APPENDIX 'I'

CW 3310 SPECIFICATION

PUBLIC WORKS DEPARTMENT • SERVICE DES TRAVAUX PUBLICS **Engineering Division • Division de l'ingénierie**	**Effective Date:** **Draft** **DIVISION 4**
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 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.

1.1.2 This specification also covers hot and cold weather concreting.

1.1.3 Replace 1.2 Definitions of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 1.2 of this specification.

1.1.4 Replace 5.3 Portland Cement Concrete Constituent Materials of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 2.0 MATERIALS of this specification.

1.1.5 Replace 6. Design Requirements of CW 3310-R17, PORTLAND CEMENT CONCRETE PAVEMENT WORKS with 3.0 DESIGN REQUIREMENTS of this specification.

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, and splash strips. Type 1 Concrete can be used instead of Type 2 Concrete.

1.2.5 Type 3 is early-age strength concrete and shall be used for 24 hours early opening after placement.

1.2.6 Type 4 is early-age strength 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 3 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 high ambient temperature (27 °C or more) and evaporation rate that exceeds 0.75 kg/m^2 /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 air temperature falling below 5 °C within 24 h of placing or the average daily temperature for more than three consecutive days is fallen to, or is expected to fall, below 5°C as forecast by the nearest official meteorological office. The daily temperature is the average of the highest and lowest 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, gravel, air-cooled iron blast-furnace slag, 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 A23.2, Table 10 (FA1) and Table 11 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 A23.2-24C 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 2.8.

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 percentage by mass of total sample	Frequency of Test
coarse aggregate	Petrographic examination* – PN	CSA A23.2-15A	125	1 year
	Unconfined freeze-thaw	CSA A23.2 24A	6	Twice per season
	Micro-Deval	CSA A23.2-29A	17	Twice per season
	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
	Flat and elongated particles - Flat particles - Elongated particles	CSA A23.2-13A	 25 40	1 year
	Alkali-silica reactivity	CSA A23.2-25A	0.15	2 years

Material	Parameter	Test Method	Maximum percentage by mass of total sample	Frequency of Test
fine aggregate	Petrographic examination	CSA A23.2-15A	see note	1 year
	Micro-Deval	CSA A23.2-23A	20	1 year
	Clay lumps	CSA A23.2-3A	1	2 years
	Low density granular material	CSA A23.2-4A	0.5	2 years
	Alkali-silica reactivity	CSA A23.2-25A	0.15	2 years
	Organic impurities	CSA A23.2-7A	free from injurious amounts	2 years

- 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.
- Where multiple sources of coarse or fine aggregates are blended, the blended aggregate shall, in the combined blended proportions, meet the deleterious limits and physical requirements of this Specification.
- 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.

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.

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 MRMCA 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 2.2.1)

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. A new mill certificate

shall be provided for each change of source of fly ash or when a new batch of fly ash is delivered. The certificate shall be produced prior to the start of production of concrete and approved by the City of Winnipeg, Research and Standards Engineer. Check tests of the cement may be undertaken by a Testing Laboratory designated by the City of Winnipeg, Research and Standards Engineer. Any cement which fails to comply with the requirements of CSA A3001 will be rejected, notwithstanding any certificate of acceptance that may have been previously given. Cement that has been rejected must be removed immediately by the Concrete 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 two (2) sets* 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 three (3) 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	(Note 1)	30 MPa
Air-void test according to ASTM C457***	@ 28	See Note***						
Rapid chloride penetrability test (RCPT) according to CSA A23.2-23C****	@ 28	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 1000 coulombs at 28 days based on the charge passed, with no single result greater than 1250 coulombs for mixes without fly ash and shall be equal to or less than 1250 coulombs at 28 days based on the charge passed, with no single result greater than 1500 coulombs for mixes with fly ash. For Type 2, the average of chloride ion penetrability shall be equal to or less than 1500 coulombs at 28 days based on the charge passed, with no single result greater than 1750 coulombs.

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	340	320	400	340	300
Maximum Supplementary Cementing Materials – Fly Ash** (%) (see Note 2)	20%	20%	15%	20%	15%	10%	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) @ 28 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.

***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.

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.

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, to the satisfaction of the Contract Administrator, 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/m^2/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 immediately after checking the surface with the long metal straight edge and shall be reapplied between finishing operations.

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 material 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.

4.1.2.3 Type 6 Concrete shall be used for cold weather concreting. The Contractor shall submit the maturity relationships for the mix to the City of Winnipeg Research and Standards Engineer two weeks prior to cold weather concrete placement. The Contractor shall provide the maturity meters and all necessary wires and connectors. The Contractor shall be responsible for the placement, protection, and maintenance of the maturity meters and wires. No additional measurement or payment will be made for the supply and installation of wires and connectors.

4.1.2.4 A minimum of three maturity meters shall be used for each day's concrete paving operations. 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.

4.1.2.5 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.

4.1.2.6 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.

4.1.2.7 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, artificial heat shall be introduced immediately.

4.1.2.8 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.

4.1.2.9 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.

4.1.2.10 The protection method shall not be completely removed until the concrete has cooled to the 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.

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

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