

APPENDIX 'K'

CONCRETE CONSITUENT MATERIALS, MIX DESIGN REQUIREMENTS, AND HOT AND COLD WEATHER CONCRETING

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E-Spec	Concrete Constituent Materials, Mix Design Requirements, and Hot and Cold Weather Concreting

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1.0 DESCRIPTION

1.1 General

- 1.1.1 PORTLAND CEMENT CONCRETE PAVEMENT WORKS shall be in accordance with CW3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS, except as otherwise specified herein.
- 1.1.2 This specification covers Portland cement concrete constituent materials and design requirements for the preparation of Portland Cement Concrete for all concreting operations relating to the construction of pavements, curbs, gutters, private approaches, bull-noses, median slabs, median, safety median and boulevard splash strips, sidewalk and other related concrete works.
- 1.1.3 This specification also covers hot and cold weather concreting.
- 1.1.4 Replace 2.0 Definitions of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 1.2 of this specification.
- 1.1.5 Replace 5.3 Portland Cement Concrete Constituent Materials of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 2.0 MATERIALS of this specification.
- 1.1.6 Replace 6.0 Design Requirements of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 3.0 DESIGN REQUIREMENTS of this specification.
- 1.1.7 Replace 9.8. Weather Conditions of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 4.0 HOT AND COLD WEATHER CONCRETING of this specification.
- 1.1.8 Replace 13.0 Basis of Payment of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 5.1 BASIS OF PAYMENT FOR CW 3310-R17 of this specification.
- 1.1.9 Replace 13.0 Basis of Payment of CW 3230-R8, FULL-DEPTH PATCHING OF EXISTING PAVEMENT SLABS AND JOINTS with 5.2 BASIS OF PAYMENT FOR CW 3230-R8 of this specification.
- 1.1.10 Replace 13.0 Measurement and Payment for CW 3235-R9, RENEWAL OF EXISTING MISCELLANEOUS CONCRETE SLABS with 5.3 MEASUREMENT AND PAYMENT FOR CW 3235-R9 of this specification.
- 1.1.11 Replace 4.0 Measurement and Payment for CW 3240-R10, RENEWAL OF EXISTING CURBS with 5.4 MEASUREMENT AND PAYMENT FOR CW 3240-R10 of this specification.
- 1.1.12 Replace 13.0 Basis of Payment for CW 3325-R5, PORTLAND CEMENT CONCRETE SIDEWALK with 5.5 BASIS OF PAYMENT FOR CW 3325-R5 of this specification.
- 1.1.13 This specification also replaces 2.0 Definitions, 5.3 Portland Cement Concrete Constituent Materials, 6.0 Design Requirements, 9.8. Weather Conditions, and 13.0 Basis of Payment of CW3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS where other

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specifications (e.g. CW3230-R8, CW3235-R9, CW3240-R10, CW3325-R5) reference CW3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS.

- 1.1.14 All requirements and tests shall be in accordance with the latest edition of CSA A23.1-19/CSA A23.2-19, except as otherwise specified herein.

1.2 **Definitions**

- 1.2.1 Reinforced Concrete Pavement - A Portland Cement Concrete pavement with distributed steel reinforcement in the pavement slab and with deformed tie bars across longitudinal joints and smooth dowels across transverse contraction joints. Distributed steel reinforcement consists of smooth or deformed bars.
- 1.2.2 Plain-Dowelled Pavement - A Portland Cement Concrete pavement with no reinforcing steel in the pavement slab and with deformed tie bars across longitudinal joints and smooth dowels across transverse contraction joints.
- 1.2.3 Type 1 Concrete shall be used for expressways, major arterials, minor arterials, industrial/commercial collectors, residential major collectors, residential minor collectors, and industrial/commercial local pavements.
- 1.2.4 Type 2 Concrete shall be used for residential roads and alleys, curb and gutter sections, curbs, commercial approaches, residential approaches, miscellaneous concrete slab and splash strips. Type 1 Concrete can be used instead of Type 2 Concrete.
- 1.2.5 Type 3 is early opening concrete and shall be used for 24 hours early opening after placement.
- 1.2.6 Type 4 is early opening concrete and shall be used for 72 hours early opening after placement.
- 1.2.7 Type 5 Concrete shall be used for Sidewalks. Type 1 or Type 2 Concrete can be used instead of Type 5 Concrete.
- 1.2.8 Type 6 Concrete is cold weather concreting and shall replace all other concrete types for all applications when cold weather exists, except Type 8.
- 1.2.9 Type 7 is concrete for restoration of utility pavement cuts.
- 1.2.10 Type 8 is concrete for temporary restoration.
- 1.2.11 Coarseness Factor - A measure of the coarseness of the combined aggregate materials being incorporated into the concrete mix, defined as the percentage of all plus 2 500 sieve particles, which are also retained on the 10 000 sieve. Coarseness Factor = 100 (cumulative % retained on 10 000 Sieve divided by the cumulative % retained on 2 500 Sieve).
- 1.2.12 Hot weather is defined as one or a combination of the ambient air temperature being at or above 27 °C, or when there is a probability of the temperature rising above 27 °C during the concrete placing period (as forecast by the nearest official meteorological office), or the evaporation rate that exceeds 0.75 kg/m² /h due to high concrete temperature (maximum temperature of 32 °C for fresh concrete), low relative humidity and high wind speed that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results.

1.2.13 Cold weather is defined as a period when there is a probability of the ambient air temperature falling below 5 °C within 24 hours of placing or the average daily temperature for three consecutive days has fallen to, or is expected to fall, below 5°C as forecast by the nearest official meteorological office. The daily temperature is the mean temperature which is the average of the maximum and minimum temperature during the period from midnight to midnight.

1.2.14 The protection period is the time required to prevent concrete from being affected by exposure to cold weather and to develop a minimum compressive strength of 24 MPa. Concrete compressive strength shall be determined by maturity meters and field cured cylinders. In no case shall the protection period be less than seven (7) days.

2.0 MATERIALS

2.1 Concrete Constituent Materials

2.1.1 Aggregates

2.1.1.1 Aggregate shall consist of crushed stone or gravel or a combination of these materials conforming to the requirements of this Specification.

2.1.1.2 Each of the fine- and coarse-fractions of the combined aggregate shall meet all the requirements of CSA A23.1, Table 10 (FA1) and Table 11, respectively and shall be handled and weighed separately to maintain uniformity. The supplier shall provide the City of Winnipeg, Research and Standards Engineer with test data in accordance with CSA A23.2-30A to demonstrate that the material will produce concrete of acceptable quality that meets all the relevant requirements of this Specification.

2.1.1.3 The combined aggregate gradation and allowable deviations shall comply with the requirements in Table CW 3310.1.

TABLE CW 3310.1 - Combined Aggregate Gradation Limits and Allowable Deviations

Sieve Size	Percent of Total Dry Weight Passing Each Sieve	Allowable Deviation From The Job Mix Formula, % By Mass Passing Sieve
28 000	100%	-
20 000	90% - 100%	± 2%
14 000	75% - 95%	± 2%
10 000	60% - 75%	± 3%
5 000	35% - 50%	± 3%
2 500	27% - 35%	± 2%
1 250	20% - 30%	± 2%
630	10% - 20%	± 2%
315	5% - 10%	± 2%
160	1% - 4%	± 1%
80	0% - 2%	± 1%

2.1.1.4 The fineness modulus of fine aggregate shall be not less than 2.3 nor more than 3.1.

2.1.1.5 Aggregates shall conform to CSA-A23.1, Clauses 4.2.3.1 to 4.2.3.6. Each of the fine- and coarse-fractions shall comply with the physical requirements in Table CW 3310.2 and the test results shall be provided with the mix design submittal.

TABLE CW 3310.2 - Limits for Deleterious Substances and Physical Properties of Aggregates

Material	Parameter	Test Method	Maximum Limits	Frequency of Test
coarse aggregate	Clay lumps	CSA A23.2-3A	0.25%	2 years
	Low density granular material	CSA A23.2-4A	0.5%	2 years
	Material finer than 80 µm	CSA A23.2-5A	1.0%	1 year
	Relative density and absorption	CSA A23.2-12A	Note*	1 year
	Flat and elongated particles	CSA A23.2-13B	25%	1 year
	- Flat particles		40%	
	- Elongated particles			
	Petrographic examination** – PN	CSA A23.2-15A	125	1 year
	Unconfined freeze-thaw	CSA A23.2 24A	6%	Twice per season
	Alkali-silica reactivity	CSA A23.2-25A	0.15%	2 years
Alkali-carbonate reactivity	CSA A23.2-26A	Note*	1 year	
Micro-Deval	CSA A23.2-29A	17%	Twice per season	
fine aggregate	Clay lumps	CSA A23.2-3A	1%	2 years
	Low density granular material	CSA A23.2-4A	0.5%	2 years
	Material finer than 80 µm	CSA A23.2-5A	3.0%	1 year
	Organic impurities	CSA A23.2-7A	free from injurious amounts	2 years
	Petrographic examination**	CSA A23.2-15A	Note**	1 year
	Micro-Deval	CSA A23.2-23A	20%	1 year
	Alkali-silica reactivity	CSA A23.2-25A	0.15%	2 years

- *No acceptance/rejection values; however, the results shall be submitted.
- **Petrographic examinations shall be used to calculate the petrographic number (PN), to provide an appraisal of the physical-mechanical quality of coarse aggregate. Determination of PNs applies solely to coarse aggregates and should not be used for fine aggregates. The petrographic report for the fine aggregate shall include a comment on the suitability of the material for use in the production of concrete mix.
- The Coarseness Factor of the combined aggregate shall be between 45 and 65.
- Quarried limestone and dolomite shall not be acceptable as concrete aggregate materials.

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2.2 Hydraulic Cement

2.2.1 Hydraulic Cement shall be either General Use (GU) or General Use Limestone (GUL) conforming to the requirements of the latest edition of CSA A3001. High-early-strength Portland cement (HE) may also be used for cold weather concreting only. Cement shall be kept in weather tight storage that will protect it from moisture and contamination, and in such a manner as to permit inspection, sampling and identification, where required, of each lot.

2.3 Supplementary Cementing Materials

2.3.1 Fly ash shall conform to the requirements of CSA A3001 Class F. Fly ash shall be added to concrete mixtures as a separate constituent material. The use of blended hydraulic cement is not permitted.

2.4 Water

2.4.1 Potable water, which is water suitable for human consumption, is permitted to be used as mixing water in concrete without testing. Non-potable water and combined water shall conform to ASTM C1602M, Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete. The concrete supplier shall maintain documentation on the characteristics of the mixing water in compliance with the requirements of Tables 1 and 2 in ASTM C1602M. Testing to verify compliance with the requirements in Table 1 shall be conducted on the Type 1 hand placement paving mix with fly ash. The testing frequency for mixing water shall be in accordance with Appendix X1 of ASTM C1602M. Information on the testing frequency of the concrete mixing water shall be included in the concrete suppliers' quality control program. The source(s) of concrete mixing water and test data indicating compliance with ASTM C1602M shall be provided with the Mix Design Statement submitted to the City of Winnipeg, Research and Standards Engineer.

2.5 Admixtures

2.5.1 Air-Entraining Admixture

2.5.1.1 The air-entraining admixture shall conform to the requirements of ASTM C260, Standard Specification for Air-Entraining Admixtures for Concrete.

2.5.2 Chemical Admixtures

2.5.2.1 Chemical admixtures shall conform to the requirements of ASTM C494, Standard Specification for Chemical Admixtures for Concrete. Chloride-based chemical admixtures will not be permitted under any circumstances.

2.5.3 Cold-Weather Admixture Systems

2.5.3.1 Cold-weather admixture systems shall conform to the requirements of ASTM C1622, Standard Specification for Cold-Weather Admixture Systems.

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3.0 DESIGN REQUIREMENTS

3.1 Concrete Suppliers

- 3.1.1 The City of Winnipeg, Research and Standards Engineer will maintain a list of approved concrete suppliers. To obtain approval, concrete suppliers must annually submit the following information to the Research and Standards Engineer prior to April 1st:
- 3.1.1.1 Concrete suppliers Approval Guidelines and Application is available at the City of Winnipeg, Corporate Finance, Material Management Division website at: <https://www.winnipeg.ca/matmgt/Spec/Default.stm>
 - 3.1.1.2 Names of suppliers and sources for all materials and admixtures
 - 3.1.1.3 Concrete mix designs with unique mix design codes signed and dated by person selecting the mix proportions
 - 3.1.1.4 Copy of valid Concrete Manitoba certificate for concrete batch plant
 - 3.1.1.5 Copies of valid scale calibration reports for the concrete batch plant
 - 3.1.1.6 Test data for aggregates (in accordance with clause 2.1.1)
 - 3.1.1.7 The mill certificate for the cement and fly ash including chemical and physical composition and analysis, fly ash source and name of supplier.
 - 3.1.1.8 Sieve analysis test reports for the individual aggregates and the combined aggregate gradations to be used in the concrete. The sieve analysis test reports shall be representative of the material to be used during concrete production.
 - 3.1.1.9 Performance data from trial batches prior to construction to demonstrate the concrete mix will achieve the performance criteria in Table CW 3310.3.



Table CW 3310.3: Performance Criteria and Testing

	Time (day)	Type 1	Type 2	Type 3, and Type 6	Type 4	Type 5	Type 7**	Type 8
A minimum of one (1) set* of concrete compressive strength tests for the slipform paving mix with and without fly ash according to CSA A23.2-9C	@ 1	--	--	20 MPa	--	--	--	--
	@ 3	15 MPa	15 MPa	--	20 MPa	--	--	--
	@ 7	20 MPa	20 MPa	--	--	--	--	--
	@ 28	35 MPa	32 MPa	35 MPa	35 MPa	--	--	--
A minimum of two (2) sets* of concrete compressive strength tests for the hand placement paving mix with and without fly ash according to CSA A23.2-9C	@ 1	--	--	20 MPa	--	--	--	--
	@ 3	15 MPa	15 MPa	24 MPa	20 MPa	12 MPa	20 MPa	12 MPa
	@ 7	20 MPa	20 MPa	--	--	--	--	--
	@ 28	35 MPa	32 MPa	35 MPa	35 MPa	30 MPa	35 MPa	30 MPa
Air-void test according to ASTM C457	@ 28	See Note***						
Rapid chloride penetrability test (RCPT) according to CSA A23.2-23C	@ 56	See Note ****						

*Each set contains at least three (3) cylinders at each specified date. The average of each set shall be equal to or greater than the specified strength, with no single result less than 85% of the specified strength.

** Type 7 is concrete for restoration of utility pavement cuts and shall be adjusted to meet the specified strength for other types based on the application and shall include set retarders or hydration stabilizers to extend the discharge time to 150 min.

***A minimum of one sample for air-void test at 28 days shall be performed for each cement for Type 1, Type 2, and Type 3 with fly ash, and Type 6. The air-void test shall meet the following requirements:

- Spacing factor shall not exceed 230 µm, with no single value greater than 260 µm; and,
- Air content shall be greater than or equal to 5.0% and less than 8.0%.

****A minimum of two samples for rapid chloride penetrability test shall be performed for Type 1, Type 2 and Type 3 for mixes with and without fly ash. For Type 1 and Type 3, the average penetrability shall be equal to or less than 1250 coulombs at 56 days based on the charge passed, with no single result greater than 1500 coulombs for mixes with and without fly ash. For Type 2, the average of chloride ion penetrability shall be equal to or less than 1500 coulombs at 56 days based on the charge passed, with no single result greater than 1750 coulombs.

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- 3.1.1.10 Quality control program for all materials, including a proposed sampling and testing plan with minimum sampling and testing frequencies;
- 3.1.1.11 The laboratory(s) to be used and its credentials;
- 3.1.1.12 The quality control personnel and their qualifications; and,
- 3.1.1.13 Frequency of production equipment inspection, verification of calibration, and any certification of the production facility.
- 3.1.2 The City of Winnipeg, Research and Standards Engineer will conduct inspections at least once a year during production. Samples of materials may be taken and tested.
- 3.1.3 Testing for qualification or acceptance purposes shall be done in accordance with this Specification and the applicable test procedures and standard practices of CSA A23.2. There shall be no charge for any materials taken for testing purposes.
- 3.1.4 Changes in the source of any concrete constituent materials will not be permitted without approval of the City of Winnipeg, Research and Standards Engineer. For new sources, all materials shall be tested.
- 3.1.5 Once approved, all concrete shall be supplied in accordance with the approved Mix Design Statement. No changes in the concrete mix designs will be permitted without written permission from the City of Winnipeg, Research and Standards Engineer.



3.2 Concrete Properties

3.2.1 The Mix Design Statements for all concrete types shall be submitted to the City of Winnipeg, Research and Standards Engineer for approval. The concrete mix shall be proportioned such as to yield concrete having the required workability, strength and durability in Table CW 3310.4.

Table CW 3310.4: Concrete Properties

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8
Minimum Cementitious Content (kg/m ³)	360	340	360	360	320	400	340	300
Maximum Supplementary Cementing Materials – Fly Ash** (%) (see Note 2)	20%	20%	15%	20%	15%	0%	20%	20%
Maximum Water/Cementitious Ratio								
- Slip form paving	0.4	0.4	0.4	0.4	-	0.35	-	-
- Hand placement	0.42	0.42	0.42	0.42	0.42	0.36	0.42	0.45
Slump (mm)								
- Slip form paving	50 ± 20	50 ± 20	50 ± 20	50 ± 20	-	50 ± 20	-	-
- Hand placement	70 ± 20	70 ± 20	70 ± 20	70 ± 20	80 ± 20	70 ± 20	100 ± 20	100 ± 20
Nominal Maximum Aggregate Size (mm)	20	20	20	20	20	20	20	20
Air Content (%)	5-8	5-8	5-8	5-8	5-8	5-8	5-8	5-8
Minimum Compressive Strength (MPa)								
- @ 1 days	-	-	20	-	-	20	Note 1*	-
- @ 3 days	15	15	-	20	-	24		-
- @ 7 days	-	-	-	-	-	-		-
- @ 28 days	35	32	Note 1*	Note 1*	30	Note 1*		30
Maximum Rapid Chloride Penetrability Test*** (coulombs) @ 56 days. (see Note 3)	1500	1750	Note 1*	Note 1*	-	Note 1*	-	-

*The concrete shall meet Type 1 or Type 2 based on the application.

**The use of fly ash in concrete mix will be permitted. The Contractor will have the option to replace cement up to but not exceeding the above limits, by weight of total cementitious materials, depending on the concrete type. The use of fly ash will be permitted when the average daily temperature is 10°C and rising for the next five (5) consecutive days of placement as forecast by the nearest official meteorological office. The use of fly ash will not be permitted when the average daily temperature is below 10°C and the average daily temperature for more than five (5) consecutive days has fallen to, or is expected to fall, below 10°C within fourteen (14) days of placement as forecast by the nearest official meteorological office unless authorized in writing by the City of Winnipeg, Research and Standards Engineer.

***The concrete supplier shall develop and submit maturity relationships for Type 1 and Type 6 mixes.

***Rapid chloride penetrability test will be required where there is evidence of concrete damage as a result of inadequate curing and adverse weather conditions, including hot weather, wind, rain, sleet, snow and cold weather. The Contract Administrator shall be allowed access to all sampling locations and reserves the right to take samples for testing at any time.

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3.3 Plant Quality Control

- 3.3.1 The concrete supplier shall provide quality control for the plant to ensure all materials meet the approved mix designs. This information shall be submitted bi-weekly and will be monitored by the City of Winnipeg, Research and Standards Engineer. Failure to submit the quality control results shall be cause for immediate suspension of the concrete supplier.
- 3.3.2 A new mill certificate for cement and fly ash shall be provided monthly during production.
- 3.3.3 Check tests of any concrete constituent materials may be undertaken by a Testing Laboratory designated by the City of Winnipeg, Research and Standards Engineer. The concrete supplier shall be equipped with a suitable means or device for obtaining a representative sample of the cement and fly ash. The device shall enable the sample to be readily taken in proximity to the cement or fly ash weigh hopper and from a container or conveyor holding only cement or fly ash to prevent contamination. Any materials which fails to comply with the requirements of CSA A3001 will be rejected, notwithstanding any certificate of acceptance that may have been previously given. Materials that has been rejected must be removed immediately by the concrete supplier.

4.0 HOT AND COLD WEATHER CONCRETING

- 4.1 The Contractor shall be responsible for taking all necessary measures to protect freshly laid concrete from adverse weather conditions, including hot weather, wind, rain, sleet, snow and cold weather, except as otherwise specified herein.
- 4.1.1 Hot weather concreting
- 4.1.1.1 When the ambient air temperature is at or above 27 °C, or when there is a probability of the temperature rising above 27 °C during the placing period (as forecast by the nearest official meteorological office), the Contractor shall provide-protection for the concrete from the effects of hot and/or drying weather conditions.
- 4.1.1.2 When drying conditions are greater than or equal to 0.75 kg/m²/hr as estimated by use of Figure D1, Appendix D, Guidelines for Curing and Protection of CSA A23.1, the plastic concrete surface shall be protected from drying by application of an evaporation retardant. The evaporation retardant shall be applied according to the manufacturer's recommendations.
- 4.1.2 Cold weather concreting
- 4.1.2.1 When there is a probability of the air temperature falling below 5 °C within 24 h of placing or the average daily temperature for more than three successive days is fallen to, or is expected to fall, below 5°C as forecast by the nearest official meteorological office, cold weather concreting requirements shall apply.
- 4.1.2.2 Concrete shall be placed on unfrozen base material, free of water, snow, and ice. Frozen base material will be identified by measuring the surface temperature using infrared thermometers or similar devices. If the surface temperature is less than or equal to 0°C, the base will be considered frozen. The Contractor shall use suitable heating methods to maintain the base temperature above 0°C. Salt shall not be used to thaw ice, snow, or frost.

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- 4.1.2.3 Type 6 Concrete shall be used for cold weather concreting.
- 4.1.2.4 Where less than 30 cubic meters of concrete will be placed, the Contractor shall protect the concrete using a minimum of one layer of insulated tarp with R-value more than 5 for a minimum of seven (7) days after completion of placing operations unless otherwise specified by the Contract Administrator.
- 4.1.2.5 Where 30 cubic meters of concrete or more will be placed, a minimum of three maturity meters shall be used. One maturity meter shall be placed in the final 4 m of paving, and the two other maturity meters shall be placed at locations designated by the Contract Administrator. Each maturity meter shall be capable of recording the time and temperature at three depths, ½ inch below the surface, mid slab and ½ inch above the bottom of the pavement. Locations where the maturity meters are placed shall be protected in the same manner as the rest of the concrete.
- 4.1.2.6 The Contract Administrator shall provide all necessary wires and connectors for maturity meters. The Contractor shall be responsible for the placement, protection, and maintenance of all wires and connectors. No additional measurement or payment will be made for the placement, protection, and maintenance of all wires and connectors.
- 4.1.2.7 The Contractor shall maintain the internal concrete temperature above 10 °C during the protection period, a minimum of seven (7) days after completion of placing operations, and until the concrete has developed a minimum compressive strength of 24 MPa. Temperature and concrete compressive strength shall be determined by maturity meters and field cured cylinders. A minimum of four (4) readings for temperature shall be collected in the first three (3) days and then two times daily thereafter.
- 4.1.2.8 The Contractor shall provide suitable protection methods to the Contract Administrator for approval such as insulation (blankets and boards), heating systems such as electric blankets and hydronic heating systems, unheated or heated enclosures, or a combination of the methods to maintain the internal concrete temperature above 10 °C. In no case shall the protection method be less than one layer of insulated tarp with R-value more than 5.
- 4.1.2.9 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.
- 4.1.2.10 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 at 28 days. 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. All costs associated with coring, transmittal of cores, and petrographic examination and compressive testing shall be borne by the Contractor regardless of the outcome of the examination.
- 4.1.2.11 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 by the Contractor at his own expense.
- 4.1.2.12 The protection method shall not be completely removed until the concrete has cooled to the

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temperature differential given in CSA A23.2, Table 20. The Contractor shall provide suitable methods for gradual cooling to the Contract Administrator for approval such as loosening the forms while maintaining cover with plastic sheeting or insulation, gradual decrease in heating inside an enclosure, or turning off the heat and allowing the enclosure to slowly equilibrate to ambient temperature. If the concrete cracks due to a sudden temperature change, concrete shall be removed and replaced by the Contractor at his own expense.

4.1.2.13 Concrete damaged as a result of inadequate protection against weather conditions shall be removed and replaced by the Contractor at his own expense.

4.1.2.14 No additional measurement or payment will be made for cold weather concreting

5.0 BASIS OF PAYMENT

5.1 BASIS OF PAYMENT FOR CW 3310-R17

5.1.1 Concrete Pavements, Median Slabs, Bull-noses and Safety Median

5.1.1.1 Construction of concrete pavements, median slabs, bull-noses and safety median will be paid for at the Contract Unit Price per square metre for the "Items of Work" listed here below, measured as specified herein, which price shall be payment in full for supplying all materials and performing all operations herein described and all other items incidental to the work included in this Specification. The unit price shall be reduced for deficiencies in pavement thickness as per Clause 5.3 of this Specification.

Items of Work:

- i. "Construction of 250 mm Type (*) Concrete Pavement (**)(***)"
- ii. "Construction of 230 mm Type (*) Concrete Pavement (**)(***)"
- iii. "Construction of 200 mm Type (*) Concrete Pavement (**)(***)"
- iv. "Construction of 150 mm Type (*) Concrete Pavement (**)(***)"
- v. "Construction of Type (*) Concrete Median Slabs (****)"
- vi. "Construction of Monolithic Type (*) Concrete Median Slabs (****)"
- vii. "Construction of Type (*) Concrete Safety Medians (****)"
- viii. "Construction of Monolithic Type (*) Concrete Curb and Sidewalk (****)"
- ix. "Construction of Monolithic Type (*) Concrete Bull-noses"

* Specify the Concrete Type

** Specify either Reinforced or Plain-Dowelled

*** Specify Slip Form Paving if required

**** Specify referenced Standard Detail

5.1.2 Concrete Pavements for Early Opening

5.1.2.1 Construction of concrete pavements for early opening will be paid for at the Contract Unit Price per square metre for the "Items of Work" listed here below, measured as specified herein, which price shall be payment in full for supplying all materials and performing all operations herein described and all other items incidental to the work included in this Specification. The unit price shall be reduced for deficiencies in pavement thickness as per Clause 5.3 of this Specification.

Items of Work:

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- i. "Construction of 250 mm Type (*) Concrete Pavement for Early Opening (**)(***)"
- ii. "Construction of 230 mm Type (*) Concrete Pavement for Early Opening (**)(***)"
- iii. "Construction of 200 mm Type (*) Concrete Pavement for Early Opening (**)(***)"
- iv. "Construction of 150 mm Type (*) Concrete Pavement for Early Opening (**)(***)"

* Specify either Type 3 or Type 4

** Specify either Reinforced or Plain-Dowelled

*** Specify Slip Form Paving if required

5.1.3 Pavement Thickness Tolerances

5.1.3.1 At the option of the Contract Administrator, pavement thickness may be determined by coring pavement sections representing each day's pour and determining the pavement thickness by averaging the depth of the cores.

5.1.3.2 Pavement found deficient in thickness by more than five (5%) percent shall be paid for at the reduced price. The reduced price = P_R x contract price;

P_R is in % and T_D is in %

Where: $P_R = 100 - [(T_D - 5) / 5] \times 25$

Where: T_D = thickness deficiency greater than or equal to 5%, up to 10%.

5.1.3.3 When the pavement thickness is deficient by more than ten (10%) percent and the judgement of the Contract Administrator is that the area of such deficiency should not be removed and replaced, payment will be fifty (50%) percent of Contract Unit Price.

5.1.3.4 The cost of initial cores will not be paid for by the Contractor. Additional cores requested by the Contractor to determine the extent of areas deficient in thickness, shall be paid for by the Contractor.

5.1.4 Concrete Curbs, Curb and Gutter, and Splash Strips

5.1.4.1 Construction of concrete curbs, curb and gutter, and splash strips will be paid for at the Contract Unit Price per metre for the "Items of Work" listed here below, measured as specified herein, which price shall be payment in full for supplying all materials and performing all operations herein described and all other items incidental to the work included in this Specification.

Items of Work:

- i. "Construction of Type (*) Concrete Barrier Curb (**)"
- ii. "Construction of Type (*) Concrete Modified Barrier Curb (**)"
- iii. "Construction of Type (*) Concrete Curb and Gutter (**)"
- iv. "Construction of Type (*) Concrete Mountable Curb (**)"
- v. "Construction of Type (*) Concrete Lip Curb (**)"
- vi. "Construction of Type (*) Concrete Curb Ramp (**)"
- vii. "Construction of Type (*) Concrete Safety Curb (**)"
- viii. "Construction of Type (*) Concrete Splash Strips (***)"

* Specify the Concrete Type

** Specify height, type and Referenced Standard Detail

***Specify height, monolithic or separate, type, width, and referenced Standard Detail

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5.1.4.2 No measurement or payment shall be made for supply or placement of bonding grout for concrete curbs.

5.1.4.3 Drilled curb ramp tie bars are to be paid in accordance with CW 3230.

5.1.5 Dowel Assemblies

5.1.5.1 Supply and installation of dowel assemblies will be paid for at the Contract unit Price per metre for "Supply and Installation of Dowel Assemblies", measured as specified herein, which price shall be payment in full for supplying all materials and performing all operations herein described and all other items incidental to the work included in this Specification.

5.1.6 Drilled Tie Bars and Dowels

5.1.6.1 Supply and installation shall be in accordance with clause 9.2.3 of CW 3310-R17.

5.2 BASIS OF PAYMENT FOR CW 3230-R8

5.2.1 Full Slab Replacement

5.2.1.1 Replacement of complete slabs will be paid for at the Contract Unit Price per square metre for the "Items of Work" listed here below, measured as specified herein, which price shall be payment in full for supplying all materials and for performing all operations herein described and all other items incidental to the work included in this Specification.

Items of Work: Slab Replacement

- i. 250mm Type (*) Concrete Pavement (**)
- ii. 230mm Type (*) Concrete Pavement (**)
- iii. 200mm Type (*) Concrete Pavement (**)
- iv. 150mm Type (*) Concrete Pavement (**)

* Specify the Concrete Type

** Specify either Reinforced or Plain-Dowelled

5.2.2 Full Depth Partial Slab Patches

5.2.2.1 Full-depth partial slab patches will be paid for at the Contract Unit Price per square metre for "Items of Work", listed here below, measured as specified herein, which price shall be payment in full for supplying all materials and for performing all operations herein described and all other items incidental to the work included in this Specification.

Items of Work: Partial Slab Patches

- i. 250mm Type (*) Concrete Pavement (**)
- ii. 230mm Type (*) Concrete Pavement (**)
- iii. 200mm Type (*) Concrete Pavement (**)
- iv. 150mm Type (*) Concrete Pavement (**)

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- * Specify the Concrete Type
- ** Specify class of patch

5.2.3 Dowels in Drilled Holes

5.2.3.1 Installation of dowels into hardened concrete will be paid for at the Contract Unit Price for "Drilled Dowels", measured as specified herein, which price shall be payment in full for supplying all materials and for performing all operations herein described and all other items incidental to the work included in this Specification.

*Specify diameter(s) of dowels

5.2.4 Tie Bars in Drilled Holes

5.2.4.1 Installation of tie bars into hardened concrete will be paid for at the Contract Unit Price for "Drilled Tie Bars"* measured as specified herein, which price shall be payment in full for supplying all materials and for performing all operations herein described and all other items incidental to the work included in this Specification.

*Specify size(s) of tie bars.

5.3 MEASUREMENT AND PAYMENT FOR CW 3235-R9

5.3.1 Removal of Miscellaneous Concrete Slabs

5.3.1.1 Removal of miscellaneous concrete slabs will be measured on an area basis and paid for at the Contract Unit Price per square metre for the "Items of Work" listed here below. The area to be paid for will be the total number of square metres of existing miscellaneous concrete slabs removed in accordance with this specification, accepted and measured by the Contract Administrator.

Items of Work:

Miscellaneous Concrete Slab Removal

- i.) Median Slab
- ii.) Monolithic Median Slab
- iii.) Safety Median
- iv.) 100mm Sidewalk
- v.) 150mm Reinforced Sidewalk
- vi.) Bullnose
- vii.) Monolithic Curb and Sidewalk

5.3.2 Installation of Miscellaneous Concrete Slabs

5.3.2.1 Installation of miscellaneous concrete slabs will be measured on an area basis and paid for at the Contract Unit Price per square metre for the "Items of Work" listed here below. The area to be paid for will be the total number of square metres of miscellaneous concrete slabs installed in accordance with this specification, accepted and measured by the Contract Administrator.

Items of Work:



Miscellaneous Concrete Slab Installation

- i.) Type (*) Concrete Median Slab**
- ii.) Type (*) Concrete Monolithic Median Slab**
- iii.) Type (*) Concrete Safety Median**
- iv.) Type (*) Concrete 100mm Sidewalk**
- v.) Type (*) Concrete 150mm Reinforced Sidewalk***
- vi.) Type (*) Concrete Bullnose**
- vii.) Type (*) Concrete Monolithic Curb and Sidewalk**

* Specify the Concrete Type

** referenced Standard Detail to be specified

*** renewal area to be specified

5.3.2.2 All costs for installing sign support clamps and constructing isolations for boulevard and median appurtenances will be included in the payment for the "Items of Work" listed for miscellaneous concrete slab installation.

5.3.2.3 All costs for excavation, sub-grade compaction, placement of sub-base, placement of leveling course and backfill materials, slabs installation and boulevard grading to the limits as identified in Section 3.2 of this specification will be included in the payment for the "Items of Work" listed for Installation of Miscellaneous Concrete Slabs.

5.3.2.4 Additional base course over and above leveling course material will be paid in accordance with CW 3110.

5.3.3 Miscellaneous Concrete Slab Renewal

5.3.3.1 Miscellaneous concrete slab renewal will be measured on an area basis and paid for at the Contract Unit Price per square metre for the "Items of Work" listed here below. The area to be paid for will be the total number of square metres of existing miscellaneous concrete slabs removed and installed in accordance with this specification, accepted and measured by the Contract Administrator.

Items of Work:

Miscellaneous Concrete Slab Renewal

- i.) Type (*) Concrete Median Slab**
- ii.) Type (*) Concrete Monolithic Median Slab**
- iii.) Type (*) Concrete Safety Median**
- iv.) Type (*) Concrete 100mm Sidewalk* (***)
- v.) Type (*) Concrete 150mm Reinforced Sidewalk (***)
- vi.) Type (*) Concrete Bullnose**
- vii.) Type (*) Concrete Monolithic Curb and Sidewalk**

* Specify the Concrete Type

** referenced Standard Details to be specified.

*** renewal area to be specified.

- a.) Less than 5 sq. m
- b.) 5 sq. m to 20 sq. m
- c.) Greater than 20 sq. m

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5.3.3.2 All costs for the slab removal, excavation, sub-grade compaction, placement of leveling course and backfill materials, slabs installation and boulevard grading to the limits as identified in Section 3.3 of this specification will be included in the payment for the “Items of Work” listed for Miscellaneous Concrete Slab Renewal.

5.3.3.3 Additional base course over and above leveling course material will be paid in accordance with CW 3110.

5.3.3.4 All costs for installing sign support clamps and constructing isolations for boulevard and median appurtenances will be included in the payment for the “Items of Work” listed for Miscellaneous Concrete Slab Renewal.

5.3.4 Adjustment of Precast Concrete Sidewalk Blocks

5.3.4.1 Adjustment of precast concrete sidewalk blocks will be measured on an area basis and paid at the Contract Unit Price per square metre for “Adjustment of Precast Sidewalk Blocks”. The area to be paid for will be the total number of square metres of precast concrete sidewalk blocks adjusted to grade in accordance with this specification, accepted and measured by the Contract Administrator.

5.3.4.2 No measurement or payment will be made for any precast sidewalk blocks damaged or lost during replacement.

5.3.5 Supply of Precast Concrete Sidewalk Blocks

5.3.5.1 Supply of precast concrete sidewalk blocks will be measured on an area basis and paid at the Contract Unit Price per square metre for “Supply of Precast Sidewalk Blocks”. The area to be paid for will be the total number of square metres of precast concrete sidewalk blocks supplied in accordance with this specification, accepted and measured by the Contract Administrator.

5.3.6 Removal of Precast Concrete Sidewalk Blocks

5.3.6.1 Removal of precast concrete sidewalk blocks will be measured on an area basis and paid at the Contract Unit Price per square metre for “Removal of Precast Sidewalk Blocks”. The area to be paid for will be the total number of square metres of precast concrete sidewalk blocks removed in accordance with this specification, accepted and measured by the Contract Administrator.

5.4 MEASUREMENT AND PAYMENT FOR CW 3240-R10

5.4.1 Concrete Curb Removal

5.4.1.1 Concrete curb removal will be measured on a length basis and paid for at the Contract Unit Price per metre for the “Items of Work” listed here below. The length to be paid for will be the total number of metres of concrete curb removed in accordance with this specification, accepted and measured by the Contract Administrator.

Items of Work:

Concrete Curb Removal

i.) Barrier*

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- ii.) Modified Barrier*
- iii.) Curb and Gutter
- iv.) Mountable Curb
- v.) Lip Curb
- vi.) Modified Lip Curb
- vii.) Curb Ramp
- viii.) Safety Curb
- ix.) Splash Strips**

* Integral or Separate to be specified.

** Monolithic or Separate.

5.4.1.2 Removal of existing asphalt material immediately in front of the curb that is required for installation will be included in the payment for the “Items of Work” listed for Concrete Curb Removal when the asphalt overlay is not identified to be removed.

5.4.2 Concrete Curb Installation

5.4.2.1 Concrete curb installation will be measured on a length basis and paid for at the Contract Unit Price per metre for the “Items of Work” listed here below. The length to be paid for will be the total number of metres of concrete curb or splash strip installed in accordance with this specification, accepted and measured by the Contract Administrator.

Items of Work:

Concrete Curb Installation

- i.) Type (*) Concrete Barrier**
- ii.) Type (*) Concrete Modified Barrier**
- iii.) Type (*) Concrete Curb and Gutter**
- iv.) Type (*) Concrete Mountable Curb**
- v.) Type (*) Concrete Lip Curb**
- vi.) Type (*) Concrete Modified Lip Curb**
- vii.) Type (*) Concrete Curb Ramp**
- viii.) Type (*) Concrete Safety Curb**
- ix.) Type (*) Concrete Splash Strips***

* Specify the Concrete Type

** reveal height, type and reference to Standard Detail to be specified.

*** reveal height, monolithic or separate, type, width and reference to Standard Detail to be specified.

5.4.2.2 The placement and compaction of asphalt material immediately in front of the curb will be included in the payment for the “Items of Work” listed for Concrete Curb Installation when the asphalt overlay is not identified to be removed.

5.4.2.3 No payment will be made for leveling course.

5.4.2.4 Base course will be paid in accordance with CW 3110.

5.4.2.5 Supply and placement of bonding grout for concrete curbs will not be measured for payment.

5.4.3 Concrete Curb Renewal

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5.4.3.1 Concrete curb renewal will be measured on a length basis and paid for at the Contract Unit Price per metre for the "Items of Work" listed here below. The length to be paid for will be the total number of metres of concrete curb or splash strip removed and installed in accordance with this specification, accepted and measured by the Contract Administrator.

Items of Work:

Concrete Curb Renewal

- i.) Type (*) Concrete Barrier** (***)
- ii.) Type (*) Concrete Modified Barrier**
- iii.) Type (*) Concrete Curb and Gutter** (***)
- iv.) Type (*) Concrete Mountable Curb**
- v.) Type (*) Concrete Lip Curb**
- vi.) Type (*) Concrete Modified Lip Curb**
- vii.) Type (*) Concrete Curb Ramp**
- viii.) Type (*) Concrete Safety Curb**
- ix.) Type (*) Concrete Splash Strips (***) (****)

* Specify the Concrete Type

* reveal height, type and referenced Standard Detail to be specified.

** renewed length to be specified.

- a.) Less than 3 m
- b.) 3 m to 30 m
- c.) Greater than 30 m

*** reveal height, monolithic or separate, type, width and reference to Standard Detail to be specified.

5.4.3.2 All costs for removal, excavation, sub-grade compaction, leveling course and backfill materials, curb installation and boulevard grading to the limits as identified in Section 3.4 of this specification will be included in the payment for the "Items of Work" listed for Concrete Curb Renewal.

5.4.3.3 Base course will be paid in accordance with CW 3110.

5.4.3.4 For installation lengths greater than 30 metres, the length will include breaks for approaches, isolations or fixed obstacles such as light standards or poles.

5.4.3.5 Curb ramp tie bars are to be paid in accordance with CW 3230.

5.4.3.6 Supply and placement of bonding grout for concrete curbs will not be measured for payment.

5.5 BASIS OF PAYMENT FOR CW 3325-R5

5.5.1 Concrete Sidewalks

5.5.1.1 Construction of concrete sidewalks will be paid for at the Contract Unit Price per square metre for "100 mm Type (*) Concrete Sidewalk", measured as specified herein, which price shall be payment in full for supplying all materials and for performing all operations herein described and all other items incidental to the work included in this Specification.

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5.5.2 Leveling Course

5.5.2.1 No payment shall be made for leveling course.

5.5.3 Excavation, Sub-grade Compaction, and Base Course

5.5.3.1 Excavation, sub-grade compaction, and additional base course shall be paid for in accordance with Specification CW 3110.