplier shall have sufficient quantity of aggregates to complete the entire concrete section scheduled for that day at the place of production prior to the start of any concrete placement.

Fine aggregate shall be washed and classified to conform to the gradation limits specified in Table 10 CSA Standard A23.1, and not more than 45% of the fine aggregate shall pass any sieve and be retained in the next consecutive sieve. As per CSA A23.1:19 Clause 4.2.3.3.2.1, individual sands that are combined to meet the requirements of CSA A23.1:19 Table 10 do not need to individually meet the requirements of CSA A23.1:19 Table 10 provided that the final blend meets the requirements.

Coarse aggregates shall consist of washed crushed stone meeting the grading limits specified in CSA A23.1:19 Table 11 with respect to the specified maximum nominal size aggregate. The maximum combination of flat, elongated, and flat and elongated particles, as defined in CSA A23.2-13A:19, shall not exceed 20% of the mass as per CSA A23.1:19 Table 12. The maximum Petrographic Number of coarse aggregate shall not exceed 125 for class C-1, C-2, F-1, C-XL, A-XL, A-1, and A-2 concrete. The maximum Petrographic Number shall not exceed 140 for all other classes of concrete. The maximum absorption of coarse aggregate shall not exceed 2%.

4.1.2 Water/Admixtures. Water used in concrete production and curing shall conform to CSA A23.1:19 Clause 4.2.2 and be clean and free from injurious amounts of oil, acid, alkali soluble chlorides, organic matter, sediment, or any deleterious substances.

As per CSA A23.1:19 Clause 4.2.4, air entraining admixtures shall meet the requirements of ASTM C260. Other chemical admixtures shall meet the requirements of ASTM C494. Admixtures shall be stored above freezing temperatures at all times and in accordance with the manufacturer's recommendations. Calcium chloride or any admixtures containing chlorides shall not be used.

4.1.3 Cementing Materials. Portland cement, Portland limestone cement, blended cements and supplementary cementing materials shall meet the respective requirements of CSA Standard A3000 and shall be specified by one or more of the types described in CSA A23.1:19 Tables 6 to 8.

4.1.4 Self-Consolidating Concrete. Materials used in SCC shall comply with CSA A23.1:19 Clause 8.6.2.

4.2 Formwork. Formwork shall meet the requirements of CSA A23.1:19 Clause 6.5 and this specification. Formwork shall be constructed from lumber devoid of warp and defects in order to achieve a face alignment free from distortion. This shall apply to all panel forms including prefabricated boards, plywood, and steel panels. Prior to assembly and placement of reinforcing steel, all forms and panels shall be treated with a non-staining, non-reactive mineral oil or liquid, as approved by the Engineer. Patching and/or parging shall be prohibited until approved by the Engineer.

Formwork shall be supported by shores to sustain all horizontal and vertical loads during placing of the PCC. Column forms shall be seamless heavy gauge galvanized steel and/or fibre column molds.

4.3.1 Proportioning. Concrete mixtures shall be proportioned in accordance with CSA A23.1:19, Alternative #1 and the Contractor shall accept responsibility for concrete properties and performance. The physical properties for various structural elements are identified in Table 5.7.1 of this specification.

Self-Consolidating Concrete (SCC) workability requirements have been identified in Table 5.7.2 of this specification. SCC shall meet the requirements of CSA A23.1:19 Section 8.6.4 as well as requirements within this specification and project requirements.

4.3.2 Mix Proportions. The Concrete Supplier shall select mix proportions that shall produce concrete of specified quality, yield, and strength complying with Alternative #1 CSA-A23.1:19, Table 5.7.1 and 5.7.2 of this specification. Typical mixture designs include, but are not limited to:

- 25 MPa, Exposure Class F-2 or F-4⁽¹⁾
- 30 MPa, Exposure Class F-1 or C-3
- 32 MPa, Exposure Class C-2
- 35 MPa, Exposure Class C-1
- 50 MPa, Exposure Class C-XL

⁽¹⁾ Not outlined in Table 5.7.1. Standards for this mix type will be on a project level basis.

A report outlining the proposed mixture designs shall be signed by a Professional Engineer registered to practice in Nova Scotia. The Professional Engineer shall attest to the validity of the material test data stated in Section 3.3. Mix designs incorporating alkali reactive aggregate shall be adjusted to limit excessive expansions as identified in CSA A23.2-27A:19.

4.3.3 Changes to Mixture Designs or Material Properties. If material sources and characteristics change after the Concrete Supplier becomes qualified, the Contractor shall provide physical properties and certified test results as indicated in Section 3.3 of this specification. In the event mixture designs are modified without changing material characteristics, the revised mixture designs shall be submitted to the Engineer. Changes shall include, but not be limited to the following:

- Changing sources of materials used in concrete production.
- Substituting concrete materials that are from the same source.
- Adding any material to the concrete that was not included in the original mix design, with the exception of retarder.
- Adjusting the quantities of the materials in the concrete as stated on the mix design outside of the following tolerances:
 - Coarse and fine aggregate: +/- 5% of the specified quantity.
 - Supplementary cementing materials: 95% to 100% of the specified quantity.
 - Admixtures: dosage or range of dosage specified (not to exceed manufacturer's recommended

- limits).
- Water: specified range.

4.3.4 Concrete Mix Specifications. The mix design specifications can be found in Table 5.7.1 and 5.7.2 of this specification showing typical mixtures and maximum nominal aggregate sizes. Maximum nominal aggregate sizes not shown may be used with corresponding parameters as per CSA A23.1:19 except minimum compressive strength as specified in Tables 5.7.1 and 5.7.2 for a given element and class of exposure.

4.4 Curing Compounds. Liquid membrane curing compound shall be white pigmented Type 2 Class B, meeting the requirements of ASTM C309.

Curing compound shall also be tested for non-volatile content in accordance with ASTM D1644 Method A, relative density in accordance with ASTM D244, and rate of settlement in accordance with ASTM D1309. The non-volatile content shall be within +/- 2.5% of the approved curing compound's manufactured specification, and the relative density shall be within +/- 0.01 of the approved curing compound's manufactured specification, and the rate of settlement shall not be less than 145 ml at two (2) hours and not less than 125 ml at twenty-four (24) hours.

4.5 Damp-Proofing. All damp-proofing material shall conform to Division B, Section 9.13.2. of the National Building Code of Canada 2015.

4.6 Concrete Sealer. Concrete sealer shall be Type 1C silane penetrating transparent sealer and approved by the Department. The Contractor shall supply proof of acceptance to the Department prior to use.

Table 5.7.1 - Concrete Mixture Design Specifications

Element	Leveling Slab		Tremie and Concrete Under Water	General	Roadway Curbs & Sidewalks, Jersey Barrier, Driveway Entrances, Abutment, Wingwall, Slope Protection, Culvert, Road Drain, Sign Base	Bridges ⁽⁶⁾	
	40 ⁽¹⁾	20 ⁽¹⁾				20 ⁽¹⁾	10 ⁽¹⁾
Maximum Nominal Aggregate, mm	40 ⁽¹⁾	20 ⁽¹⁾	20	20	20	20 ⁽¹⁾	10 ⁽¹⁾
Exposure Class	F-1		C-3	C-4	C-2	C-1	
Minimum 28 Day Compressive Strength, MPa	30		30	25	32	35	
Maximum Water to cementing Material Ratio ⁽²⁾	In accordance with CSA A23.1:19 Table 2						
Air Content, %	5.5 ± 1.5	6.5 ± 1.5	6.5 ± 1.5 ⁽⁷⁾	N/A	6.5 ± 1.5	6.5 ± 1.5	7.5 ± 1.5
Slump, mm ⁽⁴⁾	Targets to be set meeting the requirements of CSA A23.1:19 Clause 4.3.2.3.2						
Maximum Chloride Ion Penetrability, coulombs	N/A		N/A	N/A	N/A	1,500 within 91 days	
Air Void Parameters of Hardened Concrete ⁽⁶⁾	CSA A23.1:19 Clause 4.3.3.3		CSA A23.1:19 Clause 4.3.3.3	N/A	CSA A23.1:19 Clause 4.3.3.3	CSA A23.1:19 Clause 4.3.3.3	
Required Admixtures ⁽³⁾	Water Reducer, Air Entrainment						

⁽¹⁾ Either aggregate size may be utilized unless otherwise specified.

⁽²⁾ Portland Cement shall be Type GU, GUb, GUL, GULb unless otherwise specified. The limits outlined are per the requirements of CSA A23.1:19 Table 2.

⁽³⁾ Other admixtures such as Retarders, Non-Chloride Accelerators, or Superplasticizers may be used, at manufacturer's recommended dosage rates. Notification shall be provided to the Engineer prior to placement.

⁽⁴⁾ The contractor shall set slump targets appropriate to the scope of the work, while meeting the tolerances outlined in CSA A23.1:19 Clause 4.3.2.3.2.

⁽⁵⁾ For High Performance Concrete (HPC) structures, refer to Division 5, Section 18

⁽⁶⁾ Any mix design containing air shall be subject to testing to determine the air void parameters of the hardened concrete, the frequency at which is defined within this specification.

⁽⁷⁾ Air entrainment is only required if the concrete will be exposed to freeze-thaw conditions.

Table 5.7.2 - Concrete Mixture Design Specifications (SCC)⁽¹⁾

Workability Property	Method	Minimum	Maximum	Governing Property
Slump Flow ⁽²⁾	CSA A23.2-19C:19	500mm	800mm	Filling Ability
T-50 cm Time		2 seconds	7 seconds	Segregation Resistance
VSI Value		0	1	Segregation Resistance
J-ring	CSA A23.2-20C:19	-	Difference between slump flow and J-ring slump flow ≤ 25mm	Filling Ability and Passing Ability

⁽¹⁾ Table is in accordance with CSA A23.1:19 Table 22. Additional requirements or modifications will be listed in contract specifications.

⁽²⁾ Target value of slump flow plus the specified tolerance of +/- 70mm shall be between 500mm and 800mm.

5.0 PRODUCTION AND DELIVERY

5.1 Concrete Production. Concrete shall be produced at a stationary or portable plant. Concrete shall not be supplied to any Department project unless the Ready-Mixed Concrete Supplier is qualified by the Department and so designated.

5.1.1 Mixing and Transporting. The concrete materials shall be mixed and transported in a manner which will not segregate or damage the mix in any fashion. Concrete shall be mixed utilizing stationary or truck mixers. The mixer shall carry the manufacturer's rating plate in a prominent position, indicating:

- The gross volume of the mixer.
- The rated maximum mixing capacity.
- The minimum and maximum speeds for mixing and agitating of the mixer.

All mixers shall be capable of combining the concrete ingredients into a thoroughly mixed and uniform mass. In no case shall the mixer loading exceed its rated maximum mixing capacity.

The mixer shall be rotated at the Manufacturer's recommended mixing speed during charging and mixing. Ready-mix trucks are to also discharge all contents prior to recharging.

Where ready mix trucks are used to transport the concrete, the Department reserves the right to request the Contractor to subject any truck suspected of poor mixing to a uniformity test as outlined in CSA A23.1:19 Clause 5.2.4.5. If said truck fails the uniformity test, then the concrete and the truck shall be rejected. The truck shall not be permitted on the Department site until appropriate repairs have been completed and certified.

Prior to unloading each truck on site, the supplier shall provide the Department, or Department's representative with the batch delivery ticket. The ticket shall contain all the information required in CSA A23.1:19 Clause 5.2.5.5.1 as well as outline the quantities of the materials batched and the mix identification code outlined in Section 3.3 of this specification.

The contract number for the project must be included in the delivery address field.

6.0 CONSTRUCTION METHODS

6.1 Formwork Design. Formwork design and the proposed method of construction shall meet all necessary requirements in terms of strength and properties of material, rigidity and erection tolerances as presented in Section 6.1 of this specification. Formwork shall also be compliant with the requirements of CSA S269.1 as well as other requirements described in CSA A23.1:19 Clause 6.5 "Formwork".

Formwork shall be built with sufficient strength and rigidity to carry the mass or fluid pressure of the PCC as well as all

construction loads including wind, equipment, and runways which might be placed upon them. The fluid pressure on forms shall be correlated to the capacity and type of placing equipment, the rate of placing, slump, and temperature of the PCC.

Formwork shall be supported by stiff members in two directions at right angles which are sufficiently rigid to hold the unit as a whole in line and in proper position and shape. Formwork shall be accurately located, rigidly tied or braced to resist vertical or horizontal movements, and adequately supported. However, they shall be so arranged to allow for easy stripping to prevent damage of the PCC during removal. The use of twisted wires and wood spreaders are prohibited unless approved by the Engineer.

Formwork for Self-Consolidating Concrete (SCC) shall meet the requirements of CSA A23.1:19 Clause 6.5.3.1 and be designed to prevent paste loss. Design of the formwork shall assume that a full liquid head will be developed once placing is completed. Areas of focus include, but are not limited to, joints, holes for ties, and sill plates on foundation footings or slab surfaces.

6.1.1 Formwork/Falsework Construction. The Contractor shall construct the falsework and formwork in accordance with the approved drawings. Variations from the drawings shall not be permitted unless such variations are approved by the Designer, and the Engineer is provided with revised drawings prior to construction. Both the falsework and formwork shall be designed and constructed to provide the necessary rigidity and to support the loads without settlement or excessive deflection.

All falsework and formwork used to support fresh concrete during construction of the following components shall be designed by a Nova Scotia Registered Professional Engineer in accordance with CSA S269.1:

- Bridge decks and pier caps.
- Columns over 3 m in height.
- Retaining walls over 3 m in height.
- Roofs of structures under which persons are required to work.
- As required on the contract drawings.

6.1.2 Construction Joints. The locations and details of vertical construction joints not indicated on the drawings shall be submitted by the Contractor to the Engineer for their approval as per the requirements of CSA A23.1:19 Clause 7.3.1.2. PCC in piers and abutments shall be placed without horizontal construction joints unless previously approved by the Engineer.

6.1.3 Removal/Re-Use of Formwork and Falsework. All formwork and falsework shall be completely removed from the structure. Formwork shall be removed progressively and with care so that corners of PCC members are not damaged or marred.

The formwork and falsework shall not be removed until 60% of the design strength has been achieved. The concrete shall cure in compliance with CSA A23.1:19 Clause 7.8 and protected in compliance with CSA A23.1:19 Clause 7.6. Formwork loading shall be designed by the formwork design Engineer in accordance with CSA S269.1.

Formwork material intended for re-use shall be clean and in satisfactory condition. Formwork shall not be re-used without the Engineer's approval.

6.1.4 Formwork Tolerances. The following tolerances in Table 5.7.3 are permitted for lines, grades or dimensions shown on the contract drawings:

Table 5.7.3 - Formwork Tolerance

Variation from Contract Drawings	Tolerance
(I) For plumb or specified batter at columns, piers and walls	12 mm in 3 m for Exposed area 25 mm in 3 m for Backfilled area
(II) For level or specified grade in slabs, beams, horizontal grooves, railing offset, etc.	12 mm in 3 m for Exposed area 25 mm in 3 m for Backfilled area
(III) X-Sectional dimensions for Piers, Columns, Beams, slabs, walls, etc.	No more than 12 mm No less than 6 mm
(IV) Bridge Deck Thickness	No more than 6 mm No less than 3 mm
(V) Footing Length & Width	No more than 50 mm No less than 12 mm
(VI) Footing thickness	minus 5% of the specified thickness

6.2 Form Preparation/Concrete Placement. The Contractor shall provide the Engineer with at least 24 hours' notice of intent to place concrete in order to permit the Engineer to schedule inspection services. All PCC placing methods shall be subject to the approval of the Engineer.

In preparation for the placing of concrete, all sawdust, chips, construction debris and other deleterious materials shall be removed from the interior of forms. All surfaces against which concrete is to be placed shall be free of standing water, except tremie concrete. The temperature of the formwork, steel reinforcement, or any other material on which the concrete is to be placed shall not exceed 27°C or be less than 5°C. The PCC shall be delivered to the point of final deposit in a manner satisfactory to the Engineer using means and equipment which will prevent segregation or loss of materials. The size of section to be placed in one continuous operation shall be as detailed on the drawings. PCC for deck slabs shall not be placed between November 15 and April 15 (unless otherwise specified), without the written approval of the Engineer.

Unless otherwise authorized by the Engineer, forms shall be moist prior to placement of the PCC. The Contractor shall be held responsible for the placing method used. PCC shall be deposited in the forms in maximum lifts of 500 mm and in layers that are approximately horizontal and as close as practicable to its final position. PCC shall not be moved horizontally with vibrators or by other methods which could cause segregation.

The conveying equipment shall be kept free from deleterious materials and cleaned at frequent intervals. Conveying equipment, if supported by formwork, shall not impart harmful vibration to PCC nor cause misalignment of forms.

Under adverse weather conditions the Contractor shall be prepared to provide suitable protection to prevent damage to PCC as per CSA A23.1:19 Clause 7.6 with methods subject to the approval of the Engineer.

Unless otherwise authorized by the Engineer, wood spreaders shall not be used in any PCC where either face will be exposed or in any wall where water tightness is required.

If the PCC details are such that a feather edge or thin section might be created by the sequence of casting, a bulkhead should be introduced to maintain an edge thickness of at least 100 mm.

6.2.1 Placing Concrete Under Water (Tremie Method). Notwithstanding the provisions elsewhere stated in this specification, the following provisions shall apply to PCC deposited under water. PCC shall be deposited under water only when specifically authorized by the Engineer. The methods, equipment, materials, forms, and cofferdams shall be approved by the Engineer before work is started, but such approval shall not in any way relieve the Contractor of liability in connection with the work.

Tremie Concrete shall comply with the provisions of CSA A23.1:19 Clauses 7.5.5, 7.5.6, and 7.5.7. The placing of PCC under water shall be carried on continuously until that portion of the structure is completed.

At the start of the concreting operation, the tremie pipe shall be sealed at the bottom with a plug or foot valve to prevent ingress of water.

All laitance, slime or other matter deposited or formed on the surface of any PCC under water shall be removed before any additional PCC is placed on same.

6.2.2 Placing and Finishing Bridge Deck Concrete. The finished surface of the deck concrete shall conform to grades and elevations shown on the contract drawings. Prior to placing deck concrete, the Contractor shall submit to the Engineer detailed information on the method and equipment proposed for handling, placing, and finishing of the concrete. The Contractor shall also demonstrate to the satisfaction of the Engineer that all necessary adjustments have been made to provide the required camber, crown, slab thickness and concrete cover over reinforcement, prior to placement.

The surface shall be finished with a mechanical screed machine, which shall be supported by guide rails and span the full width of the deck. Guide rails shall be located outside the finished surface of the deck. Supports for the guide rails shall be capable of fine adjustment and not be fixed to, or located upon, the reinforcing steel. The quantity of supports shall be such that the screed rails do not deflect more than 1 mm during the screeding operation.

Immediately prior to placement of deck concrete, the formwork shall be cleaned and thoroughly moistened. The Contractor shall also moisten the reinforcing steel with water at the request of the Engineer. All surfaces shall be free of standing water. Deck concrete shall be placed continuously between transverse joints until completion of the section. The placing sequence for continuous structures shall conform with the contract drawings.

The concrete surface shall be floated with a resin, aluminum, or magnesium float. Wood floats shall not be used.

The concrete shall be textured by means of a burlap drag, broom, or approved alternative.

There shall be no application of water or cement to the concrete surface for finishing purposes.

Deck concrete shall be continuously wet cured as indicated in Section 6.4.4 of this specification. During freezing temperatures, water curing shall be terminated 12 hours prior to the end of the protection period.

6.2.3 Roadway Concrete Curb/Gutter, Sidewalk, Jersey Barrier, Culvert Slabs and Haunches. Concrete curb/gutter shall be constructed in accordance with this specification and with drawings S-2009-019 and S-2009-021 or as noted in the Special Provision of the contract. Jersey Barrier shall be constructed in accordance with this specification and with drawing S-2009-022 or as noted in the Special Provisions of the contract. Culvert slabs and haunches shall be constructed in accordance with this specification and with drawing S-2009-051 or as noted in the Special Provisions of the contract. Roadway Curb/Gutter, Sidewalk and Jersey Barrier shall be constructed with wood or metal forms or by a slip form paver.

At driveways, concrete curb Type A shall be depressed 100 mm at the road edge and 80 mm at the rear edge. Types B, C and D shall be depressed 120 mm at the road edge and 100 mm at the rear edge. Unless otherwise specified, driveway widths as measured along the depression shall be 3.7 m for a single driveway and 5.0 m for a double driveway.

Catch basin metal frames and grates shall be adjusted to grade prior to placement of adjacent curb and gutter.

Control joints shall be compliant to CSA A23.1:19 Clause 7.3.2 and this specification. Control joints shall be formed by saw cutting or by use of a jointing tool. Control joints shall be constructed at right angles to the edge of the Curb/Gutter, Sidewalk and Jersey Barrier. Saw cuts shall be made between one quarter to one third of the depth of the section and extend along the entire exposed face. Concrete shall be saw cut as soon as possible after finishing without causing excessive raveling and before shrinkage cracks occur. Saw cutting shall be completed on a continuous basis regardless of time of day. Sidewalks shall be 1.5 m wide and 100 mm thick except at driveway entrances where the thickness shall be 150 mm unless otherwise instructed by the Engineer. The maximum spacing of control joints for curb/gutter and Jersey Barrier shall be 5.0 m. The maximum spacing of control joints for sidewalk shall be 1.5 m. Control joints shall also be placed at a distance of 1.5 m from the center of catch basins.

Expansion joints shall be constructed every 15 meters along the length of a sidewalk. The expansion joint shall be constructed at right angles to the edge of the sidewalk and shall extend for the full width and depth of the sidewalk section. The expansion joint shall be constructed using a pre-molded non-extruding bituminous impregnated fibre-board, 12 mm thick, conforming to ASTM D1751. It shall be installed 6 mm below the surface of the concrete and an edger (6mm radius) shall be used to finish the concrete on either side of the joint. The top surface of the fibre-board shall be fully exposed along its entire length.

Isolation jointing material shall be installed to provide a separation between new concrete and existing structures (e.g. curbs, buildings, lamp posts, fire hydrants, water valves, etc.). Isolation jointing material shall be a polyethylene foam, cross linked polyethylene foam, or polyurethane and shall conform to the requirements of ASTM D5249. The jointing

material shall extend the full width and depth of the section and shall be flush with the surface.

Curb/Gutter, Sidewalk and Jersey Barrier shall be cured as indicated in Section 6.4 of this specification.

The Contractor shall backfill the area behind the curb to a distance not exceeding 0.6 m from the back of the curb. The material used shall be of a common or borrow type free from large rock or organic material. Granular materials shall not be used.

6.3 Consolidation. All methods of consolidation shall be subject to the approval of the Engineer. PCC shall be consolidated thoroughly and uniformly by means of hand tamping, vibrators, or finishing machines to obtain a dense, homogeneous structure, free from cold joints, voids, and honeycombing as per CSA A23.1:19 Clause 7.5.4.1.

A sufficient number of vibrators shall be employed to adequately handle the anticipated rate of placement. The size and frequency of vibrators shall be compliant with the requirements of CSA A23.1:19 Clause 7.5.4.2 and shall be used in accordance with the manufacturer's instructions. A stand-by vibrator shall be available on the site at all times.

Internal vibrators shall be used wherever practicable. External type vibrators may be used where surfaces cannot be properly consolidated with the internal type alone.

Insertion of internal vibrators shall be made systematically at intervals such that the zones of influence of the vibrator overlap. Additionally, the vibrator shall penetrate the upper part of the previously placed lift of the concrete by its own mass and vibration as per CSA A23.1:19 Clause 7.5.4.2.

Extreme care shall be taken to ensure that the internal type vibrators do not displace the reinforcing steel or the forms. Vibrators shall have rubber or non-metallic vibrating heads if epoxy coated reinforcing steel is used.

6.4 Protection and Curing of Concrete. PCC and SCC shall be protected in accordance with CSA A23.1:19 Clause 7.6 and this specification. PCC and SCC shall be protected from freezing, premature drying, high temperature, and moisture loss for a period of time necessary to develop the desired properties of the concrete. All freshly placed and consolidated PCC and SCC shall be suitably protected from the elements and from defacement due to building operations, traffic, and vandals. The effects of direct sunshine, drying winds, cold, excessive heat, and running water are particularly harmful. The PCC and SCC shall be protected by the use of adequate tarpaulins or other suitable material to completely cover, or enclose, all freshly finished surfaces.

The curing time shall be as indicated in CSA A23.1:19 Tables 2 and 19 with respect to the exposure class of the concrete as per CSA A23.1:19 Clause 7.8, unless otherwise specified in this specification or by the Engineer. Curing shall begin immediately following the placing and finishing operations and the concrete has hardened sufficiently to prevent surface defects. The contractor shall provide the proper temperature and moisture conditions for the appropriate time until the concrete develops its desired properties. If at the end of the specified curing period the concrete has not met the strength limits prescribed in CSA A23.1:19 Table 19, then curing shall continue until the contractor can provide proof that the strength requirements have been achieved. Curing shall be achieved by one or more of the following:

6.4.1 Burlap. Burlap shall be immersed in water for a period of at least 24 hours immediately prior to placement. Two layers of pre-soaked burlap shall be carefully laid on the surface as soon as the PCC has set sufficiently to support the mass of the burlap without marking the surface. Strips shall be overlapped 150 mm, secured to the surface and kept wet throughout the curing period. The concrete surface shall be protected with evaporation retarders until such time that the surface is sufficiently hard to accept placement of the burlap without marking the surface.

6.4.2 Moisture Vapour Barrier. The Contractor shall provide an effective vapour barrier and prevent any flow of air between it and the PCC surface. Where polyethylene sheet is used, it shall be white opaque pigmented with a minimum thickness of 100 µm. The vapour barrier shall be secured to the surface and overlapped 150 mm. The concrete surface shall be protected with evaporation retarders until such time that the surface is sufficiently hard to accept placement of the vapour barrier without marking the surface.

6.4.3 White Pigment Liquid Membrane. Curing compounds shall not be used on a surface where a bond is required for additional PCC. A curing compound may be approved by the Engineer under certain circumstances where the application of moisture is impracticable and where such compounds will not jeopardize the appearance of the PCC. Curing compounds shall be applied at the Manufacturer's recommended application rate. Curing compounds are not permitted on construction joints, surfaces requiring weatherproofing sealants or deck sections. Curing compounds shall be applied immediately after texturing of the concrete surface. Curing compounds shall be applied to all surfaces which

are exposed during construction. After removal of formwork, curing compounds shall be applied to the newly exposed surface(s).

6.4.4 Water. All PCC bridge decks shall be cured with water unless otherwise directed by the Engineer. PCC exposed surfaces shall be kept continuously moist for a minimum of seven (7) consecutive days after placing. The water for curing shall be clean and free from any material which could cause staining or discoloration of the PCC. Water used in curing of concrete shall be clean and free of deleterious substances as per CSA A23.1:19 Clause 7.8.2.1. To ensure this requirement is satisfied, the water shall be potable.

6.4.5 Curing Blankets. Use curing blankets that consist of a top layer of copolymer material and a bottom layer of absorbent, non-woven, synthetic fabric. Ensure that the layers are securely bonded together so there will be no separation of the layers during handling and curing of the concrete. When tested according to ASTM C171, ensure that moisture loss does not exceed 0.010 grams per square centimeter and that reflectance is at least 70 percent. Curing blankets must be unrolled into a flood of water placed immediately in advance of the roll. Curing blankets are to be used on horizontal surfaces.

6.5 Hot Weather Concreting. When the air temperature is at or above 27°C, or is likely to rise above 27°C during the placement period, special measures, as detailed in CSA A23.1:19 Clause 7.2.1, shall be taken by the Contractor to protect the concrete from the effects of hot and/or drying weather conditions. The temperature of the formwork, reinforcing steel or the material on which the concrete is to be placed, shall not exceed 27°C.

Concrete temperatures shall not exceed those specified in CSA A23.1:19 Table 14, as well as the maximum hydration temperature of 70°C as per CSA A23.1:19 Clause 8.5.5.

6.6 Cold Weather Concreting. When the mean air temperature is at or below 5°C or when the temperature is likely to fall below 5°C within twenty-four (24) hours of placement, the Contractor shall place, cure and protect PCC in accordance with CSA 23.1 Clause 7.2.2 and this specification.

PCC shall not be placed on or against any surface which is at a temperature less than 5°C. Snow and ice shall be removed before PCC is deposited on any surface. Calcium chloride or other de-icing chemicals shall not be used as a de-icing agent in the forms.

Concrete shall be placed within the temperature limits specified in CSA A23.1:19 Table 14.

During periods of cold weather, the temperature of the concrete surface shall be continuously monitored with readings taken every 60 minutes using temperature probes to ensure the curing temperature is maintained above 10 °C and the maximum temperature differential between the concrete surface and ambient does not exceed the limits in CSA A23.1:19 Table 20 prior to stripping. Thermal insulation may be required to be removed in stages per Section 6.7.3 of this specification.

6.7 Protection Classes. Protection and curing depend upon the outside temperature, the wind velocity, and the size of the PCC section. Under normal circumstances the following methods of protection may be required to maintain the protection necessary for the conditions described.

Heating of the mixing water and/or aggregates shall be required for the following classes of protection in Sections 6.7.1 to 6.7.3, inclusive.

6.7.1 Special Protection. When the outside temperature during placing or during the protection period may fall below 5°C, adequate covering of all surfaces with tarpaulins or polyethylene sheets shall be provided.

6.7.2 Special Protection with Insulation. When the outside temperature during placing or during the protection period may fall below 0°C, all surfaces shall be covered with an approved insulating material, over which tarpaulins or polyethylene sheets are placed.

6.7.3 Complete Housing with Heat. When the outside temperature during placing or during the protection period may fall below -5°C, a complete housing of the PCC, together with supplementary heat, shall be provided. The Contractor shall ensure that heat is supplied uniformly around the PCC. For mass concrete, defined as minimum section dimension in excess of 2 m, the temperature gradient shall not exceed 20°C/m from the interior of the element to the exterior face. In thin sections, less than 2 m, the temperature differential from the interior to the exterior shall not exceed 20°C. Steam or hot air blowers may be used, but a means of maintaining relative humidity of not less than 95% shall be provided. When dry heat is used, hot air shall not be permitted to flow directly onto the PCC surface. Exhaust fumes

shall be vented.

The protection and curing shall continue to maintain the temperature of the PCC no less than 10°C for the curing period defined in CSA A23.1:19 Tables 2 and 19 after placement. The PCC shall be kept above 0°C for a total period of fourteen (14) days.

At the end of the curing and protection period, protection and heating shall be withdrawn in such a manner as not to induce thermal shock stresses in the PCC. The temperature of the concrete shall be gradually reduced to avoid cracking due to sudden temperature changes near the end of the curing period. The protection shall not be completely removed until the concrete has cooled to the temperature differential stated in Table 20 of CSA A23.1:19 as per Clause 7.2.2.5.

6.8 Concrete Surface Finish

6.8.1 Formed Surface. All formed surfaces shall receive the basic treatment as indicated below. In addition to the basic treatment, all exposed surfaces shall receive a "Smooth Form" finish as indicated below.

6.8.1.1 Basic Treatment. No defects shall be repaired until inspected by the Engineer. Upon removal of the forms, all cavities, honeycomb, surface voids, bugholes (greater than 6 mm diameter) and other deficiencies must be patched with a sand cement mortar of the same composition as that used in the PCC. Mortar shall be composed of cement, fine aggregate and water, proportioned and mixed as specified. When the proportioning of cement and fine aggregate is not specified, the mortar shall consist of one (1) part by volume of cement and two (2) parts of fine aggregate. The quantity of water used in mixing the mortar shall be sufficient to make it capable of being freely spread with the trowel. Mortar shall be mixed in quantities which can be utilized within 60 minutes. Mortar shall not be re-tempered or re-mixed with water after initial set. Grout materials applied following the manufacturer's recommendations can be used for patching with approval from the Engineer.

All bolts, ties, nails, or other metal not specifically required for construction purposes, shall be removed or cut back to a depth of 25 mm from the surface of the PCC unless otherwise directed by the Engineer. The cavity shall be kept saturated for 60 minutes prior to the application of a latex bonding agent or neat cement paste. The mortar shall be pressed or packed into the depressions to completely fill the cavity and then finished to match the adjacent surface. Fins, unsightly ridges, or other imperfections shall be chipped or rubbed off flush with the surface. Mortar patches in excess of 25 mm shall be applied in layers not exceeding 25 mm with a 30-minute interval between the placing of layers. The surface of the patch shall be textured equivalent to the adjacent concrete.

Where honeycombing has occurred in non-structural elements, the affected area shall be removed and filled with mortar as previously described. Where honeycombing has occurred in structural elements, the corrective method of treatment shall be carried out as directed by the Engineer.

All concrete and mortar shall be cured and protected in accordance with CSA A23.1:19 and Section 6.4 of this specification.

6.8.1.2 Smooth Form Finish. Smooth Form Finish shall be in accordance with CSA A23.1:19 Clause 7.10.2.6 and this specification. A Smooth Form Finish shall be a uniform, high quality concrete which has been homogeneously placed and thoroughly compacted. A Smooth Form Finish shall be uniform in colour, pattern and texture. Exposed surfaces of curbs, sidewalks, parapet walls, abutments, piers, and any other surfaces the Engineer may designate, shall have a Smooth Form Finish.

If the concrete does not exhibit such finish after form stripping and the basic treatment, the Contractor shall perform any or all of the following operations, as directed by the Engineer, in order to obtain a Smooth Form Finish:

- Cut out all corrodible metal within 25 mm of the surface and repair the cavities as indicated in Section 6.8.1.1, basic treatment. Any reinforcement cut out shall be replaced while achieving the specified concrete cover.
- Remove fins and other projections to leave a smooth, plane surface.
- Remove stains, rust marks or other blemishes which detract from the specified uniformity of appearance.

6.8.1.3 Finishing SCC. Finishing SCC after placement shall meet the requirements of CSA A23.1:19 Clause 8.6.6.

6.8.2 Open Surfaces. The finished surface of concrete placed for such items as bridge decks, approach slabs, sidewalks and curbs shall conform to the lines, grades and elevations shown on the contract drawings and as stated

herein.

6.8.2.1 Sidewalks. Sidewalk surfaces shall be laid out in blocks by use of a jointing tool, saw cutting or as indicated on the plans. Concrete edges and expansion joints shall be formed in the concrete at the designated locations. Joints shall be rounded using a 6 mm radius edging tool. Sidewalk surfaces shall be struck-off with a strike board and floated. The finished surface shall not vary more than 3 mm under a 3 m straight edge and shall be lightly broomed transversely to produce a textured, non-slip surface. Curing operations, shall be in accordance with Section 6.4 of this specification.

6.8.2.2 Decks. The deck shall be finished using a mechanical screed machine followed by bullfloating and final texturing. Final finishing, texturing, and curing shall be completed within 5 meters behind the screed machine. A work bridge (mobile catwalk) shall be used following the screed machine for bullfloating and finishing operations.

The finishing machine shall be self-propelled and travel on rails. It shall be fitted with a rotating cylinder screed, an adjustable powered screw auger and a vibrator mounted in front of the screed. It shall be capable of forward and reverse movement under positive control. There shall be provision for raising all screeds to clear the screeded surface without adjusting the legs. It shall also be provided with a locking device at each leg to prevent vertical adjustment. The finishing machine shall be capable of obtaining an acceptable surface texture without excessive additional hand finishing.

A work bridge riding on the screed rails behind the finishing machine with a working platform not higher than 0.4 m above the finished surface, shall be provided to facilitate hand finishing work, concrete inspection, and placing of curing materials. On placements longer than 40 m or wider than 10 m, a second work bridge shall be provided. When two work bridges are required, the trailing work bridge shall ride on the screed rails and shall be used for the purpose of placing the curing materials and shall have sufficient clearance to allow for the proper placing of the curing materials. Screed rail chairs shall be adjustable in height and made of metal.

The finish deck surface shall be tight, smooth, free from ridges, depressions, undulations, or blemishes. The surface shall receive a texture finish as indicated in Section 6.2.2 of this specification. Except across the crown, the deck surface shall be such that when tested with a 3 m long straight edge placed in any direction, there shall not be a gap greater than 3 mm between the bottom of the straight edge and the surface of the concrete.

Areas which do not meet the required surface profile shall be clearly marked and removed by the Contractor at the Contractor's expense. The Contractor shall, as directed by the Engineer:

- Grind down any areas higher than 3 mm but less than 10 mm.
- Remove and replace deviations exceeding 10 mm. The quality of the repair shall be equal to or greater than the adjacent concrete in the undisturbed slab.

6.9 Damp-Proofing. The back face of abutments, wingwalls and retaining walls, from the top of footing to underside of curbs, as well as the top and sides of "culvert type structures", where PCC will be in contact with the earth fill, shall be damp-proofed.

Damp-proofing shall consist of one coat of emulsified asphalt diluted with clean water to a maximum of 50% by volume applied uniformly by brush or spray at the rate of 0.4 to 0.5 L/m² of surface area, followed, after the prime coat has cured, by one full strength coat of emulsified asphalt applied at a minimum rate of 0.5 L/m² of surface area.

7.0 QUALITY CONTROL / QUALITY ASSURANCE

7.1 General. In accordance with CSA A23.2-25C:19 Clause 8, the Department shall be responsible for quality assurance processes to verify the requirements of the concrete are met. Additionally, the Contractor shall be responsible for the quality control processes to ensure and verify that the requirements for concrete as delivered are met.

Testing by the Department personnel, or representative, shall not relieve the Contractor of the overall responsibility for the strength and acceptability of the concrete supplied. The Contractor is responsible for ensuring the concrete placed meets the specified properties.

7.1.1 Quality Control Inspection. To ensure the requirements for the concrete as delivered are met, the Contractor shall provide Quality Control measures to ensure the specified properties are within specification tolerances. All Quality Control sampling and field testing shall be performed by CCIL certified field testing technicians and Quality Control

laboratory testing must be performed by a concrete testing laboratory certified by CCIL in accordance with CSA Standard A283.

Each load shall be tested by the Contractor to verify the specified properties are within their respective tolerances. Testing shall include but not be limited to:

- Air content - CSA A23.2-4C:19
- Slump - CSA A23.2-5C:19
- Temperature - CSA A23.2-17C:19
- Slump Flow (SCC) - CSA A23.2-19C:19

The Contractor shall cast a set of test specimens for every 50 m³ of concrete placed, or fraction thereof. The test specimens shall be used to determine the compressive strength of the concrete placed. All test specimens shall be secured in an approved storage medium meeting the requirements of CSA A23.2-3C:19 Clause 9.3.2 prior to leaving the site. A set of specimens shall consist of three (3) specimens, one (1) specimen tested at 7 days and the remaining two (2) tested at 28 days. The Contractor shall cast additional test specimens as required to prove compliance with Section 6.1.3 of this specification.

To verify compliance with the specified concrete properties, the Contractor must submit reports containing the following information to the Engineer and HCS within 24 hours of placement:

- Air content, slump, and temperature of concrete for every truck delivered to site. Testing shall be done in accordance with CSA A23.2-25C:19. Testing shall be carried out at the point of discharge from the truck and as close as possible to final deposit into the forms.
- Any adjustments made to the concrete loads prior to placement and what time the adjustment was made. This shall be noted and submitted on the QC placement report and the batch ticket.
- Any additional requirements within contract documents, or additional testing the contractor deems necessary to ensure the quality of the product is met.
- Volume of each load (metric units) and keep a running tally of total volume placed.
- Air temperature during the time of each concrete test.
- The truck number of the truck being tested.

The Contractor must also provide:

- Documentation proving compliance with Section 6.1.3 of this specification before formwork/falsework is stripped. The documentation shall include the results of compressive strength specimens tested to CSA A23.2-9C:19.
- During cold weather concreting, monitor and record the temperature of the concrete for entire curing period. Time intervals of temperature readings shall not exceed 60 minutes.
- 7 day and 28 day compressive strength test results.

The Contractor shall ensure concrete is placed, and trucks fully discharged, within two (2) hours of initial mixing as per CSA A23.1:19 Clause 5.2.5.3.1, unless otherwise approved via mix design submission. Concrete exceeding this tolerance shall be rejected unless its use is approved in writing by the Concrete Supplier and the Contractor and is accepted by the Engineer. Justification for the approval must be provided with the Concrete Supplier's approval.

Concrete temperatures exceeding the limits presented in CSA A23.1:19 Table 14 will be rejected unless its use is approved in writing by the Concrete Supplier and the Contractor and is accepted by the Engineer. Justification for the approval must be provided with the Concrete Suppliers approval. During periods of cold and warm weather as defined in Section 6 of this specification, the Contractor shall monitor the concrete temperature at varying intervals during discharge to ensure compliance.

The above Quality Control testing, as well as any other testing the contractor does to ensure the supplied concrete meets project specifications, shall serve as the basis of the contractor accepting or rejecting the load. If the load is accepted, the Department's Quality Assurance representative will test between 10% and 90% of the load to confirm compliance with project specifications. If Quality Control and Quality Assurance results differ, the testing performed by the Quality Assurance representative will be the definitive result for acceptance purposes.

7.1.2 Quality Assurance Inspection. Department personnel, or representative may complete the following actions prior to concrete placement:

- Examining to confirm that all equipment needed to transport and place the concrete is available and conforms to specifications.
- Examining vibrators to confirm they are of sufficient size, quantity, and operating frequency.
- Examining the formwork for cleanliness and temperature with reference to the appropriate specifications.
- All problems shall be brought to the attention of the Engineer or resolved as previously directed by the Engineer.
- Inspect the condition of reinforcing steel and general cover provided within formwork and advise the Contractor of any deficiencies if instructed by the Engineer.
- Supervise such corrective actions as directed by the Engineer.
- All inspections, instructions, corrective actions, and placement details are to be noted in the field placement report (including pictures).
- Any added requirements noted within contract documents.

During concrete placement, the Department personnel, or representative shall test each load of concrete for temperature, slump, and air content in accordance with CSA A23.2-25C:19. Testing shall be carried out at the point of discharge from the truck and as close as possible to final deposit into the forms. All results are to be noted in the field placement report.

The Department's personnel, or representative shall cast a set of five (5) compressive strength test specimens for every 50 m³ of concrete placed, or fraction thereof, or as directed by the Engineer. Three (3) test specimens will be used to determine the compressive strength of the concrete placed, and the additional test specimens will be tested only if requested by the Engineer for appeal purposes. All test specimens are to be cast from the same load of concrete. All test specimens shall be secured in an approved storage medium meeting the requirements of CSA A23.2-3C:19 Clause 9.3.2, provided by the Department's personnel, or representative, prior to leaving the site.

Class C-1 or Class C-XL concrete shall be randomly tested for Chloride Ion Penetrability and Air-Void Parameters of Hardened Concrete, unless otherwise directed by the Department. The frequency of testing for the Chloride Ion Penetrability and Air-Void Parameters of Hardened Concrete shall be a minimum of one (1) test per mixture for every 75 m³ of the project, unless otherwise specified by the Engineer. The specimens shall be randomly sampled adhering to the above frequencies and shall be sampled between 10% and 90% truck discharge. The Engineer will determine when the sampling is to take place. Chloride Ion Penetrability shall be tested at 91 days of age, and Air-Void Parameters of Hardened Concrete shall be tested at 7 days of age. When specimens are cast for the Chloride Ion Penetrability and Air-Void Parameters of Hardened Concrete, the results will represent all concrete placed within the 75 m³. Additionally, all other concrete mixtures that contain air entrainment will also be subject to Air-Void Parameters of Hardened Concrete testing at the same frequency as C-1 and C-XL. For every sample taken, an additional specimen for both Chloride Ion Penetrability and Air-Void Parameters of Hardened Concrete shall be cast and only be tested if requested by the Engineer for an appeal.

The Department's personnel, or representative shall confirm concrete is placed, and trucks fully discharged, within two (2) hours of initial mixing as per CSA A23.1:19 Clause 5.2.5.3.1, unless otherwise approved via mix design submission.

The Departments personnel, or representative shall confirm concrete temperatures do not exceed the limits presented in CSA A23.1:19 Table 14.

The Department or its representative will also note the following items on the concrete placement report.

- Volume of each load (metric units) and keep a running tally of total volume placed.
- Air temperature during the time of each concrete test.
- The truck number of the truck being tested.

This documentation shall be reported to the Engineer and HCS within 24 hours of placement.

Quality Assurance testing documentation is to be sent to the Engineer and Highway Construction Services (HCS) staff, adhering to the specified time constraints below. After reviewing all results from both Quality Control and Quality Assurance personnel, the Quality Assurance results shall be disseminated by the Engineer to the Contractor within five business days of their availability.

7.2 Field Adjustments. It is the responsibility of the Contractor to ensure all concrete placed meets the specified properties. At a minimum, the Contractor shall test the concrete for the specified properties, as close as possible to final placement and document all results. If the Contractor measures air content or slump outside the specified limit, the Contractor shall be allowed to adjust the concrete, conforming to the procedures outlined in CSA A23.1:19 Clause 5.2.5, and truck is to be fully discharged within 120 minutes. The Contractor will then retest the concrete to verify the effectiveness of the adjustment and document the results. The Contractor may make subsequent adjustments to the

concrete as necessary, conforming to the procedures outlined in CSA A23.1:19 Clause 5.2.5, and truck is to be fully discharged within 120 minutes. Once necessary adjustments are completed the Contractor will then decide to proceed with placement to the forms or to reject the load, while assuming responsibility for either decision. If the contractor elects to place the adjusted concrete, no further adjustments to the load shall occur once placement to the forms has begun. All adjustments shall be recorded on the batch ticket and initialed by the contractor's representative. The Department's representative will then test the concrete between 10% and 90% of the load. If the concrete fails to meet the Department Specifications, the Department representative shall report the results to the Engineer immediately, who will then decide if the load is to be accepted or rejected. A minimum of two tests shall be performed on the failing property prior to concrete rejection by the Department's representatives.

No water shall be added after the initial introduction of the mixing water for the mix, except at the start of discharge only when:

- The measured slump is less than specified, and
- No more than 60 minutes have elapsed after water and cement have been combined, and
- The concrete is in a stationary or truck mixer, and
- Does not exceed the batch mix design stated water to cementing materials ratio.

When water is added to the mix, it shall comply with CSA A23.1:19 Clause 5.2.5.3.2 and this specification.

7.3 Strength Tests. For acceptance based on compressive strength, a set of test specimens shall be cast, cured, and tested by the Department or its representative in accordance with the relevant test methods indicated in Section 7.1 of this specification. The specified 28-day compressive strength is the acceptance criteria for concrete. A set of specimens shall consist of three (3) specimens, one (1) specimen tested at 7 days and the remaining two (2) tested at 28 days. The compressive strength result of a sub-lot, as defined in Section 7.5, will be evaluated based on the requirements of CSA A23.1:19 Clause 4.4.2.2.1.1. Additionally, the 28-day compressive strength data within the sub-lot will be averaged and rounded to one decimal place for penalty/bonus evaluation. A 28-day compressive strength data point shall be defined as the average between two (2) same day 28-day compressive strength tests.

7.4 Strength Criteria (With Pay Adjustment). The Department reserves the right to reject any concrete which does not meet all the requirements for the class of concrete specified. The Department also reserves the right to reject any portion of a placement if there exists evidence that this portion has a strength that is below the minimum acceptable required under this section. The Department may, at the discretion of the Engineer, accept concrete which does not meet the specified strength requirements provided that the structural adequacy of the section is not jeopardized. The determination of structural adequacy will be completed by the Department's bridge designer or standard agreement holder.

Where required, determination of structural adequacy is independent of, and in addition to, the payment reduction described below. Where design calculation is required, the Contractor shall reimburse the Department for all costs incurred up to a maximum of \$250 per m³ of concrete placed.

Concrete shall be tested in accordance with CSA A23.2-25C:19. The concrete shall also be considered satisfactory if the 28-day strength for the sub-lot meets the requirements of CSA A23.1:19 Clause 4.4.2.2.1.1. If the concrete does not meet this standard, the Department has the right to require one or more of the following as per CSA A23.1:19 Clause 4.4.2.2.1.3:

- Changes in the mix proportions for the remainder of the work.
- Additional curing on those portions of the structure represented by the test specimens that failed to meet specified requirements.
- Non-destructive testing/ evaluation.
- Cores to be drilled from the portions of the structure in question in accordance with CSA A23.1:19 Clause 4.4.2.2.2.
- Other methods the Department may specify.

Additional curing shall only be an option if one of the curing methods outlined in Section 6 of this specification are still in effect from initial curing.

Coring of the concrete to verify strength will be permitted only for concrete which is to be replaced or reinforced. Coring will not be permitted for which a reduced payment is to be made for under strength.

The Contractor must obtain the Department's approval to core a structure. The Contractor shall initiate a request to the Engineer within five (5) business days of receipt of the appeal compressive strength tests which show continued failure

of the concrete strength. When coring is permitted, cores shall be taken at locations directed by the Department. Coring shall be completed within five business days of the Department's approval for the coring. The cost of coring shall be borne by the Contractor.

The compressive strength of the concrete in the area of the structure represented by the core tests shall be sampled and tested in accordance with CSA A23.2-25C:19 and evaluated in accordance with CSA A23.1:19 Clause 4.4.2.2.2 except as modified below.

In the event the Contractor cores the section in question, within the timelines indicated above, and the average of each set of three (3) cores from the portion of the structure in question is equal to at least 85% of the specified strength, with no single core being less than 75% of the specified strength, the concrete shall be deemed acceptable for meeting the specification.

If the appeal processes described reveals the strength of the concrete remains inadequate, the Department may order replacement or reinforcing, at the Contractor's expense, of the sections in the structure. Alternatively, at the Department's discretion, concrete of a specific class which is otherwise acceptable but fails to meet the strength requirements listed above may be accepted at a reduced price.

7.5 Lots and Sub-lots. A lot shall consist of all concrete within a single mixture design, as provided by the Contractor for a given project. If the quantity of a mix is greater than 5000 m³, the Department will consider proposals to divide the concrete into two lots, based on placement in separate structures or in different construction seasons.

Each lot will be divided into sub-lots from 2 m³ to a maximum of 500 m³. Concrete of a specific mixture type placed in one placement, or concrete of the same mixture type placed on the same day, shall be considered a sub-lot. A minimum of three sets of acceptance cylinders will be made from each section placed (sub-lot). If testing within one placement or concrete placed within the same day does not result in three sets of acceptance cylinders, sub-lots shall be combined, at the Department's discretion, to achieve the minimum requirement.

7.6 Bonus/Penalty. The Department will calculate the mean strength of all the acceptance tests in each sub-lot with a volume of 2 m³ or more. The concrete in each sub-lot will be accepted at the contract price or prices, provided the sub-lot meets the requirements of CSA A23.1:19 Clause 4.4.2.2.1.1. When the sub-lot does not meet the requirements of CSA A23.1:19 Clause 4.4.2.2.1.1 with respect to the specified 28-day strength, the Department may require the Contractor to replace the concrete without a penalty adjustment or may accept the concrete with the penalty adjustment applied. If the sub-lot is compliant with the above requirements, the Department will use the calculated mean strength of the sub-lot, and overall Lot variability to evaluate bonus criteria. When the average strength is not more than 10 MPa above the specified nominal 28-day strength, the Department will apply a bonus adjustment to the Sub-lot if the overall Lot does not exceed variability limits described in Section 9. The bonus or penalty adjustment will be as described in Section 9 Basis of Payment.

7.6.1 Appeal Testing. The Contractor shall not be permitted to appeal any test result when the sub-lot meets or exceeds the required strength. If the Department's QA laboratory determines that the 28-day compressive strength was below the specified strength, the QA representative shall communicate this to the Engineer in writing within the same business day. The Engineer will then provide notice to the Contractor of the strength results and require notification of the Contractor's intent to appeal within two (2) business days of the 28-day test. If requested, the appeal specimens shall be tested within three (3) business days of the 28-day test.

If the Contractor appeals the regular test results, the additional test specimens cast will be tested to verify the compressive strength of the sub-lot. The pay adjustment will be based on the average strength obtained from the two appeal specimens. The appeal test results shall govern, be considered final, and be used in the pay adjustment calculation. The appeal specimens shall be cast and tested by the Department's Quality Assurance representative.

The Contractor may have a representative present during appeal testing. During the period of the testing, the Contractor's representative shall comment on anything concerning the testing which they do not consider to be valid, and the Engineer shall respond to all comments in order to resolve them. Prior to leaving the testing laboratory any unresolved comments regarding the testing procedures are to be given to the Engineer in writing.

The strength obtained from the appeal testing shall be binding on both the Contractor and the Department.

7.6.2 Appeal Testing Costs. If the appealed test results indicate that a penalty no longer applies, the testing costs incurred shall be borne by the Department. The Contractor shall be responsible for any other costs that the Contractor may incur.

If the appealed test results confirm a negative price adjustment or rejection, the sampling and testing costs, and any other costs that they may incur as a result of the appeal, shall be borne by the Contractor.

8.0 METHOD OF MEASUREMENT

8.1 General. Measurement shall be made at the contract unit price per cubic meter for Cast in Place Concrete. The quantity of concrete for payment shall be the volume in cubic meters computed from the dimensions shown on the drawings or as revised by the authority of the Engineer. No deductions shall be made for the volume of concrete displaced by steel reinforcement, joint material, structural shapes, chamfers, tops of piles, or cylindrical voids of 110 mm diameter or less.

8.1.1 Mud and Leveling Slabs. The quantity of concrete used for Mud or Leveling Slabs shall be determined by volume in cubic meters based on the delivery slip and placed in the work.

8.1.2 Curb/Gutter. The quantity of Curb/Gutter, including curb backing, shall be measured by the linear meter for the length accepted by the Engineer. No deduction shall be made for the reduced height at driveways and other entrances.

8.1.3 Sidewalks and Driveways. The quantity of Sidewalk, Driveway and other entrances shall be measured by the square meter accepted by the Engineer and placed in the work.

8.1.4 Jersey Barrier. The quantity of Jersey Barrier shall be measured by the linear meter accepted by the Engineer and placed in the work.

9.0 BASIS OF PAYMENT

9.1 General. Except as noted herein payment will be made at the contract unit price bid per cubic meter for Cast in Place Concrete or price adjusted as described below. The payment for Cast in Place Concrete shall be considered full compensation for the cost of furnishing all materials, aggregates, cement, supplementary cementing materials, water, admixtures, and other materials, non-metallic expansion joint materials, tools, equipment, falsework, forms, bracing, labour, curing, surface finish, damp-proofing and all other items of expense required to complete the concrete work as shown on the plans, and as outlined in the specifications.

Payment for roadway Curb/Gutter and Jersey Barrier will be made at the contract unit price bid per linear meter. Payment for curb backing shall be included in the unit price for Curb/Gutter. Payment for Roadway Sidewalk and Driveway entrances will be made at the contract unit price per square meter. Price adjustment for concrete measured by the linear or square meter shall be calculated as per Division 5, Section 13 of the Standard Specifications.

9.1.1 Penalty/Bonus Adjustment. The penalty or bonus adjustment will apply to the calculated quantity of cubic meters of concrete incorporated into the work and accepted by the Engineer. The total adjustment added to or subtracted from payments due to the Contractor shall be the algebraic sum of all penalties and bonuses calculated for all the sub-lots in excess of 2 m³. A Penalty/Bonus adjustment shall not apply if the sub-lot is less than 2 m³.

9.1.2 Compressive Strength Price Adjustment. Concrete which fails to meet CSA A23.1:19 Clause 4.4.2.2.1.1. and is proven to be structurally adequate, may be accepted at an adjusted price. The penalty adjustment will be determined based on the requirements of Table 5.7.4:

Table 5.7.4: Concrete Compressive Strength Price Adjustments

Concrete Compressive Strength – Sub-lot Price Adjustments				
Strength	Meets requirements of CSA A23.1:19 Clause 4.4.2.2.1.1. Average sub-lot strength is more than 10 MPa above the specified strength.	Meets requirements of CSA A23.1:19 Clause 4.4.2.2.1.1. Average sub-lot strength is no more than 10 MPa above the specified Strength	Does not meet requirements of CSA A23.1:19 Clause 4.4.2.2.1.1. The lowest moving average of 3 consecutive compressive strength tests within the sub-lot is below specified strength by no more than 5 MPa. No individual test is more than 5 MPa below specified strength	Does not meet requirements of CSA A23.1:19 Clause 4.4.2.2.1.1. The lowest moving average of 3 consecutive compressive strength tests within the sub-lot is more than 5 MPa below specified strength. An individual set is more than 5 MPa below specified.
Payment per cubic meter component	100%	100% + Bonus	100% - PA	No Payment and Full Section Removal or 100% - Maximum Penalty at the Engineers discretion.

The penalty adjustment (PA) will be calculated as shown below:

$$PA = \$1500 + (\$10 (SS - AS)) * V$$

where:

PA = Penalty Adjustment (\$ + \$/m³)

V = Volume placed (m³)

SS = Specified strength (MPa)

AS = Lowest average strength of three consecutive tests that do not meet CSA A23.1:19 Clause 4.4.2.2.1.1 Part B. (MPa)

The Maximum Penalty that can be applied is \$1500 + \$250/ m³

9.1.2.1 Improper Curing Penalties. Failure to carry out proper curing procedures, including temperature control in cold weather, and timelines as described within this specification shall result in the following penalty structure:

- 1st occurrence, \$1000 penalty.
- 2nd occurrence, \$2000 penalty.
- Each occurrence thereafter, \$5000 each occurrence.

An occurrence shall be defined as when an inspection by the Department or representative reveals that a concrete surface during the curing period is not visibility wet or does not have measures in place to ensure proper curing temperatures during cold weather.

If the contractor fails to reinstate proper curing conditions within 30 minutes of notification, this will be treated as a separate occurrence. If there are two or more occurrences on the same section of concrete, the Engineer may request it to be removed and replaced at the contractor's expense.

9.1.3 Bonus Adjustment. When the sub-lot meets requirements of CSA A23.1:19 Clause 4.4.2.2.1.1, and average sub-lot strength is between the specified strength and 10 MPa above the specified strength, the sub-lot shall receive a

bonus payment based on the overall variability of the entire Lot, provided that no other sub-lots within the Lot are subject to penalty adjustment. For concrete having a specified strength of 35 MPa or less, this will be determined by calculating the standard deviation of the Lot with respect to the specified compressive strength. For concrete having a compressive strength greater than 35 MPa, the variability will be determined by the coefficient of variability with respect to the specified compressive strength. The basis for these calculations has been described in Section 9.1.3.1 of this specification. The bonus criteria have been defined in Tables 5.7.5 and 5.7.6 below.

Table 5.7.5 – Bonus Criteria Based on Lot Variability⁽¹⁾

Lot Variation Standard for Concrete ≤ 35 MPa					
Variability:	Excellent	Very Good	Good	Fair	Poor
Standard Deviation from the Specified Strength	Below 2.8 MPa	2.8 – 3.3 MPa	3.4 – 4.0 MPa	4.1 to 4.8 MPa	Above 4.8 MPa
Bonus Paid per m ³	\$10	\$5	\$2	No Bonus	No Bonus

⁽¹⁾ Standard deviation ranges in accordance with ACI 214R-11

Table 5.7.6 – Bonus Criteria Based on Lot Variability⁽¹⁾

Lot Variation Standard for Concrete > 35 MPa					
Variability:	Excellent	Very Good	Good	Fair	Poor
Coefficient of Variation from the Specified Strength	Below 7.0 MPa	7.0 to 8.9 MPa	9.0 to 10.9 MPa	11.0 to 14.0 MPa	Above 14.0 MPa
Bonus Paid per m ³	\$10	\$5	\$2	No Bonus	No Bonus

⁽¹⁾ Variation ranges in accordance with ACI 214R-11

9.1.3.1 Variability Calculation. For concrete with a specified compressive strength ≤ 35 MPa, the variability of the lot will be determined by calculating the standard deviation of the lot.

$$s = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}}$$

Where:

s = Standard Deviation (MPa)

n = Number of Strength Results on Record⁽¹⁾

\bar{X} = Sample Mean (MPa)

X = Compressive Strength Test Result. Each test data point shall be the average of two (2) 100 mm x 200 mm compressive strength cylinders cast on the same sample broken at 28 days. (MPa)

⁽¹⁾ One strength result shall be defined as the average of two (2) same date 28-day cylinders.

The overall variation of the lot is considered poor if the standard deviation is above 4.8 MPa based on the requirements of ACI 214R-11. This value is based on evaluating the concrete within a normal-distribution curve since concrete within the Department's scope should not exceed 70 MPa. Thirty (30) or more data points shall be considered satisfactory

and will not require modification. If less than thirty (30) data points exist, but equal or exceed 15, the standard deviation shall be multiplied by the modification factors within Table 5.7.7 to account for to account for uncertainty.

Table 5.7.7 – Standard Deviation Modification Factors (ACI 214R-11)

Number of Tests	Modification Factors
15	1.16
20	1.08
25	1.03
30	1.00

If less than 15 data points are available for the lot, variability analysis will not be applicable for bonus adjustment evaluation and no bonus will be assigned for any of the sub-lots.

For concrete with a specified compressive strength > 35 MPa, the variability of the lot will be determined by calculating the coefficient of variation of the lot.

$$V = \frac{s}{\bar{X}}(100)$$

Where:

V = Coefficient of variation (%)

\bar{X} = Sample Mean (MPa)

s = Standard Deviation (MPa)

The overall variation of the lot is considered poor if the coefficient of variation is above 14% based on the requirements of ACI 214R-11. This value stems from evaluating the concrete within a normal-distribution curve since concrete within the Department's scope will not exceed 70 MPa. Thirty (30) or more data points shall be considered satisfactory and will not require modification. If less than 30 data points are available, but equal or exceed 15, the coefficient of variation shall be multiplied by the modification factors within Table 5.7.7 to account for uncertainty.

If less than 15 data points are available for the lot, variability analysis will not be applicable for bonus adjustment evaluation. In this event, the bonus for the sub-lot shall be calculated using the following formula:

$$BA = V \times (\$2 (AS - SS))$$

where

BA = Bonus Adjustment (\$/m³)

V = Volume placed (m³)

SS = Specified strength (MPa)

AS = Average strength of sub-lot (MPa)

This bonus adjustment will only be assigned if the average sub-lot strength is between the specified strength and 10 MPa above the specified strength and no other sub-lots within the Lot are subject to penalty adjustment.

The bonus adjustment shall not exceed \$10/m³.

9.1.4 Resistance Level to Chloride Ion Penetrability Adjustment. Testing completed in accordance with CSA A23.2-23C:19 to determine the concrete's resistance to chloride ion penetrability may warrant a penalty or require full replacement at the contractor's expense if the concrete fails to meet the specified limit. The penalty adjustment shall be applied to the sections and quantities the testing represents as defined in Section 7.1.2 of this specification. The penalty shall be charged in the form of \$ per m³ of concrete placed as defined in Tables 5.7.8 and 5.7.9, plus an

additional baseline fee of \$1500 for Department resources used to investigate the out of specification test result. Additionally, testing for Class C-1 exposure concrete deemed “Excellent” according to the criteria in Table 5.7.8 shall be awarded a bonus in the form of \$ per m³ of concrete placed for the section/quantity this test represents unless the material comprising the sections and quantities do not meets requirements of CSA A23.1:19 Clause 4.4.2.2.1.1, and/or the average sub-lot strength is greater than or equal to 10 MPa above the specified strength. In this case the material comprising the sections and quantities shall not be eligible to receive a bonus payment based on the resistance level to chloride ion penetration.

5.7.8 - Price Adjustment for Resistance to Chloride Ion Penetrability.

C-1 Exposure Concrete					
Resistance level to Chloride Ion Penetrability	Excellent	Good	Adequate	Poor	Very Poor
Charge passed, coulombs	<500	≥500 and <1000	≥1000 and <1500	≥1500 and <2000	≥2000
Unit Price Adjustment Factor	\$10 / m ³	\$0 / m ³	\$0 / m ³	Full removal and replacement or -\$50 / m ³ , at the Engineer's discretion	Full removal and replacement or -\$250 / m ³ , at the Engineer's discretion

5.7.9 - Price Adjustment for Resistance to Chloride Ion Penetrability.

High Performance Concrete (Class C-XL)					
Resistance level to Chloride Ion Penetrability	Excellent	Good	Adequate	Poor	Very Poor
Charge passed, coulombs	<500	≥500 and <1000	≥1000 and <1500	≥1500 and <2000	≥2000
Unit Price Adjustment Factor	\$0 / m ³	\$0 / m ³	Full removal and replacement or -\$50 / m ³ , at the Engineer's discretion	Full removal and replacement or -\$120 / m ³ , at the Engineer's discretion	Full removal and replacement or -\$250 / m ³ , at the Engineer's discretion

9.1.5 Air Void Parameters of Hardened Concrete Price Adjustment. Testing to determine the air void parameters of hardened concrete completed to ASTM C457M that does not meet the requirements of CSA A23.1:19 Clause 4.3.3.3 shall have the respective sections (as defined in Section 7.1.2 of this specification) subject to a penalty or require full replacement at the contractor's expense. The penalty shall be charged in the form of \$ per m³ of concrete placed as defined in Tables 5.7.10 and 5.7.11, plus an additional baseline fee of \$1500 for Department resources used to investigate the out of specification test result.

5.7.10 - Price Adjustment for Air Void Parameters of Hardened Concrete, \$/m³ (Water to Cementing Materials Ratio > 0.36)

Spacing Factor (mm)	Air Content, %																				
	≤ 1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	≥3.0
<0.200	Reject	\$250	\$234	\$224	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$62	\$52	\$36	\$26	\$26	\$0
0.200	Reject	\$250	\$240	\$229	\$219	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$62	\$52	\$36	\$26	\$0
0.210	Reject	\$250	\$240	\$229	\$219	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$62	\$47	\$0		
0.220	Reject					\$229	\$219	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$57	\$0	
0.230	Reject								\$250	\$245	\$224	\$208	\$198	\$182	\$156	\$130	\$120	\$104	\$0		
0.240	Reject												\$250	\$245	\$240	\$229	\$219	\$208			
≥0.250	Reject																				

5.7.11 - Price Adjustment for Air Void Parameters of Hardened Concrete, \$/m³ (Water to Cementing Materials ≤ 0.36)

Spacing Factor (mm)	Air Content, %																					
	≤ 1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	≥3.0	
<0.200	Reject	\$250	\$234	\$224	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$62	\$52	\$36	\$26	\$26	\$0	
0.200	Reject	\$250	\$240	\$229	\$219	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$62	\$52	\$36	\$26	\$0	
0.210	Reject	\$250	\$240	\$229	\$219	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$62	\$47	\$0			
0.220	Reject					\$229	\$219	\$208	\$198	\$182	\$161	\$151	\$135	\$125	\$109	\$99	\$89	\$73	\$57	\$0		
0.230	Reject								\$250	\$245	\$224	\$208	\$198	\$182	\$156	\$130	\$120	\$104	\$0			
0.240	Reject												\$250	\$240	\$224	\$193	\$172	\$161	\$146	\$0		
0.250	Reject															\$250	\$245	\$182	\$0			
>0.250	Reject																					

9.1.6 Appeal Testing. The Contractor shall not be permitted to appeal any Air Void Analysis of Hardened Concrete or Chloride Ion Penetrability test result when the results meet the specified limits within this specification. If the Department’s QA laboratory determines that the result of either of the two testing methods exceed the Department specifications, resulting in a penalty adjustment, the QA representative shall communicate this to the Engineer in writing within the same business day. The Engineer will then provide notice to the Contractor of the results and require notification of the Contactor’s intent to appeal within 2 (two) business days of the completed test. If requested, the appeal specimens shall be tested within three (3) business days of the original test result.

If the Contractor appeals the regular test results, the additional test specimens cast will be tested to verify the result for Air Void Analysis of Hardened Concrete or Chloride Ion Penetrability, whichever is subject to the appeal. The appeal test results shall govern, be considered final, and be used in the pay adjustment calculation. The appeal specimens shall be cast and tested by the Department’s Quality Assurance representative.

The Contractor may have a representative present during appeal testing. During the period of the testing, the Contractor’s representative shall comment on anything concerning the testing which they do not consider to be valid, and the Engineer shall respond to all comments in order to resolve them. Prior to leaving the testing laboratory any unresolved comments regarding the testing procedures are to be given to the Engineer in writing.

9.2 Payment for Cold and Hot Weather Concreting. If additional costs are required to meet the cold and hot weather concrete practice requirements outlined in this specification, those costs must be included in the submitted unit price. No additional payment will be made from the Department outside of what is originally agreed upon.

10.0 WARRANTY