SPECIFICATIONS FOR
REINFORCED CAST-IN-PLACE CONCRETE

1.0 DESCRIPTION

The Work shall consist of:

1. Supplying of materials and the mixing and placing of reinforced cast-in-place concrete as shown and described on the Drawings and in this Specification, including placing, vibrating/compacting, finishing and curing;

2. Supplying, fabricating, constructing, maintaining and removing temporary works, including falsework and formwork;

3. Heating and cooling concrete, if necessary;

4. Developing concrete mix design(s) that meets the performance requirements, including trial batches;

5. Quality control (QC) testing of all materials; and

6. Supplying and installing water seals and joint fillers (when applicable).

"Performance" Alternative

Concrete supplied under this Specification will be specified in accordance with the latest version of "Performance" alternative in Table 5 of CSA A23.1, with the exception that the Contractor shall submit the proposed concrete mix design(s) details:

The Contractor shall:

1. Submit the exact mass or volumetric proportions of all constituent materials of the concrete mixture(s) proposed by the Supplier;

2. Work with the Supplier to establish the concrete mix properties to meet the performance criteria for the plastic and hardened concrete, considering the Contractor's criteria for construction and placement and the Department's performance criteria;

3. Submit documentation to the satisfaction of the Engineer demonstrating that the proposed mix design(s) will satisfy the fresh, mechanical and durability performance requirements;

4. Prepare and implement a quality management plan to ensure that the Department's performance criteria will be met and submit documentation demonstrating the Department's performance requirements have been met;

5. Provide certification from a Professional Engineer registered or licensed to practice in Manitoba that the concrete plant, equipment and truck mixers comply with the requirements of the latest version of CSA A23.1 and this Specification;

6. Certify that all materials to be used in the concrete comply with the requirements of the latest version of CSA A23.1 and this Specification;

7. Certify that the concrete mix design(s) satisfy the requirements of the latest version of CSA A23.1 and this Specification;

8. Certify that the production and delivery of concrete will meet the requirements of the latest version of CSA A23.1 and this Specification;

9. Certify that the concrete complies with the performance criteria specified; and

10. Ensure that the concrete supplier prepares and implements a quality control plan to ensure that the Department's and the Contractor's performance criteria will be met.

Department's Performance Criteria

The Department's basic performance criteria are provided in this Specification and identified on the Drawings. When required, additional site-specific requirements will be described in the Special Provisions of the project.

Contractor's Performance Criteria

The submission shall include the Contractor's performance criteria for each mix design including:

- Placeability (i.e. pumping, buggies, truck chute, etc.).
- Workability;
- Proposed slump, slump retention time and permissible slump loss; and
- Initial and final setting times.

2.0 REFERENCES AND RELATED SPECIFICATIONS

All reference standards and related specifications shall be active or the latest revision at the date of tender advertisement.

2.1 References

- CSA A23.1/A23.2, Concrete Materials and Methods of Concrete Construction/Test methods and Standard Practices for Concrete
- CAN/CSA A3001, Cementitious Materials for Use in Concrete
- CSA G30.14, Deformed Steel Wire for Concrete Reinforcement
- CAN/CSA G30.18, Carbon Steel Bars for Concrete Reinforcement
- CAN/CSA G40.20/G40.21, General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steel
- CAN/CSA G164, Hot Dip Galvanizing of Irregularly Shaped Articles
- AASHTO T 176, Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
- CSA A23.2-24A, Test method for the resistance of unconfined coarse aggregate to freezing and thawing
- ASTM C29, Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
- ASTM C40, Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
- ASTM C42, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- ASTM C70, Standard Test Method for Surface Moisture in Fine Aggregate
- ASTM C88, Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
- ASTM C117, Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- ASTM C127, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
- ASTM C128, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

- ASTM C131, Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- ASTM C136, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
- ASTM C138, Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- ASTM , Standard Test Method for Clay Lumps and Friable Particles in Aggregates
- ASTM C260, Standard Specification for Air-Entraining Admixtures for Concrete
- ASTM C295, Standard Guide for Petrographic Examination of Aggregates for Concrete
- ASTM C309, Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
- ASTM C457, Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete
- ASTM C494, Standard Specification for Chemical Admixtures for Concrete
- ASTM C535-, Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- ASTM C578, Standard Specification for Rigid Cellular Polystyrene Thermal Insulation
- ASTM C586, Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method)
- ASTM C1017, Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
- ASTM C1064, Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
- ASTM C1084, Standard Test Method for Portland-Cement Content of Hardened Hydraulic-Cement Concrete
- ASTM C1012, Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
- ASTM C1105, Standard Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction
- ASTM C1202-19, Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
- ASTM C1293, Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
- ASTM C 1567, Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
- ASTM C 1583, Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)
- ASTM C1581, Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage
- ASTM C 1602, Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
- ASTM C1622, Standard Specification for Cold-Weather Admixture Systems
- ASTM D 75, Standard Practice for Sampling Aggregates
- ASTM D 516, Standard Test Method for Sulfate Ion in Water
- ASTM D4791, Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
- ASTM D5821, Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
- ASTM D6928, Standard Test Method for Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
- ASTM D7428, Standard Test Method for Resistance of Fine Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus

2.2 Related Specifications

- Specifications for Aggregate for Portland Cement Concrete
- Specifications for Superstructure Concrete

- Specifications for Supplying and Placing Concrete Reinforcement
- Specifications for Temporary Works

3.0 SUBMITTALS

The Contractor shall submit the following to the Engineer, in accordance with Special Provisions:

1. Concrete mix design(s) that meets the minimum performance criteria for the various types of concrete(s) as shown on the Drawings and specified in Section 4.3 of this Specification. The concrete mix design shall be sealed, signed and dated by a Professional Engineer registered or licensed to practice in the Province of Manitoba. Any changes to the concrete mix design(s) shall be reviewed by the Engineer prior to the Contractor implementing the change.

   Concrete mix designs will be considered valid for the calendar year in which they have been submitted and approved by the Department on any previous Contract. The Contractor shall provide confirmation in writing that the mix design has not changed from what was previously approved.
   The concrete mix design(s) for the required type(s) of concrete shall specify the following:

   1. Types of the cementitious materials used and their contents in kilograms per cubic meter or equivalent units.

   2. Designated size, or sizes, of aggregates, and the gradation.

   3. Aggregates source location(s) and their types (e.g. siliceous, carbonate, etc.).

   4. Weights of aggregates in kilograms per cubic meter or equivalent units. Mass of aggregates is saturated surface dry (SSD) basis.

   5. Minimum and maximum water content in kilograms per cubic meter or equivalent units and the design water/cementitious ratio.

   6. The limits for slump.

   7. The limits for fresh and hardened air content.

   8. Quantity in millilitres per cubic meter or equivalent units and brand name for each type of admixture.

   9. Certification that all concrete constituents are compatible and comply with the stipulated standards in this specification.

   10. Concrete test reports of the adopted mix(es) including calibration graphs for strength – maturity relationship, as required.

   11. Certification and demonstration that the concrete mix(es) will meet the specified concrete performance criteria requirements.

   12. Valid provincial concrete association “Certificate of Concrete Production Facilities” provided by the concrete supplier.

   The intended method of placement shall be taken into consideration in the development of the concrete mix design(s) as concrete to be pumped must be designed accordingly.

   Trial batches shall be tested and evaluated for the specified requirements. All specified properties shall be verified in accordance with the test methods specified herein. The trial batching shall be undertaken so that it replicates the actual batching practices and placing procedures at the site. If a

concrete pump will be used to place concrete on-site, then the concrete used in the trial batches will pass through a pump line equal to the longest pump line required during construction before sampling.

Any change in any one of the constituent materials of the concrete shall require a new concrete mix design submittal. If, during the progress of the work, the mix design is found to be unsatisfactory for any reason, including poor workability, the Contractor shall revise the mix design(s) and submit the proposed changes to the Engineer for review.

The Contractor shall also submit test data showing that the concrete supplied will meet the performance criteria stated in this Specification for each concrete type. At a minimum, the test data shall prove that the minimum compressive strength, flexural strength and residual post-cracking strength index (Fibre Reinforced Concrete only), rapid chloride penetrability, density, air content, temperature and slump of the concrete to be supplied meets or exceeds the performance criteria. All tests shall be based on the concrete samples taken from the point of discharge into the formwork. For example, at the concrete chute from the delivery truck if being placed by buggies, or at the end of the pump should the Contractor wish to pump the concrete into place.

All testing of concrete and concrete constituents by the Contractor shall be done by an independent laboratory certified in accordance with the latest version of CSA A283 for the appropriate category. As a minimum, the following material test results for the concrete and concrete constituent materials shall be submitted:

1. All aggregates shall comply with the latest version of CSA A23.1, Clauses 4.2.3.1 to 4.2.3.6. Aggregate testing specified in the latest version of CSA A23.1, Clauses 4.2.3.3, 4.2.3.4, 4.2.3.5.1, 4.2.3.6, 4.2.3.7, and Tables 10, 11 and the Standard requirements for concrete exposed to freezing and thawing listed in Table 12.

2. Abrasion and impact testing results for coarse aggregate in accordance with the latest version of CSA A23.2-16A.

3. Report on alkali-aggregate reactivity testing, CSA A23.2-27A (latest version).

4. Report on aggregate petrographic examination, CSA A23.2-15A (latest version).

5. Report on chloride ion penetrability test ASTM C1202 (latest version) for concrete mixes with a specified exposure class of C-XL or C-1.

6. Report on the water-soluble chloride ion content by mass of cementing material in the concrete, CSA A23.2-4B (latest version).

7. Report on Air Content of Hardened Concrete tested in accordance with ASTM C457 (latest version) for all concrete mixes with specified Categories 1 and 2 air content.

Concrete materials testing results shall not be more than 12 months old at time of submission, with the exception of CSA A23.2-2A and CSA A23.2-5A which shall not be older than 90 days at time of submission.

2. Qualified Ready Mix Concrete Supplier (Supplier) that he/she is proposing to use at least 21 days prior to placing concrete. The Engineer will verify acceptability of the Supplier. Acceptance of the Supplier and the concrete mix design(s) by the Engineer does not relieve or reduce the responsibility of the Contractor or Supplier from the requirements of this Specification.

   If the Contractor proposes to use an on-site batch plant, the concrete batching plant shall be calibrated and certified in accordance with CSA A23.1 (latest edition).

The Contractor shall provide evidence that scales and calibrated weights have been certified for the current calendar year by the Weights and Measures Services of the Government of Canada before the scales will be accepted for use.

Where the scale has not been certified for the current calendar year, the Engineer may randomly test the scale using procedures specified by Weights and Measures Inspection Services and approve the scale for use on the project.

3. Detailed design notes, calculations and Shop Drawings for any temporary works, including falsework, formwork or hoarding, that are sealed, signed and dated by a Professional Engineer registered or licensed to practice in the Province of Manitoba. Shop Drawings are to be submitted to the Engineer prior to the Contractor proceeding with the work. Shop Drawings shall not be required for any temporary works that will be erected to a height less than 1.5 metres.

   For timber falsework, formwork and hoarding, the Shop Drawings shall specify the type and grade of lumber and show the dimensions and spacing of all members. The Shop Drawings shall also show the type, dimensions and spacing of all ties or other hardware and the type, dimensions and spacing of all bracing and support members.

4. A concrete pour plan for review and discussion at the first pre-pour meeting. The concrete pour plan shall be submitted to the Engineer three weeks prior to the first scheduled pour. As a minimum, the concrete pour plan shall identify the following items for each type of concrete:

   (i) Type and class of concrete including specific reference to high performance or mass concrete where applicable;
   (ii) Compressive strength, slump and air content of concrete;
   (iii) Quality control plan identifying type and frequency of tests, as well as an action plan for dealing with non-conformances;
   (iv) Method of placement and any special considerations such as the requirement for use of high range water reducing admixtures (superplasticizers);
   (v) Sequencing requirements for placement of concrete in walls or substructure units with heights in excess of 2.0 metres and lengths in excess of 20 metres;
   (vi) Formwork and shoring requirements;
   (vii) Temperature control requirements (ambient and concrete); and
   (viii) Any other pour-specific items that the Contractor or Engineer may need to address to ensure the successful completion of the pour.

5. A temperature management plan for concrete to be cast in cold weather conditions (see Clause 5.12), where the plan shall include the minimum requirements for monitoring the ambient and concrete temperatures.

6. A temperature management plan for mass concrete. Mass concrete is defined as all structural concrete components or portions thereof with minimum dimensions of 1.0 metres or more in all three directions. The temperature management plan for mass concrete shall include the following minimum requirements for monitoring the ambient and concrete temperatures of each mass concrete pour:

   (i) Thermocouple groupings that consist of three thermocouples installed at 1.0 metre below the top of the mass concrete component. The individual thermocouples shall be installed at the following depths:
      a. Mid-depth;
      b. Inside face of the exterior mat of vertical reinforcement; and
      c. Within 10 millimetres of the concrete surface.
   (ii) Thermocouple groupings shall be installed at the following locations:
      a. One group of thermocouples at mid-length in the pour for mass concrete components less than 20 metres in length;

b. Two groups of thermocouples at third points in the pour for mass concrete components from 20 to 45 metres in length; and
c. Three groups of thermocouples at quarter points in the pour for mass concrete components greater than 60 metres in length.

(iii) Thermocouple readings to monitor and record temperatures as per the following:
a. At completion of the pour;
b. At one-hour intervals for the first 4 hours after completion;
c. At four-hour intervals from 4 to 24 hours after completion; and
d. At daily intervals from 1 to 7 days after completion.

(iv) Thermocouple readings (or calibrated thermometer) to monitor and record ambient temperatures adjacent to the top and side surfaces of the mass concrete at thermocouple group locations.

7. Copies of all material quality control test results.

4.0 MATERIALS

4.1 General

The Contractor is responsible for the supply, storage and handling of all materials set forth in this Specification. Materials are to be obtained from the same source of supply or Manufacturer for the duration of the contract. Storage of materials shall conform to CSA Standards A23.1 (latest version) and A23.4 (latest version). Any change in the materials source(s) shall be reported to and reviewed by the Engineer prior to the Contractor or Concrete Supplier implementing that change.

Materials susceptible to frost damage shall be protected from freezing.

4.2 Materials Supplied by the Engineer

The following materials will be supplied by the Engineer unless specified otherwise in the Special Provisions:

1. Benchmark plug(s); and

2. Identification plaque and cadmium plated screws.

4.3 Concrete

The Contractor shall design and be responsible for the performance of all concrete mixes supplied under this Specification. Concrete shall be designed for the properties and exposure classes shown on the Drawings and as specified in this Specification.

Concrete shall meet the requirements for hardened concrete as specified in **Table 4.1**.

Table 4.1: Performance Requirements for Reinforced Cast-In-Place Concrete

Type of Concrete	Minimum Compressive Strength at 28 Days [MPa]*	Class of Exposure	Air Content Category	Minimum Post-Cracking Residual Strength Index***	Special Requirements
Substructure					
Cast-In-Place Piles, Pile Caps & Spread Footings	35	S-1	1		
Pier Shafts, Pier Tops & Abutments (headwalls, wingwalls, backwalls, & retaining walls)	35	C-1	1		
Cast-in-Place Concrete Culverts and All Other Miscellaneous Concrete	35	C-1	1		
Superstructure					
Diaphragms, Approach Slabs & Transition Slabs	35**	C-1	1		
Curbs & Barriers	45	C-1	1	0.15	Synthetic Fibres
Deck, Overlay & Sidewalk (Conventional Deck Design)	45	C-1	1	0.15	Synthetic Fibres
Deck, Overlay & Sidewalk (GFRP with External Strapping Design)	45	C1	1	0.15	Synthetic Fibres

*For concrete comprising slow reactivity supplementary cementing materials (fly ash, slag, natural pozzolans), the strength values and other hardened properties are required at 56 days.

**Structural design may require compressive strengths for diaphragms that are greater than the minimum compressive strength noted in this Specification In these cases, the minimum compressive strength requirement noted on the Drawings shall govern.

***The minimum post-cracking strength index is required at 7 days.

The water-soluble chloride ion content by mass of cementitious material in the concrete shall not exceed 0.15%.

The temperature of all types of concrete shall be between 5°C and 25°C at discharge. Temperature requirements for mass concrete and concrete containing silica fume shall be between 10°C and 20°C at discharge.

1. Aggregates

    1. General

        All aggregates shall be handled to prevent segregation and inclusion of any foreign substances, and to obtain uniformity of materials. The coarse and fine aggregates, and aggregates secured from different sources, shall be piled in separate stockpiles. The site of the stockpiles shall be cleaned of all foreign materials and shall be reasonably level and firm or on a built-up platform. If the aggregates are placed directly on the ground, material shall not be removed from the stockpile within 150 millimetres of the ground level. This material shall remain undisturbed to avoid contaminating the aggregate being used with the ground material.

Aggregate sieve analysis, on a periodic basis (at minimum once per calendar year) specified by the Engineer, is required for both coarse and fine aggregates to verify gradation compliance with CSA A23.1 (latest version).
If either the coarse or the fine aggregate consists of a blend from more than one source, the aggregate sieve analysis shall show the gradation of the blended aggregates.

The potential for deleterious alkali-aggregate reactivity shall be assessed in accordance with CSA A23.2-14A (latest version) and CSA A23.2-27A (latest version). Current test data evaluating the potential alkali-silica reactivity of aggregates tested in accordance with CSA A23.2-25A (latest version) is required. Current test data evaluating the potential alkali-carbonate reactivity of aggregates tested in accordance with CSA A23.2-26A (latest version) will be required if carbonate-base aggregate is used in the project.

Petrographic examination of the aggregate shall be done by an experienced/certified petrographer employed by a CSA certified laboratory in accordance with CSA A23.2-15A (latest version). The petrographic report shall identify deleterious substances, harmful characteristics, or undesirable components of the aggregate in relation to the specified performance criteria, exposure class and intended use. The report shall also identify potentially reactive constituents and provide recommendations on appropriate mitigation measures required for use of this aggregate in concrete. The report shall confirm that the aggregate is suitable for the specified performance criteria, exposure class and intended use. The weighted petrographic number of aggregates shall not exceed 125 for use in concrete under all exposure classes.

Alkali-aggregate reactivity tests and petrographic examination shall be done on a yearly basis.

2. Coarse Aggregate

The maximum nominal size of coarse aggregate shall be 20 millimetres and meet the grading requirements of CSA A23.1 (latest version), Table 11, Group I. Coarse aggregate shall be uniformly graded and not more than 1% shall pass a 75 µm sieve. Coarse aggregate shall consist of crushed stone or gravel or a combination thereof, having hard, strong, durable particles free from elongation, dust, shale, earth, vegetable matter or other injurious substances. Coarse aggregate shall be clean and free from alkali, organic or other deleterious matter; shall have a minimum of two fractured faces; and shall have an absorption not exceeding 2%.

Coarse aggregates other than crushed stone or gravel or combinations such as recycled concrete aggregates, air-cooled iron blast-furnace slag coarse aggregate, etc. are not permissible unless approved by the Engineer.

The aggregate retained on the 5 millimetres sieve shall consist of clean, hard, tough, durable, angular particles with a rough surface texture, and shall be free from organic material, adherent coatings of clay, clay balls, an excess of thin particles or any other extraneous material.

Tests of the coarse aggregate shall not exceed the limits for standard requirements prescribed in CSA A23.1 (latest version), Table 12, Concrete exposed to freezing and thawing.

When the thickness of deck overlay concrete is specified as 50 millimetres or less, the nominal maximum size of aggregate shall be 14 millimetres.

The shale content shall not exceed 0.5% measured by mass of dry coarse aggregate. The combined amount of ironstone, shale, chert and/or mica shall not exceed 1% by mass of dry coarse aggregate.

3. Fine Aggregate

Fine aggregate shall meet the grading requirements of CSA A23.1 (latest version), Table 10, FA1, be graded uniformly and not more than 3% shall pass a 75 µm sieve. Fine aggregate shall consist of sand, stone, screenings, other inert materials with similar characteristics or a combination thereof, having clean, hard, strong, durable, uncoated grains free from injurious amounts of dust, lumps, shale, alkali, organic matter, loam or other deleterious substances.

Recycled fine aggregate (e.g. from recycled concrete) is not permitted unless approved by the Engineer.

Tests of the fine aggregate shall not exceed the limits for standard requirements prescribed in CSA A23.1 (latest version), Table 12.

2. Admixtures

Air-entraining admixtures shall conform to the requirements of ASTM C260 (latest version).

Chemical admixtures shall conform to the requirements of ASTM C494 (latest version) for conventional mixes and ASTM C1017 (latest version) for flowing concrete.

Cold-weather admixture systems in accordance with ASTM C1622 (latest version) can be used to protect the concrete in cold weather.

All admixtures shall be compatible with all other constituent materials. The addition of calcium chloride accelerators and air-reducing agents, will not be permitted, unless otherwise approved by the Engineer. Trial batches shall be performed to confirm the compatibility of the admixtures used.

Appropriate low range water reducing and/or superplasticizing admixtures shall be used in all concrete containing silica fume.

3. Cementitious Materials

Cementitious materials shall conform to the requirements of CAN/CSA A3001 (latest version) and shall be free from lumps or humidity clusters. Normal portland cement, Type GU or GUb, Portland limestone cement, GUL or GULb, or sulphate resistant, Type HS, HSL, HSb or HSe, shall be supplied unless otherwise specified on the Drawings or in the Special Provisions.

Portland limestone cement, HSL, HSLb, GUL or GULb shall not be used for Class S-1 substructure elements unless approved by the Engineer.

Should the Contractor choose to include a silica fume mineral admixture in the concrete mix design, the substitution of silica fume shall not exceed 8% by mass of normal portland cement. Condensed silica fume shall conform to CAN/CSA A3000 (latest version) – Cementitious Material Compendium, Type SF, with a SiO_2 content of at least 85%, a maximum of 10% ignition loss and no more than 1% SO_3 content.

Should the Contractor choose to include fly ash in the concrete mix design, the fly ash shall be Type F and the substitution shall not exceed 25% by mass of normal portland cement. Fly ash shall conform to CAN/CSA A3000 (latest version) – Cementitious Material Compendium, Type F.

Cementitious materials shall be stored in a suitable weather-tight building that shall protect these materials from dampness and other destructive agents. Cementitious materials that have been stored for a length of time resulting in the hardening or the formation of lumps shall not be used in the Work.

4. Water

Water to be used for mixing and curing concrete or grout and saturating the substrate shall be potable, shall conform to the requirements of CSA A23.1 (latest version) and shall be free of oil, alkali, acidic, organic materials or deleterious substances. The Contractor shall not use water from shallow, stagnant or marshy sources.

Water of unknown quality shall satisfy the requirements listed in Table 9 of CSA A23.1 (latest version).

5. Synthetic Fibres

The synthetic fibres for the deck, overlay, sidewalk, curb and barrier concrete shall consist of 100% synthetic (non-metallic) fibres. The dosage shall be designed by the Contractor to meet the requirements for post-cracking residual strength as specified in Clause 4.3, Table 4.1.

Synthetic fibres must be approved as identified in MTI's Approved Products List – Bridges & Structures and shall be to the satisfaction of the Engineer. Any synthetic fibre that is not in MTI's Approved Products List will be subject to approval by the Engineer.

4.4 Formwork

Forms for exposed surfaces shall be made of good quality plywood in "like-new" condition and uniform in thickness, with or without a form liner.

4.5 Non-Shrink and Non-Metallic Grout

Non-shrink and non-metallic grout must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any non-shrink or non-metallic grout that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.6 Insulation

Insulation shall conform to the requirements of ASTM C578 Type 6 or 7, minimum compressive strength 275 kPa, 50 millimetres thick polystyrene or as specified on the Drawings.

Insulation must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any insulation that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.7 Curing Compound

Curing compound shall conform to ASTM C309 (latest version), Type 1-D with fugitive dye or Type 2 white pigmented, as approved by the Engineer.

Where a curing compound is specified to be used, two coats shall be applied.

Type 2 white pigmented shall only be used on the surfaces of bridge decks, approach slabs, structural slabs, on surfaces that will not be exposed to view or on surfaces where their use has been approved by the Engineer.

4.8 Evaporation Reducer

Evaporation reducer must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be used in conformance with the manufacturer's recommendations and to the satisfaction of the Engineer. Any evaporation reducer that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.9 Architectural Concrete Form Liner

Architectural concrete form liner shall be as specified on the Drawings, in the Special Provisions or as approved by the Engineer.

4.10 Permeable Formwork Liner

Permeable formwork liner, required for both faces of the concrete barrier faces or as specified on the Drawings, must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any permeable formwork liner that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.11 Preformed Expansion Joint Filler

Preformed expansion joint filler as specified on the Drawings or in the Special Provisions shall be asphalt impregnated fibreboard satisfying ASTM D1751 (latest version). Preformed expansion joint filler must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any preformed expansion joint filler that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.12 Preformed Contraction Joint Filler

Preformed contraction joint filler as specified on the Drawings or in the Special Provisions shall be 13 millimetres thick polystyrene conforming to the requirements of ASTM C578 Type 10, with a minimum compressive strength of 100 kPa. Preformed contraction joint filler must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any preformed contraction joint filler that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.13 Flexible Joint Sealant

Flexible joint sealant shall be grey polyurethane sealant. Flexible joint sealant must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any flexible joint sealant that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.14 Impregnated Expanding Foam Sealant

Impregnated expanding foam sealant must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any impregnated expanding foam sealant that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer. The Manufacturer's recommended top coat shall be used for traffic bearing applications.

4.15 Hot Poured Joint Sealer

Hot poured joint sealer must be approved as identified in MTI's Approved Products List – Bridges and Structures and shall be to the satisfaction of the Engineer. Any hot poured joint sealer that is not in MTI's Approved Products List – Bridges and Structures will be subject to approval by the Engineer.

4.16 Water Stops

Water stops shall be as specified on the Drawings or as approved by the Engineer and shall be the correct grade for the location that they are to be used.

4.17 Miscellaneous

Miscellaneous materials shall be as specified on the Drawings, in the Special Provisions, or as approved by the Engineer.

5.0 CONSTRUCTION METHODS

5.1 Supplying Concrete

1. Pre-Pour Meetings

The Contractor, his/her on-site construction superintendent and his/her concrete supplier shall attend the following pre-pour meeting(s) with representatives of the Water Control and Structures, Design and Construction Branch at a mutually agreed upon date(s) to review the concrete pour plan and to discuss general and specific issues affecting the proposed pours:

(i) Two weeks prior to the first scheduled pour on-site; and
(ii) Two weeks prior to the first scheduled pour using high performance concrete (fibre reinforced) for deck, curbs or barriers (if applicable).

The concrete pour plan may be revised at the request of the Contractor or Engineer based on discussions at the pre-pour meeting. The Contractor shall not proceed until a revised concrete pour plan has been submitted and written approval has been received from the Engineer.

2. Proportions of Concrete Materials

Coarse and fine aggregate materials shall be separated and measured separately by weighing, except in cases where other methods are approved by the Engineer. The apparatus provided for weighing the aggregates and cement shall be suitably designed and constructed for this purpose and approved by the Engineer. The course and fine aggregate as well as the cement shall be weighed separately. The precision of all weighing devices shall be such that successive quantities can be measured to within 1% of the desired amount. The mixing water shall be measured by volume or by weight and adjusted for retained moisture in the aggregates. The water measuring device shall be capable of control accurate to ± 0.5% of the design quantity. All measuring devices shall be approved by the Engineer. Unless otherwise approved, air entraining agent and other admixtures shall be added to the mix in a water-diluted solution. The dilution of the solution shall meet the Manufacturer's requirements. For mix adjustments at the site, the Contractor shall maintain facilities and equipment to control the amount of superplasticizer and air entrainment so that the required tolerances can be met.

The Contractor shall ensure that all scaling devices have been calibrated within one year and shall submit the relevant certificates to the Engineer. They shall be tested and approved for accuracy prior to the commencement of batching operations. Scaling devices shall be subject to testing by the Engineer at any time. The standard masses used for the testing of scaling devices shall be supplied to the Engineer. No adjustments to scaling devices shall be made without the Engineer's approval.

When sacked cement is used, the quantities of the aggregates for each batch shall be exactly sufficient for one or more full sacks of cement and no batch requiring fractional sacks of cement shall be permitted.

When ice is used as part of the mixing water, the ice shall be measured by mass. The ice shall be completely melted by the time mixing is completed.

For concrete containing silica fume added separately from the cement, (not as a blended cement), the silica fume shall be added to the aggregate with the cement. Silica fume shall not be added to a truck mixer in pulpable bags.

Only trained personnel shall be allowed to introduce admixtures at the job site. The Contractor shall submit the proposed procedures for adding admixtures in approved dosages at the job site in the concrete pour-plan submittal Mixing Concrete.

1. General

   Ready-mix concrete shall be mixed and delivered by one of the following operations:

   1. Mixed completely in a stationary mixer and the mixed concrete transported to the point of delivery in a truck agitator or in a truck mixer operating at agitating speed; or

   2. Mixed completely in a truck mixer.

   Continuous mixers used in conjunction with volumetric proportioning will not be approved. The use of non-agitating trucks for delivering concrete mixed off-site will not be permitted.

2. Stationary Mixer

   The mixing of concrete shall be done in a batch mixer of a size and type suitable for the intended use. Mobile continuous mixers or other such concrete supply equipment will not be approved for use.

   Each mixer and agitator shall have attached by the Manufacturer in a prominent place, a metal plate or plates on which it is plainly marked the various uses for which the equipment is designed, the capacity of the drum or container in terms of the volume of concrete that can be mixed or agitated and the speed of rotation of the mixing drum or blades.

   All concrete shall be mixed thoroughly until it is uniform in appearance, with all ingredients uniformly distributed. In no case shall the mixing time per batch be less than two minutes for mixers of one cubic metre capacity or less. The “batch” is considered as the quantity of concrete inside the mixer. This figure shall be increased by 30 seconds for each additional half cubic metre capacity or part thereof. The mixing period shall be measured from the time all materials are in the mixer drum.

   The effective mixing time to achieve adequate uniformity and homogeneity of the mixed concrete shall be determined for each mix according to the constituents used and shall be approved by the Engineer.

   Stationary mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged before the specified mixing time has elapsed.

   Batches shall be used that do not require fractional bags of cement.

   Each batch shall be entirely discharged from the mixer before any of the ingredients for a following batch shall be placed in the drum of the mixer.

   All water used for cleaning the inside of the drum of the mixer shall be entirely drained before ingredients for a batch of concrete shall be placed in the drum.

   The Contractor shall in no case load the mixer above its rated capacity. The Contractor shall maintain the mixer in good condition. Inner surfaces of the mixer shall be kept free of hardened concrete and mortar. Mixer blades that are bent or worn down so as to affect the mixing efficiency shall be repaired. Any mixer leaking mortar or causing waste of materials through faulty charging shall be taken out of service until repaired. The Contractor shall, at all times, operate the mixer at the speed recommended by the Manufacturer and shall, if requested, supply the Manufacturer's certification of the mixing capacity of the machine in use.

The mixer shall be fitted with an accurate and dependable means for measuring the water added that is not affected by variation in pressure in the water supply line. All joints, valves and other parts shall be maintained so that there is no leakage of water into the mixer drum. Failure of the Contractor to have an accurately working and dependable water gauge on a mixer shall be cause for the Engineer to prohibit the mixer to be used.

Water shall be released first and continue to flow while the solid materials are entering the mixer. The water discharge pipe shall be so arranged and be of such size that the flow into the mixer is completed within the first quarter of the mixing time, and the water is delivered well within the mixer where it will be quickly mixed with the entire batch.

Air entraining agents and admixtures shall be placed in the mixer after the initial water is in the mixer drum but before the remaining materials are added. Superplasticizer shall be added after initial mixing and as per the Manufacturer's recommendation.

A record of the actual proportions used for each batch shall be kept by the Contractor and a copy of this record shall be submitted to the Engineer after each pour.

The Engineer may, from time to time, make slump tests of individual batches in order to determine the uniformity of the concrete consistency at approximately one-quarter and three-quarter points of the load. If these tests indicate a variation in the slump exceeding 25 millimetres, the mixer or agitator shall not be used until the condition is corrected.

3. Truck Mixing

Truck mixers shall be of the revolving drum type, watertight, and constructed so that the concrete can be mixed to ensure uniform distribution of materials throughout the batch. All materials for the concrete shall be accurately measured in accordance with Section 5.1.2 and charged concurrently at the proportions that satisfy the approved mix design into the drum at the proportioning plant. Increases in water/cementitious ratio is not permitted in any situation.

The maximum size of batch in truck mixers shall not exceed the maximum rated capacity of the mixer as stated by the Manufacturer and stamped in metal on the mixer, based on the purpose of using the truck mixer (agitating or mixing).

For mixing concrete, truck mixing shall commence immediately upon introduction of ingredients into the drum and be continued for not less than 70 revolutions and not more than 100 revolutions. The speed shall not be less than 6 revolutions per minute (rpm), nor more than 18 rpm according to the truck mixer manufacturer.

For agitating concrete, the speed should not be more than six drum revolutions per minute.

When adjustment to the mix by adding air entrainment or superplasticizer at the site is approved by the Engineer, the mixer shall be run for a minimum of 30 additional revolutions to ensure homogeneity of the concrete before discharge. Adding water on route or on-site will not be permitted.

Discharge chutes shall be kept clean and free from hardened concrete and shall be wetted down prior to use.

3. Time of Hauling

The maximum time allowed for all types of concrete to be delivered to the site of the Work, including the time required to discharge, shall not exceed 90 minutes after batching or before the drum has reached 300 revolutions, whichever comes first. Batching of all types of concrete is considered to

occur when any of the mix ingredients are introduced into the mixer, regardless of whether the mixer is revolving. For concrete that includes silica fume, this requirement is reduced to 60 minutes.

Each batch of concrete delivered to the site shall be accompanied by a time slip issued at the batching plant, bearing the time of batching. In hot or cold weather, or under conditions contributing to quick stiffening of the concrete, a time less than 90 minutes may be specified by the Engineer as required. The Contractor will be informed of this requirement in the coordination meetings for the pouring plan or 24 hours prior to the scheduled pouring of concrete.

To avoid the reduction of delivery and discharge time in hot weather, the Contractor will be allowed to use crushed ice or chilled water as a replacement for a portion of the mixing water, after approval from the Engineer, provided the specified *w/cm* is maintained. All the ice shall be melted completely before discharging any of the concrete at the delivery point.

Under no circumstances shall the Contractor add retarders to the concrete mix without first obtaining the written approval of the Engineer.

The concrete, when discharged from truck mixers or truck agitators, shall be of the consistency and workability required for the job without the use of additional mixing water (design *w/cm* shall be maintained).

A record of the actual proportions used for each concrete pour shall be kept by the Supplier and a copy of this record shall be submitted to the Engineer upon request.

4. Delivery

The Contractor shall verify that the Supplier has sufficient plant capacity and adequate transporting equipment to ensure continuous delivery at the required rate. The rate of delivery of concrete during concreting operations shall be such that the development of cold joints will not occur, according to the concrete pour plan. The methods of delivering and handling the concrete shall facilitate placing with a minimum of re-handling, and without damage to the structure (e.g. formworks) or altering the concrete stability (e.g. segregation).

The concrete production facility shall have radio or telephone communication with the personnel in charge of the placement operations.

5. Pour Schedules and Sequencing

The Contractor shall provide to the Engineer the proposed pour schedule for all concrete pours. If, in the opinion of the Engineer, the amount of a pour is deemed larger than can be poured with the facilities provided, the Contractor shall either:

a) Limit the amount to be poured at any time (using adequate construction joints) as approved by the Engineer; or

b) Augment the available facilities, labour and equipment in order to complete the proposed pour; or

c) In the case of continuous pouring, provide additional crews and have adequate lighting to facilitate proper placing, finishing, curing and inspection.

The Contractor shall adhere strictly to the concrete pouring schedule, if specified on the Drawings or in the Special Provisions.

For monolithic fully formed components, concrete for columns, substructure units, culvert walls and other similar vertical members shall be placed and allowed to set and settle for a period of time before concrete for integral horizontal members, such as caps or slabs, is placed. The

time period shall be adequate to allow completion of settlement due to loss of bleed water and shall be not less than 12 hours for vertical members over 4.5 metres in height, not less than 4 hours for members between 3.0 and 4.5 metres in height and not less than 2 hours for members between 1.5 and 3.0 metres in height. When supplementary cementitious materials, blended cements, special cements, retarders or accelerators are used, this period may need to be adjusted and approved by the Engineer. All walls greater than 2.0 metres in height shall be placed in lifts. Concrete placement of the lifts shall be sequenced to ensure that horizontal and/or vertical cold joints do not occur in the concrete.

Concrete shall not be placed in the superstructure until the substructure forms have been stripped sufficiently to determine the character of the supporting substructure concrete.

Concrete for cast-in-place deck girder spans whose depth is less than 1,200 millimetres may be placed in one continuous operation or may be placed in two separate operations: first, to the top of the girder stems, and second, to completion. For cast-in-place deck girder spans more than 1,200 millimetres in depth, the concrete shall be placed in two operations unless the falsework is non-yielding. At least 5 days shall lapse after placement of stems, or the specified concrete strength has been attained before the top deck slab is placed.

For cast-in-place box culverts, the base slab shall be placed and allowed to gain 50% of the design compressive strength before the remainder of the culvert concrete is placed. For culverts with wall heights 1,500 millimetres or less, the sidewalls and top slab may be placed on one continuous operation. For higher culvert walls, the requirements for vertical members described above shall apply.

5.2 Falsework and Formwork

1. General

The Contractor shall construct the formwork and falsework in accordance with the submitted Shop Drawings. Variations from the formwork and falsework Shop Drawings will not be permitted unless the Engineer is provided with revised Shop Drawings that have been sealed, signed and dated by the Professional Engineer.

2. Design

The design, fabrication, erection and use of concrete formwork shall conform to the requirements of CSA S269.1 (latest version) and CSA A23.1 (latest version).

All forms shall be of wood, metal or other materials as approved by the Engineer, and shall be designed and built mortar-tight. The forms shall be sufficiently rigid to prevent distortion during construction operations including placing and curing of the concrete, due to the pressure of vibrated concrete and other loads incidental to the construction operations. The forms shall be substantial and unyielding, and shall be designed so that finished concrete will conform to the design dimensions and contours. The shape, strength, rigidity, water tightness and inner surface smoothness of re-used forms shall be maintained at all times. Any warped or bulged formwork shall not be used. Forms that are deemed unsatisfactory by the Engineer in any respect shall not be used. Form alignment shall be smooth and true to prevent misaligned edges or corners. Concrete surfaces that are misaligned shall be repaired by the Contractor in a manner acceptable to the Engineer.

Form release agents are to be applied to all forms contact surfaces to prevent bond and thus facilitate stripping. They can be applied permanently to form materials during manufacture or applied to the form before each use. When applying form release agents in the field, the Contractor shall avoid coating adjacent construction joint surfaces or reinforcing steel. Form release agents applied to these areas shall be cleaned to the satisfaction of the Engineer.

The tying of forms with wires or welded ties or the driving of bolts or nails by hand or by power tools into exposed and finished concrete surfaces will not be permitted.

For narrow walls and columns, where the bottom of the form is inaccessible, or wherever necessary, removable panels shall be provided in the bottom form panel to enable cleaning out of extraneous material immediately before placing the concrete.

The supporting of formwork on mudsills on the ground will not be permitted.

No drilling into concrete to support formwork will be permitted unless approved by the Engineer.

Falsework shall conform to CSA S269.1, Falsework & Formwork. All falsework shall be designed and constructed to provide the necessary rigidity and to support the loads without appreciable settlement or deformation.

Falsework shall be set to give the completed structure the camber specified on the Drawings, and allowance shall be made for dead load deflection and form crushing.

3. Forms for Exposed Surfaces

All form material for exposed surfaces shall be full-sized sheets in good condition and approved by the Engineer. The re-use of any forms shall be approved by the Engineer.

All forms for exposed surfaces shall be mortar-tight, filleted at all sharp corners, and given a bevel or draft in the case of all projections. At the top edges of exposed surfaces, the chamfers are to be formed by chamfer strips. Where fillets have been omitted, the concrete shall be thoroughly worked into the corners of the forms and, upon removal of the forms, the sharp edges of the concrete shall be carefully rubbed down to a 6 millimetres radius. The form lumber for filleted corners shall be a hard grade lumber which will leave a sharp, straight edge.

Metal bolts or anchorages within the forms shall be so constructed as to permit their removal to a depth of at least 50 millimetres from the concrete surface. Break-back type form ties shall have all spacing washers removed and the tie shall be broken back a distance of at least 50 millimetres from the concrete surface. All fittings for metal ties shall be of such design that, upon their removal, the cavities which are left will be of the smallest possible size. Torch cutting of steel hangers and ties will not be permitted. Formwork hangers for exterior surfaces of decks and curbs shall be an acceptable break-back type with surface cone, or removable threaded type. Cavities shall be filled with cement mortar and the surface left sound, smooth, even and uniform in color.

4. Architectural Concrete Finish Form Liner

The Contractor shall supply and install the architectural concrete finish form liner as shown on the Drawings or described in the Special Provisions in accordance with the Manufacturer’s recommended procedures.

Single use architectural concrete finish form liner shall be replaced after each use and their reuse shall not be permitted.

5. Permeable Formwork Liner

   The Contractor shall use an approved permeable formwork liner for all areas shown on the Drawings or described in the Special Provisions. The permeable formwork liner shall be replaced after each use unless otherwise approved by the Engineer.

6. Removal of Falsework and Formwork

   The Contractor is responsible for design, construction and safety of formwork. All formwork and falsework must be removed from the completed structure. Formwork and falsework shall not be removed without the approval of the Engineer.

   The minimum period during which forms and supports for concrete structures must remain in place are listed in Table 5.1 and are defined by the "Time" and the "Strength" requirements. The time requirement is based on a minimum average concrete curing temperature of 15ºC. The strength requirement refers to the minimum strength of field cured cylinders as a percentage of the specified 28 day or 56 day compressive strength.

   The minimum requirements shown in the Table 5.1 are to be defined by both “Time” and “Strength”, unless otherwise approved by the Engineer.

   If high early-strength concrete or accelerators are used, these periods may be shortened as approved by the Engineer. If ambient temperatures remain below 15°C, or if retarders or slowly reactive materials such as fly ash are used, these periods may be extended at the discretion of the Engineer.

   Other concrete tests or procedures (refer to ACI 228.1R, latest version) can be used such as the maturity method, rebound numbers, penetration resistance or pullout tests, but these methods should be correlated to the actual concrete mixture used in the project, periodically verified by job-cured specimens, and approved by the Engineer.

   The Contractor will identify who will prepare the specimens and who will perform the tests. Results of such tests, as well as records of weather conditions and other pertinent information, should be recorded by the Contractor.

   When standard beam or cylinder tests are used to determine stripping times, test specimens should be cured under conditions that are not more favorable than the most unfavorable conditions for the concrete the test specimens represent. The curing records may serve as the basis on which the Engineer will determine the review or approval of form stripping.

   In no case should supporting forms and shores be removed from horizontal members before the concrete has achieved the strength specified by the Engineer.

Table 5.1: Minimum Requirements for Removal of Formwork, Placement of Superimposed Vertical Loads, and Placement of Backfill

Structural Element	Removal of Formwork		Placing Superimposed Vertical Dead Loads*		Placement of Backfill	
	Time (days)	Strength (% f'c)	Time (days)	Strength (% f'c)	Time (days)	Strength (% f'c)
Deck Slab and Diaphragms	7	70	14	85	n/a	n/a
Pier Soffits, Shafts, and Cap	14	85	14	85	n/a	n/a
Footing and Pile Cap	3	30	7	70	14	85
Retaining Wall, Headwall and Wingwall	3	30	7	70	14	85
Curb and Traffic Barrier	3	30	7	70	n/a	n/a
Abutment Backwall, Rigid Frame Wall and Box Culvert Walls	3	30	7	70	14	85

*Examples include placement of column on footing or pile cap, girder on pier or pier cap, etc.

The days noted in the Table above do not include the day of casting the concrete.

In using the Table, consideration shall be given to the location and character of the structure, the weather and other conditions influencing the setting of the concrete, and the material used in the mix. The use of fly ash or set retarding admixtures shall require special consideration and may require additional curing time as specified by the Engineer.

Supports and forms may be removed from substructure units (SU's), diaphragms and traffic barriers earlier than the minimum curing periods specified, provided that the Contractor continues to cure the concrete in accordance with Clause 5.13 of this Specification and the Engineer has granted approval. In seeking approval, the Contractor shall, at his own expense, furnish evidence satisfactory to the Engineer that the strength of the concrete in place has attained the specified percentage of the specified 28 day strength before removal. Removal of forms prior to the minimum curing periods does not remove the Contractor's obligation to cure the exposed concrete for the minimum time periods specified for curing as stated in Clause 5.13 of this Specification. Each day the concrete remains in the forms with wet curing of the top surface at or above the minimum temperature will count towards one day of equivalent curing.

When the Contractor desires cylinder testing for other than 7 and 28 day (56 day for Class S-1) testing, it shall be the responsibility of the Contractor to supply the field cured cylinders in accordance with CSA A23.1/A23.2 (latest version). Field cured cylinders cast for strength testing for form removal shall be cured in the field under the same conditions as the concrete they represent.

The "Strength" and "Time" requirements listed in Table 5.1 are intended only for construction operations indicated and do not apply for the use of heavy equipment (e.g. concrete trucks) or other live loads on the structure. Before this type of loading can be applied to the structure, the field cured cylinder strength shall have attained 85% of the design compressive strength, the concrete shall be at least 14 days old), and the intended superimposed load should be not more than 70% of the designed load. Stockpiling of materials and the use of unauthorized equipment on the structure will not be permitted.

Methods of form removal likely to cause overstressing of the concrete shall not be used. Supports shall be removed in such a manner as to permit the concrete to take, uniformly and gradually, the stresses due to its own weight.

Upon removal of the forms or protection, surface cavity repairs, finishing and curing of the exposed areas shall begin immediately.

Falsework under all deck spans shall be completely released before forms are constructed and concrete is placed for traffic barriers and curb.

Forms for substructure footings constructed within cofferdams or cribs may be left in place, when, in the opinion of the Engineer, their removal would endanger the safety of the cofferdam or crib, and when the forms so left intact will not be exposed to view in the completed structure or have any long-term detrimental impact to the completed structure.

5.3 Placing Preformed Expansion Joint Filler

Preformed expansion joint filler shall be installed at the joints indicated on the Drawings and retained in these positions during and after the depositing of concrete.

5.4 Placing Preformed Contraction Joint Filler

Preformed contraction joint filler shall be installed at the joints in the cast-in-place curb and barriers indicated on the Drawings and retained in these positions during and after the depositing of concrete.

5.5 Placing Pourable Joint Fillers

Pourable joint fillers shall be placed as detailed on the Drawings and in accordance with Manufacturer's specifications.

Contraction and construction joints subject to construction vehicle traffic shall be protected from damage for the duration of construction. Repairing damaged joints shall be the responsibility of the Contractor. Two-component fillers shall be mixed by means of a mechanical mixer. Sand filler, if required, shall be placed by means of a funnel.

The concrete surfaces to which the joint filler is to adhere shall be clean, and when called for on the Drawings, shall be roughened through sand-blasting or shot-blasting.

5.6 Placing Water Stops

Water stops shall be placed at the joints as shown on the Drawings and retained in these positions during and after the depositing of concrete.

The type, size, location and material of water stops shall be as provided in the Drawings or Special Provisions or as approved by the Engineer. Joints in water stops shall be made in accordance with the Manufacturer’s recommendations.

5.7 Placing Hardware and Anchor Bolts

Anchor bolts and hardware shall be placed in accordance with Clause 6.7 of CSA A23.1 (latest version).

5.8 Insulation for Concrete Culverts

Insulation shall be placed as shown on the Drawings. For concrete culverts, the insulation shall be placed under the bottom slabs, wingwalls and cut-off walls as well as against the rear vertical face of the cut-off walls.

The insulating material shall be placed uniformly on top of the prepared bedding with the joints in a staggered pattern. The insulation shall be enclosed entirely in 6 mil (0.15 millimetres) polyethylene and all joints in the polyethylene shall be sealed with polyvinyl tape.

5.9 Labour Force

1. General

The Contractor's crew shall include the following workers who are skilled and experienced in placing the type of concrete that they are working with:

- Superintendent
- Concrete Finishers
- Operator of the concrete pump

The Engineer will have the authority to require the replacement of any particular worker not adequately skilled for his assigned task, and the addition of other workers, if necessary.

2. Night Pouring of Concrete

Night pouring of concrete will not be allowed without the approval of the Engineer. The Contractor shall provide the Engineer with a detailed night pouring plan including sufficient labour and equipment available to carry out the Work as specified.

5.10 Handling and Placing Concrete

1. General

The Contractor shall give the Engineer a minimum of 2 days advance notice of a concrete pour date (even if it is reported in the approved pouring schedule/plan) or a change to a pour date.

Concrete placing shall not be started until the Engineer has inspected and approved all relevant concrete placing practices, preparations and equipment including forms, foundations, reinforcement, as well as methods of mixing, conveying, spreading, consolidating, finishing, curing and protection of the concrete. Concrete shall not be placed at the job site if there is a possibility of damage to the concrete from unforeseen weathering conditions (e.g. rain, snow) or mechanical influences such as vibration caused by other operations (e.g. pile driving). As a minimum, the concrete shall be allowed to cure for a period of 3 days from the time the concrete was placed and has reached 30% of the specified 28 day (56 day for Class S-1) compressive strength before these other operations that might affect the cast concrete can resume.

All equipment proposed for use in mixing, conveying, placing and compacting the concrete shall be approved by the Engineer prior to its use. All the necessary equipment for any particular pour shall be on-site and proven to be in working condition before the pour commences, with backup equipment on-site as determined by the Engineer. The equipment shall be well maintained, suitable in kind and adequate in capacity for the work.

In preparation for the placing of concrete, all sawdust, chips and other construction debris and extraneous matter shall be removed from the interior of forms. Struts, stays and braces, serving temporarily to hold the forms in correct shape and alignment, pending the placing of concrete at their locations, shall be removed when the concrete placing has reached an elevation rendering their service unnecessary. These temporary members shall be entirely removed from the forms and not buried in the concrete.

The concrete shall be placed in a manner approved by the Engineer, and the concrete placing shall not begin until the Engineer's approval has been obtained. Concrete placing shall not be permitted when it is raining, snowing or when the air temperature is below 5°C or above 30°C or when the surface moisture

evaporation rate is in excess of 0.75 kg/square metre per hour as determined by CSA A23.1 (latest version), Appendix D, “Guidelines for Curing and Protection” unless a mitigation plan is submitted by the Contractor and approved by the Engineer. The Engineer may stop the Contractor from placing concrete in the event of adverse or even threatening adverse weather conditions when, in the Engineer’s opinion, these weather conditions may adversely influence the proper placing of the concrete. The Engineer’s decision in this matter will be final.

Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. When placing operations would involve free drop of concrete by more than 1.5 metres, it shall be deposited through metal or other pipes as approved by the Engineer. The use of chutes for the placing of concrete, except those forming a part of standard equipment on ready-mix concrete trucks, will not be permitted.

Concrete for the structure shall be placed in the forms in the concrete placement sequence shown on the Drawings, and each portion placed between construction joints shall be placed in one continuous operation. No other order of pouring shall be undertaken unless otherwise approved by the Engineer.

The concrete shall be placed in such frequent locations in the forms that there shall be no necessity for moving large quantities of concrete from place to place within the forms. Any movement of concrete required within the forms shall be done by shovelling and not with mechanical vibrators. The concrete shall be placed in layers not exceeding 600 millimetres in depth and each layer shall be vibrated by mechanical methods that will not permit the ingredients to segregate. The Contractor shall provide and use different personnel for shovelling and for vibrating to ensure that each batch of concrete is properly placed and vibrated as it is being placed, before workability loss takes place.

Whenever possible, the placement of concrete in each unit of the structure shall be a single continuous complete operation so that each unit shall be monolithic without joints.

When placing concrete in a deep beam, wall or column that is intended to be continuous and monolithic with the slab above, a delay of a maximum of 2 hours shall be scheduled before placing the upper slab or soffit concrete to allow for settlement of the lower concrete.

Where concrete is to be placed in two or more stages and where a monolithic structure is required, the upper portion shall be placed as soon as the lower portion has stiffened sufficiently. The concrete in the lower portion shall be designed so as to minimize bleeding. Any free water or laitance shall be removed before the next layer of concrete is placed.

Concrete placing operations shall not work off, or transport concrete directly over, concrete already placed, when this concrete is less than 48 hours old, no matter what system of runways, supports or protection is used on the surface of the concrete already placed, if it is subjected thereby to live or dead loads. Concrete more than 48 hours old but of less than the specified 28 day or 56 day strength shall not be loaded by any means (e.g. storage of materials) without the approval of the Engineer.

2. Vibration of Concrete

Concrete shall be mechanically compacted thoroughly and uniformly to obtain a dense and homogeneous structure free of cold joints, fill planes, voids and honeycombing. Formed surfaces shall be smooth and free from large air and water pockets. The concrete shall be well bonded to all reinforcement, hardware anchors, water stops and other embedded parts.

Concrete, during and immediately after placing, shall be thoroughly consolidated. The consolidation shall be done by mechanical vibration subject to the following conditions:

a) Internal vibrators shall be used in all sections that are sufficiently large with adequate spacing of the reinforcement that allows passage of internal vibrators, while they shall be supplemented by platform or screed-type vibrators in the event that satisfactory top surfaces cannot be obtained with the internal

type alone. The internal vibrators may be supplemented with external vibrators operated against the outside of the forms to improve vertical surfaces.

b) Vibrators shall be capable of consolidating the concrete with a minimum duration of vibration, without causing segregation and/or negative impact to air-entrainment.

c) The vibration shall be internal unless approval of other methods is given by the Engineer, or the Engineer requests the use of other methods.

d) Vibrators shall be of a type and design approved by the Engineer. They shall be capable of transmitting vibrations to the concrete at frequencies of not less than 4,500 impulses per minute.

e) The Contractor shall provide a sufficient number of vibrators to properly compact each batch immediately after the concrete has been placed in the forms.

f) At least one extra vibrator shall be on hand for emergency use.

g) Vibrator operators shall be suitably instructed in the use of vibrators, and the importance of adequate and thorough vibration of the concrete.

h) Vibrators shall be manipulated so as to thoroughly work the concrete around the reinforcement and imbedded fixtures and into the corners and angles of the forms. Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be inserted vertically and withdrawn out of the concrete slowly in a vertical direction to facilitate the removal of entrapped air bubbles. The vibration shall be of sufficient duration and intensity to thoroughly compact the concrete but shall not be continued so as to cause segregation. Vibration shall not be continued at any point to the extent that localized areas of grout are formed.

i) Vibrators shall be applied systematically and at such spacing intervals that the zones of influence overlap and the vibrator penetrates the upper part of the previously placed lift of the concrete by its own mass and vibration.

j) Vibration shall not be applied directly or through the reinforcement of sections or layers of concrete that have hardened to the degree that the concrete ceases to be plastic under vibration.

k) Vibration shall not be used to make concrete flow in the forms over distances so great as to cause segregation, and vibrators shall not be used to transport concrete in the forms.

l) Superplasticized flowing concrete mixes can have a tendency to segregate easily and require less effort to consolidate.

m) Vibration shall be supplemented by spading as necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations impossible to reach with the vibrators.

n) Form vibrators shall be attached to the forms in such a manner as to transmit the vibration to the concrete effectively and the vibrators shall be raised in lifts as filling of the forms proceeds. The dimension of each lift shall not be more than the height of concrete visibly affected by the vibration. The form vibrators shall be placed horizontally apart at distances that the zones of influence overlap.

3. Additional Requirements

When concrete placing is discontinued, for whatever reason, all accumulations of mortar splashed on the reinforcement and the form surfaces shall be removed. Dried mortar chips and dust shall not be mixed into the plastic concrete. If the accumulations are not removed prior to the concrete hardening, care shall be exercised not to damage or break the concrete-reinforcement bond at and near the surface of the concrete, while cleaning the reinforcement.

Re-tempering of partially hardened concrete with additional water will not be permitted.

After initial set of the concrete, the forms shall not be jarred, and strain shall not be placed on the projecting ends of reinforcement.

Until initial set has been achieved, concrete shall be protected from the presence of freestanding water on the surface. The Contractor shall take whatever steps may be necessary to prevent free water accumulating on the surface in the event of unexpected rainfall or similar occurrences.

Water used to clean equipment during and at the end of the pour shall be discharged clear of the structure and prevented from entering any watercourse.

4. Pumping of Concrete

When the Contractor chooses to pump the concrete, the operation of the pump shall produce a continuous flow of concrete without air pockets. The equipment shall be arranged such that vibration is not transmitted to the freshly placed concrete that may damage the concrete. When pumping is completed, the concrete remaining in the pipeline, if it is to be used, shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients.

When concrete is placed by pumping, grout, mortar or chemical lubricant used to lubricate pipelines shall not be discharged into the forms. Washout or wash-down water shall not be discharged into the forms.

5.11 Construction Joints

Constructions joints shall be constructed only as indicated on the Drawings or as shown in the pouring schedule, unless otherwise approved by the Engineer.

All construction joints on vertical surfaces shall be formed and poured with a double 20 millimetres chamfer, placed symmetrical about the construction joint, unless otherwise is shown in the Drawings/Special Provisions or directed by the Engineer.

The sides of construction joints shall be formed as shown on the Drawings or as directed by the Engineer to produce even and straight lines on exposed concrete surfaces.

The surface of hardened concrete at construction joints shall be thoroughly cleaned. In accordance with CSA A23.1 Clause 7.3.1.3, regarding the bonding of fresh concrete to rock or hardened concrete where the concrete has hardened sufficiently so that the aggregate cannot be loosened from the surface, laitance shall be removed by exposing the surface of the concrete aggregates by either a brisk wire brooming, green cutting water blasting shortly after initial set or by a light bush hammer to expose the tops of the surface aggregate to create a bond acceptable to the Engineer. The surface of the construction joint shall then be misted (to saturated surface dry) immediately before placing the new concrete. Where a bonding agent is used, surface treatment shall be as recommended by the manufacturer.

Before depositing new concrete on or against concrete that has hardened, the forms shall be re-tightened. To ensure the availability of mortar at the joint between the hardened and the newly deposited concrete, the cleaned and saturated surfaces, including vertical and inclined surfaces, shall first be covered thoroughly with

a coating of neat cement grout against which the new concrete shall be placed before the grout has attained its initial set (i.e. grout *w/c* to match concrete designed mix *w/c*).

The grout shall have a slump of not less than 150 millimetres and the concrete placed against this grout shall be well vibrated in order to ensure that the concrete and the grout are intermixed.

At construction joints where concrete is only a few hours old and is still green, and if the surface is not dirty, dry, or covered with an appreciable layer of laitance, it will not be necessary to prepare such a surface before placing new concrete.

When called for on the Drawings or in the Special Provisions, construction joints shall be coated with an epoxy resin in accordance with the Manufacturer's specifications immediately prior to the placing of the fresh concrete. The joint shall be free of all dirt, dust and loose or feathered concrete before the epoxy resin is applied.

5.12 Cold Weather Precautions

1. General

   The conditions of cold weather concreting exist when the air temperature has fallen to, or is expected to fall below, 5°C during the protection period. The protection period is defined as the amount of time recommended to prevent concrete from being adversely affected by exposure to cold weather during construction.

   When the ambient temperature falls below 5°C or when there is a probability of it falling below 5°C within 24 hours of placing the concrete, the Contractor shall make provisions for heating the water, aggregates and freshly deposited concrete.

   Concrete placed during cold weather shall develop sufficient strength and durability to satisfy the intended service recommendations when it is properly proportioned, produced, placed and protected. The necessary degree of protection increases as the ambient temperature decreases.

2. Aggregates

   Aggregates shall be heated to a temperature of not more than 60°C. For concrete containing silica fume, the aggregate shall not be heated to more than 40°C. The heating apparatus and the housing for the aggregates shall be sufficient to heat the aggregates uniformly without the possibility of the occurrence of hot spots which may burn the materials.

3. Water

   The water shall be heated to a temperature of not more than 60°C. For concrete containing silica fume, the water shall not be heated to more than 40°C.

4. Concrete

   Concrete temperature ranges at the time of placement in the forms for various pour scenarios shall be as follows:

   - 10°C to 25°C for section thickness less than 1 metre;
   - 5°C to 25°C for section thickness greater than or equal to 1 metre and less than 2 metres;
   - 5°C to 20°C for section thickness greater than or equal to 2 metres; and
   - 10°C to 20°C for concrete containing silica fume.

5. Heating Apparatus and Housing for Freshly Placed Concrete

Hoarding enclosures shall be constructed to withstand wind and harsh weather conditions such as snow loads and shall be reasonably airtight to maintain proper temperatures at concrete corners, edges and in thin sections. The housing shall provide sufficient space between the concrete and the enclosure to permit free circulation of warmed air. The heating apparatus and housing shall be sufficient to enclose and protect the structure in such a way that the air surrounding the fresh concrete is kept at a temperature of not less than 15°C and not more than 25°C for 4 days, not counting the day on which the concrete was deposited. During the next 3 days, the concrete shall be allowed to gradually cool to a temperature of not less than 10°C with the drop in temperature never exceeding 5°C over an 8 hour period. After this 7 day protection period additional considerations to gradually bring the concrete to ambient temperature shall be made at the discretion of the Engineer.

The Contractor shall maintain the protection period, a minimum of 7 days after completion of placing operations, and until the concrete has developed a minimum compressive strength of 24 MPa.

The Contractor shall submit to the Engineer for approval the protection method and the thermal control plan to demonstrate that the requirements for controlling and monitoring temperature will be achieved during the protection/thermal control period.

The Contractor shall provide 24 hour surveillance to look after the heating operations. The Contractor shall provide two maximum-minimum type thermometers for each enclosure. The thermometers shall be installed as directed by the Engineer to monitor the temperature of the concrete and the surrounding air during placing and curing. The Contractor shall develop a schedule of temperature monitoring which includes time and temperatures inside and outside of the hoarding. The Contractor shall record the information and provide a copy to the Engineer within 24 hours of every 24 hour period.

Maturity meters shall be used by the Contractor during cold weather applications. The location of the maturity meters shall be placed at locations designated/approved by the Engineer. Locations where the maturity meters are placed shall be protected in the same manner as the rest of the concrete.

The Contractor shall be responsible for all necessary wires and connectors for maturity meters as well as the placement, protection and maintenance of all wires and connectors.

Temperature and concrete compressive strength shall be determined by maturity meters and testing field cured cylinders. A minimum of four readings for temperature shall be collected in the first 3 days and then two times daily thereafter.

The heating apparatus shall be so positioned that there is no direct discharge of heat on the concrete surfaces or form work containing concrete. The relative humidity within the enclosure shall be maintained at not less than 65%.

When the ambient temperature is below -15°C, the housing shall be constructed to allow the concrete to be placed without the housing having to be opened. If the mixing is done outside of the housing, the concrete shall be placed by means of hoppers installed through the housing. The hoppers are to be plugged when not in use.

When the ambient temperature is equal to or above -15°C, the Contractor will be permitted to open small portions of the housing for a limited time to facilitate the placing of the concrete.

Before depositing any of the concrete, the Contractor shall demonstrate that enough heating apparatus is available to keep the air temperature surrounding the forms within the specified range. This shall be accomplished by bringing the temperature inside of the housing to the specified 15°C at least 24 hours prior to the start of the concrete placing. The temperature of formwork, reinforcement, previously placed concrete and/or soil shall be at least 10°C prior to the start of concrete placing.

The Contractor shall supply all required heating apparatus and the necessary fuel. When dry heat is used, a means of maintaining atmospheric moisture shall be provided.

Sufficient stand-by heating equipment must be available to allow for any sudden drop in outside temperatures and any breakdowns that may occur in the equipment.

If the internal concrete temperature at any location in the concrete falls below 10°C but not less than 5°C during the curing period, supplemental heat shall be introduced immediately.

Heating apparatus used to heat the housing shall be of a type that meets Provincial Acts and Regulations. Heating apparatus used in a housing that discharges or releases smoke or gas fumes, shall be adequately ventilated in such a manner as to carry away all such smoke or gas fumes from the housing.

If the internal concrete temperature at any location in the concrete falls below 5°C during the curing period, cores shall be collected and tested for compressive strength at 28 days (56 days for Class S-1) at the Contractor's responsibility upon approval of the Engineer. Also, the cores will be tested in accordance with ASTM C856, Standard Practice for Petrographic Examination of Hardened Concrete and CSA A23.2-14C, Obtaining and testing drilled cores for compressive strength testing. Concrete damaged by frost, as determined by the compressive strength test or petrographic analysis, shall be removed and replaced at the Contractor's expense.

If the internal concrete temperature at any location in the concrete falls below 0°C during the curing period, concrete shall be removed and replaced at the Contractor's expense.

Concrete damaged as a result of inadequate protection against weather conditions shall be removed and replaced at the Contractor's expense.

The housing shall provide sufficient clearance to permit concrete related operations including the placing of concrete to proceed unhindered. Where required, a housing shall also provide sufficient clearance to allow for the removal of forms in order that the finishing of the exposed concrete surfaces can be completed 3 days before the heating of the inside of the housing is discontinued.

6. Curing Requirements

Cold weather curing shall be in accordance with Clause 5.13 of these Specifications.

Water curing of concrete shall be terminated 18 hours prior to the end of the protection period during periods of freezing weather where the ambient temperature is below 0°C. This shall in no way alleviate the required water curing duration.

5.13 Curing

1. General

Curing shall begin immediately following the placing and finishing operations and shall provide the temperature and moisture conditions for the period of time necessary for concrete to develop the desired strength, durability and other properties. All materials and equipment needed for adequate protection and curing shall be on hand and ready for use by the Contractor before each concrete deposition is started. The concrete temperature shall be maintained at no less than 10°C throughout the curing period. Freshly deposited concrete shall be protected from freezing, abnormally high temperatures or temperature differentials, premature drying, excessive moisture and moisture loss for the period of time necessary to develop the desired properties of the concrete.

2. Curing Compound

All substructure concrete and culvert concrete with a specified exposure class of C-1 or S-1 shall receive a curing compound membrane covering.

Curing compound with fugitive dye shall be applied to all unformed horizontal and sloping concrete surfaces. The curing compound shall be applied as soon as practical after concrete placing is complete. The application of the concrete curing compound shall be stopped at least 150 millimetres short of all unfinished areas. Curing compound shall not be used on any construction joints.

The curing compound shall be water-based membrane forming and of a type on the MTI approved products list or as approved by the Engineer. It shall conform to the requirements of ASTM C309 or C1315 when tested at the rate of coverage to be used on the job, where its application should be according to the manufacturer's recommendations. The rate of each application shall not be less than the rate specified by the manufacturer of the compound.

When the concrete surface is to receive paint, finishes or toppings that require positive bond to the concrete, the Contractor shall verify that the curing procedures and subsequent coatings, finishes or toppings be compatible to achieve the necessary bond. The Contractor may be required to carry out testing to establish compatibility among the curing compound, subsequent surface treatments, concrete moisture content and the actual finished surface texture of the concrete.

Alternative surface preparation methods to ensure compatibility of the concrete surface with subsequent surface treatments including deliberate removal of the curing compound in accordance with manufacturer's recommendations is subject to the Engineer's approval.

When curing compound is used, the exposed concrete shall be thoroughly sealed immediately after the free water has left the surface. Formed surfaces shall be sealed immediately after the forms are removed and necessary finishing has been completed. The curing compound shall be applied by power-operated atomizing spray equipment in two separate applications at right angles to each other to ensure uniform and more complete coverage. Hand-operated sprayers may be used for coating small areas upon Engineer's approval. Curing compound solutions containing pigment shall be thoroughly mixed prior to use and agitated during application. When applying the solution in two applications, the second application shall follow the first within 30 minutes. Satisfactory equipment shall be provided, together with means to properly control and assure the direct application of the curing solution on the concrete surface to result in a uniform coverage rate of at least 0.27 litres per square metre.

For optimum results, liquid membrane forming compounds shall be applied immediately after the disappearance of the surface water sheen following final finishing. Delayed application of these materials not only allows drying of the surface during the period of peak water loss, but also increases the likelihood that the liquid curing compound will be absorbed into the concrete and hence, not forming a membrane.

When the evaporation rate exceeds the rate of bleeding of the concrete, the surface will appear dry even though bleeding is still occurring. Under such conditions, finishing the concrete and/or the application of curing compound can be detrimental because bleed water can be consequently trapped just below the concrete surface. This may result in map cracking of the membrane film with the subsequent reduction in moisture-retention capability. In this situation the Contractor would be required to reapply the curing compound.

When using curing compounds to reduce moisture loss from formed surfaces, the exposed surface should be wetted immediately after form removal and kept moist until the curing compound is applied. The concrete should be allowed to reach a uniformly damp appearance with no free water on the surface prior to application of the compound. Dampening the concrete prevents absorption of the curing compound, preventing the formation of a membrane.

If rain falls on the newly coated concrete before the film has dried sufficiently to resist damage, or if the film is damaged in any other manner during the curing period, a new coat of solution shall be applied to the affected portions equal in curing value to that specified above.

3. Wet Curing

All superstructure concrete with a specified exposure class of C-XL or C-1 shall be wet cured for a minimum period of 7 days (not including the day of the pour) with the first 4 days at a minimum temperature of 15°C and the subsequent 3 days at a minimum temperature of 10°C and for the time necessary to attain 70% of the specified compressive strength. The Contractor shall cover the concrete surface with a single layer of clean, soaking wet white polyester fabric as soon as the surface will not be marred by so doing. The fabric shall be pre-soaked in water prior to placing. The white polyester fabric shall receive an additional cover of 4 mil white or opaque polyethylene as soon as surface conditions permit. The fabric shall be kept saturated with soaker hoses.

The curing system shall be kept in place for the minimum specified time periods, not counting the day on which the concrete was deposited. The length of the curing period is dependant upon the thoroughness of the Contractor in maintaining a saturated surface and may be increased at the discretion of the Engineer should the Contractor fail to satisfy the above requirements. Under no conditions is the curing cover to be removed in part or in full until such time as permission is given by the Engineer to do so.

4. Curing Requirements for Concrete Slope Protection

Concrete slope protection shall receive two coats of a curing compound approved by the Engineer. The first coat is to be applied immediately after the concrete has been satisfactorily finished, and the second coat is to be applied within 30 minutes after the application of the first coat. In cases where premature drying is severe or is anticipated to be severe, then wet curing shall be required.

5.14 Concrete Finishing Under Bearings

Concrete bearing areas shall be brought to a smooth bearing surface at the elevations shown on the Drawings or determined by the Engineer.

When steel masonry plates are to be placed directly on the concrete or on filler material less than 5 millimetres thick, the surface shall be finished with a float finish. After the concrete has set, the contact area shall be ground as necessary to provide full and even bearing.

Surfaces under elastomeric bearings shall be finished by floating to a flat and even surface free of ridges.

The concrete bearing surface under the bearings shall be finished level. The maximum permitted deviation from level is 0.005 radians.

When called for on the Drawings or in the Special Provisions, recesses shall be provided. These recesses shall be grouted to the elevations shown on the Drawings or set by the Engineer in the field. The grout shall be of a non-shrinkable, non-metallic type approved by the Engineer. The grouted surfaces shall be in true level plane that do not vary by more than 2 millimetres from a true, horizontal straight edge placed in any direction across the surfaces.

The grouted areas shall be allowed to set for at least 48 hours prior to any beam erection. During cold weather, the grouted areas shall be kept heated at a minimum temperature of 15°C for a minimum period of 48 hours.

5.15 Surface Finish

All exposed concrete surfaces shall receive an ordinary surface finish unless otherwise indicated on the Drawings, in the Special Provisions or as directed by the Engineer. Ordinary surface finish shall be defined as smooth, even concrete surfaces, free of all honeycombs, objectionable fins, projections, offsets, streaks or other surface imperfections. No remedial measures will be required for satisfactory ordinary surface finish beyond the filling of the holes or cavities caused by the removal of the snap ties and tie rods.

Immediately after the removal of the forms, all defects in the concrete surfaces shall be brought to the Engineer's attention and such defects shall be repaired as herein specified or as the Engineer may approve.

Cavities or holes caused by removing snap ties and tie rods shall be filled carefully with a cement-sand grout of the same quality and mix as that used in the original concrete, eliminating all aggregates retained on a 2.36 millimetres sieve. Care shall be taken to ensure that the cavity or hole is filled to its entire depth.

All objectionable fins, projections, offsets, streaks or other surface imperfections shall be removed to the Engineer's acceptance by approved means. Cement washes of any kind shall not be used.

Honeycomb spots, if any, shall be repaired as soon as the forms are removed; and this shall be accomplished by:

(i) Removing all aggregate that is loose or that is not bonded thoroughly to the surrounding concrete;
(ii) Using a wire brush to remove any loose particles;
(iii) Washing the surface with clean water;
(iv) Dry the surface with compressed air;
(v) Applying a coating of approved bonding agent to the surface to be patched immediately prior to applying the cement-sand grout; and
(vi) Applying a curing method to the grout as recommended by the manufacturer.

Patched areas shall be rubbed flush with the surrounding surface after the cement-sand grout has hardened.

If, in the Engineer's opinion, the concrete surface does not fulfill adequately the requirements for an ordinary surface finish as described above, the Contractor shall, at his/her own expense and as may be directed by the Engineer, either:

(i) Entirely remove certain designated portions, or all of the concrete; or
(ii) Give the entire surface or certain designated portions thereof a special surface finish as approved by the Engineer.

5.16 Installing Flexible Joint Sealant

Flexible joint sealant shall be installed in accordance with the Manufacturer's recommendations. The concrete surfaces to which the joint filler is to adhere shall be clean and free of loose materials, and when called for on the Drawings or in the Special Provisions, shall be sand blasted.

5.17 Concrete Strength Requirements

The Engineer reserves the right to reject any concrete that does not meet all the technical and finishing requirements for that type of concrete.

1. Open to Traffic

   The structure shall not be opened to traffic until the concrete has attained a minimum compression strength of 100% of the design strength. The Contractor shall be responsible for any delays in the opening of the structure to traffic related to the cast concrete performance. The Contractor shall be responsible for all costs associated with any additional testing that may be required to satisfy the strength requirement.

5.18 Benchmark Plug and Identification Plaques

The Contractor shall install the benchmark plugs and identification plaques supplied by the Engineer in the following manner:

1. Benchmark Plug

   The benchmark plug shall be installed in the top of the abutment curb in the north-east corner of a reinforced concrete bridge. It shall be positioned clear of the newel post. For reinforced concrete culverts, the benchmark plug shall be placed in the top of the headwall in the north-east corner of the structure. In all cases, it shall project approximately 3 millimetres above the concrete surface and shall be located as directed by the Engineer.

2. Brass Identification Plaque

   The Identification Plaque shall be installed on the outside face of the northeast wingwall of reinforced concrete bridges and culverts. It shall be placed in a position that will remain clearly visible above the ground line. The plaque shall be attached to the forms and cast into the concrete. Cadmium plated screws shall be set through the holes and cast into the concrete to ensure that the identification plaque does not come loose.

6.0 QUALITY MANAGEMENT

6.1 Quality Control

1. General

   The Contractor is responsible for conducting appropriate and sufficient quality control measures to demonstrate and document that the performance requirements of concrete have been met. The quality control documents shall be submitted to the Engineer as requested in a timely manner.

   Sampling and testing of concrete and constituent materials for qualification purposes shall be carried out in accordance with CSA A23.2-24C. Subject to the requirements of this Specification and project special provisions, the Engineer may accept or reject proposed materials and mix designs on the basis of information provided in the qualification submittal.

   Batches of concrete that do not meet the requirements of this Specification will be rejected by the Engineer and his/her decision to be final. The Engineer reserves the right to require immediate removal of any concrete from the rejected batches that may have already been placed in the structure.

   The Contractor shall be responsible for all concrete testing, including but not limited to making test cylinders, transporting cylinders to an independent certified testing laboratory, storage, curing, breaking and providing written reports of the concrete test results to the Engineer. The quality control testing shall meet the minimum testing requirements for the specified frequency and test procedure as described in the standards referenced in this Specification (Tables 1 and 2). All testing shall be completed by qualified personnel who are certified at the time of testing as ACI/CSA-Based Concrete Field-Testing Technician – Grade 1 and the sampling shall be conducted at the point of discharge into the forms.

If Ready Mix Concrete is being used, and loads are frequently being rejected, or strength results are not to specification, the Engineer, on 24 hour notice, may temporarily pause the casting operations and/or refuse the permission for further use of the Ready Mix Supplier.

2. Aggregate

The sample of the aggregates shall be current and fully represent the material to be used in production. Sampling shall be done no more than 90 days prior to concrete production. Additional samples shall be provided periodically as determined by the Engineer.

If the fine aggregate consists of a blend from more than one source, the "Fine Aggregate Sieve" analysis shall show the gradation of the blended fine aggregates. Similarly in the case of blended coarse aggregates, the "Coarse Aggregate Sieve" analysis shall indicate the gradation of the blended coarse aggregates.

The Contractor shall make all the aggregates available for sampling by the Engineer at least 28 days prior to the first concrete pour.

The Contractor shall advise the Engineer of any changes in the aggregates subsequent to the Engineer obtaining the samples.

3. Concrete

1. Compressive Strength Tests

A "Strength Test" shall consist of the compression tests of standard test specimens, sampled, made, cured and tested in accordance with CSA Standard Specifications as referenced with modifications as indicated. Compression test shall be carried out at 28 days at minimum unless specified otherwise. The 28 day test result shall be the average of the strengths of at least three specimens. Sets of three cylinders each are required to be tested at the ages of 56 or 91 days, if the mix design comprises fly ash or slag. Additional cylinders may be cast, at the discretion of the Engineer or Contractor.

The strength level of concrete shall be considered satisfactory if for a given strength-class the following two criteria are met for concrete produced from a single mix design:

a) Each individual strength test equals or exceeds the acceptable test result (ATR), where ATR = specified strength – 3.5 MPa when the specified compressive strength is 35 MPa or less; or where ATR = 0.90 × specified strength when the specified compressive strength is above 35 MPa; and

b) The average of three consecutive strength tests for the same concrete equals or exceeds the specified strength.

The strength test result shall be the average of the strength of the specimens tested at the same age for concrete of a single mix design produced on the same day in accordance with Clause 7.2.3.3 of CSA A23.2-25C. The average strength of the test cylinders shall be considered the test result. However, if there are indications that there might have been a disruption to concrete quality control measures, the Engineer may make a distinction between specimens for testing.

2. Sampling

   Sampling of plastic concrete shall be carried out in accordance with CSA A23.2-1C.

   When a concrete pump is used to place concrete, sampling shall be at the end of the discharge hose.

3. Test Cylinders

   Making and curing concrete test cylinders shall be carried out in accordance with CSA A23.2-3C (latest version), except that the time for cylinders to reach the testing laboratory shall be between 20 and 48 hours. The test cylinders shall be cast by the Contractor in standard CSA approved moulds. The Contractor shall provide properly designed temperature-controlled storage boxes for test cylinders, as specified in CSA A23.2-3C (latest version), for a period of at least 24 hours, and further protection from adverse weather and mishandling until removed from the site. The Contractor shall provide a max-min thermometer for each storage box and record site curing temperatures for all test cylinders. Storage in a site office trailer that is used by the Contractor's personnel or the Department Staff during the first 24 hour storage period will not be permitted. Storage facilities shall be provided, installed and approved by the Engineer before any concrete is placed.

   The Contractor shall deliver the test cylinders to a pre-approved independent CSA certified testing laboratory. Handling and transporting of the cylinders shall be in accordance with CSA 23.2-3C (latest version). No extra laboratory curing time will be allowed for cylinders that are delivered late to the laboratory. A copy of the test results shall be forwarded to the Engineer within 2 days of the testing date.

   If the test cylinders were allowed to freeze or were otherwise mishandled resulting in unreliable strength test results, the Engineer may reject the affected portions of the Work, unless core-testing, at the Contractor’s expense, confirms the in-situ strength of the concrete.

4. Slump

   Slump tests shall be completed in accordance with CSA A23.2-5C (latest version).

5. Air Content

   Air content tests shall be completed in accordance with CSA A23.2-4C (latest version).

   The Contractor shall carry out air void system testing on three (one per span) hardened concrete core samples extracted from the completed structure. The locations for extraction of the core samples will be as directed by the Engineer.

6. Compressive Strength

   Test cylinders will be tested in compression in accordance with CSA-A23.2-9C (latest version).

7. Failure to Meet Slump or Air Content Specifications

   In the event that slump and/or air content are outside the specified tolerance range, as determined by the Contractor's or the Engineer’s testing, the Engineer may accept adjustments of the deficient condition as an alternate to rejection provided adjustments are made within the maximum time allowed as specified in 5.1.4. Concrete that does not meet the Specifications will be rejected after the maximum time is exceeded.

8. Coring for Compressive Strength Testing

Coring to confirm or contest low concrete strength test results shall be approved by the Engineer. When coring is approved, arrangements shall be made by the Contractor, through the Engineer, to employ an independent, certified testing service, all at the expense of the Contractor. The cores shall be taken and tested within 7 days of the testing of the 28 day cylinders representing the concrete in question. Where practical, three 100 millimetres diameter by 200 millimetres length cores free of reinforcement shall be taken for each strength test previously taken, and there shall be no doubt that the cores taken, and the cylinders under consideration represent the same batch of concrete. Cores may not be taken unless the Engineer is present. Cores shall be tested by an independent CSA certified laboratory and in accordance with the requirements of CSA A23.2-14C (latest version). The average strength of the cores as reported by the independent testing service shall constitute a test.

The foregoing procedure may be modified if the concrete in question was placed during weather conditions not suitable, in the opinion of the Engineer, to permit satisfactory curing. In the event the Contractor chooses to take cores after 7 days, they shall be taken as prescribed in the foregoing paragraph, transported to an approved laboratory, and cured for a period of time such that the total of curing time in place in the structure plus the curing time in the laboratory is equal to 28 days. The cores shall then be tested and reported as specified above.

The compressive strength of the concrete in the area of the structure represented by the core tests shall be considered adequate if:

a) The average of each set of three cores from the portion of the structure in question is equal to at least 95% of the specified strength; and

b) No single core is less than 85% of the specified strength.

In cases where the concrete strength, as indicated by the cores, is higher than the strength based on the concrete cylinder results, the core results shall be used as the basis for acceptance of and payment for the concrete. If the core strengths are lower than the strength from the concrete cylinder tests, the core strengths shall govern.

6.2 Quality Assurance

Quality assurance testing will be carried out by the Engineer and the costs for testing and provision of concrete test cylinder reports will be paid for by the Department. The quality assurance efforts (e.g. inspection and testing for verification and acceptance) made by the Engineer are intended to complement and balance the quality control efforts made by the Contractor, ensuring that the Contractor’s quality control protocols are in place, operating effectively and preventing or correcting nonconformities.

The Engineer shall be afforded full facilities for the random quality assurance inspection and testing that may be carried on to the concrete itself and/or the constituent materials. This includes at the worksite and any plant used for the manufacture of concrete. The facilities shall be adequate in the opinion of the Engineer to permit proper sampling of, but not limited to, making of test cylinders and testing slump and air content. The proper storage of all site cast concrete cylinders in accordance with the relevant Specifications is the responsibility of the Contractor and shall be approved by the Engineer prior to any concrete pour.

Additional tests will be required if the results are borderline or widely variable. In case of an unacceptable result, check tests may be permitted at the discretion of the Engineer.

All materials supplied by the Contractor to be permanently incorporated in the structure are subject to testing by the Engineer and subject to the Engineer’s approval prior to their use in construction. Concrete cylinders, slump tests and all other field tests considered necessary shall be made by the Engineer. The Contractor

shall assist the Engineer in the performance of these tests as often during the processes of mixing and depositing concrete as the Engineer shall direct. The Contractor shall be responsible for removing and replacing all defective concrete at his/her own expense.

There shall be no charge to the Department for materials taken by the Engineer for testing purposes.

7.0 METHOD OF MEASUREMENT

7.1 Cast-in-Place Concrete

The supplying and placing of cast-in-place concrete will be measured on a volume basis. The volume of cast-in-place concrete to be paid for will be the total number of cubic metres computed from the neat lines on the Drawings.

7.2 Architectural Finish Formwork

Architectural finish formwork shall be measured on an area basis. The area to be paid for will be the total number of square metres computed from the Drawing dimensions.

7.3 Insulation

Insulation will be measured on an area basis. The area to be paid for will be the total number of square metres computed from the Drawing dimensions.

7.4 Permeable Formwork Liner

Permeable Formwork Liner will be measured on an area basis. The area to be paid for will be the total number of square metres computed from the Drawing dimensions. No deductions or adjustments will be made for chamfered or filleted corners.

7.5 Heating Concrete

Heating of concrete will be measured on a volume basis. The volume of heating concrete to be paid for will be the total number of cubic metres computed from the neat lines on the Drawing.

8.0 BASIS OF PAYMENT

8.1 Cast-in-Place Concrete

The supplying and placing of cast-in-place concrete will be paid for at the Contract Unit Price per cubic metre for “Supply and Place Concrete (Substructure)”, measured as specified herein, which price will be payment in full for performing all operations herein described and other items incidental to the Work.

8.2 Architectural Finish Formwork

Architectural finish formwork will be paid for at the Contract Unit Price per square metre for “Architectural Concrete Finish”, measured as specified herein, which price will be payment in full for performing all operations herein described, and all other items incidental to the Work.

8.3 Insulation

Supply and installation of insulation will be paid for at the Contract Unit Price per square metre for "Supply and Place Insulation", measured as specified herein, which price will be payment in full for performing all operations herein described and all other items incidental to the Work.

8.4 Permeable Formwork Liner

Permeable Formwork Liner shall be paid for at the Contract Unit Price per square metre for “Permeable Formwork Liner”, measured as specified herein, which price will be payment in full for performing all operations herein described and all other items incidental to the Work.

8.5 Heating Concrete

Heating concrete materials and maintaining the temperature of the deposited concrete will be paid for at the Contract Unit Price per cubic metre for “Heating Concrete”, measured as specified herein, which price will be payment in full for performing all operations herein described and all other items incidental to the Work.

If the prevailing temperature at the time of mixing and placing concrete is such that all heating operations are not considered necessary by the Engineer, the Contractor will be instructed in writing to carry out heating in part only. Partial heating will be paid for at a percentage of the Contract Unit Price per cubic metre for “Heating Concrete”, measured as specified herein.

These percentages shall be as follows:

1)	Heating water	10%
2)	Heating aggregates	30%
3)	Housing and heating deposited concrete	60%

Table 1
AGGREGATE TESTING REQUIREMENTS

TEST	STANDARD REFERENCE	MANITOBA STANDARD	MINIMUM FREQUENCY
Sampling	CSA A23.2-1A ASTM D75/D75M		One test per hour of production or as directed by the Engineer.
Gradation Analysis	CSA A23.2-2A ASTM C136/C136M	MRB-A202	
Clay Lumps	CSA A23.2-3A ASTM C142/C142M-17		
Low-Density Granular Material (Shale Content)	CSA A23.2-4A (2019)	MRB-A208	
Material Finer than 80 μm	CSA A23.2-5A (2019)	MRB-A204	
Soundness	CSA A23.2-9A (2019) ASTM C88/C88M		
Bulk Density	CSA A23.2-10A ASTM C29/C29M		
Potential Expansivity	CSA A23.2-14A		Two tests per material or as directed by the Engineer.
Petrographic Analysis	CSA A23.2-15A ASTM C295/C295M		
Potential Alkali-Silica Reactivity	CSA A23.2-25A CSA A23.2-27A ASTM C1567		
Potential Alkali-Carbonate Reactivity	CSA A23.2-26A CSA A23.2-27A ASTM C586		As directed by the Engineer.
Coarse Aggregate Only:			
Relative Density and Absorption	CSA A23.2-12A ASTM C127	MRB-A210	One test per material or as directed by the Engineer.
Flat and Elongated Particles	CSA A23.2-13A ASTM D4791		
Los Angeles Abrasion: Small Size	CSA A23.2-16A ASTM C131/C131M	MRB-A206	
Los Angeles Abrasion: Large Size	CSA A23.2-17A ASTM C535	MRB-A205	
Micro-Deval	CSA A23.2-29A ASTM D6928	MRB-A214	As directed by the Engineer.
Crush Count	ASTM D5821	MRB-A203	One test per hour of production or as directed by the Engineer.
Flakiness Index		MRB-A216	
Dry-Rodded Unit Weight	ASTM C29/C29M	MRB-A207	
Fine Aggregate Only:			
Relative Density and Absorption	CSA A23.2-6A ASTM C128	MRB-A211	One test per material or as directed by the Engineer.
Organic Impurities	CSA A23.2-7A ASTM C40/C40M		
Surface Moisture	CSA A23.2-11A ASTM C70		
Micro-Deval	CSA A23.2-23A ASTM D7428		As directed by the Engineer.

Table 2
CONCRETE TESTING REQUIREMENTS

TEST	STANDARD REFERENCE	MANITOBA STANDARD	MINIMUM FREQUENCY
Water			
Water	ASTM C1602/C1602M		As directed by the Engineer.
Cement			
Mill Certificate	CAN/CSA 3000		As directed by the Engineer.
Admixtures			
Air Entraining	ASTM C260/C260M		As directed by the Engineer.
Chemical	ASTM C494/C494M		
Mix Design			
Proportioning	CSA A23.1 Alternative 1 or 2	MRB-C401	At the beginning of the project, repeated as many times necessary to develop a suitable concrete mix design to be approved by the Engineer.
Density of Plastic Concrete	CSA A23.2-6C ASTM C138/C138M	MRB-C404	
Batch Plant			
Calibrated by Weights and Measures	CSA A23.1		MRMCA certification and calibrated within the last calendar year.
Ready-Mix Concrete			
Sampling	CSA A23.2-1C		One complete test and set of cylinders for compressive strength testing for one out of every three loads of concrete placed including temperature, air content and slump (one out of every two loads when silica fume used).
Temperature	ASTM C1064/C1064M		
Compressive Strength	CSA A23.2-3C CSA A23.2-9C	MRB-C405	
Air Content by Pressure Method	CSA A23.2-4C	MRB-C403	
Slump and Slump Flow	CSA A23.2-5C	MRB-C402	
Flexural Strength	CSA A23.2-3C CSA A23.2-8C		As directed by the Engineer.
Air Content by Volumetric Method	CSA A23.2-7C		
Other Related Testing			
Core Compressive Strength	CSA A23.2-14C ASTM C42/C42M		As directed by the Engineer.
Petrographic Analysis of Aggregates in Concrete	ASTM C295/C295M		
Sulphate Ion Content in Water	CSA A23.2-3B ASTM D 516	MRB-C406	
Bond Tests	CSA A23.2-6B ASTM C1583/C1583M		
Cement Content	ASTM C1084		
Rapid Chloride Permeability	ASTM C1202		
Air Void Parameters	ASTM C457/C457M		