TECHNICAL SPECIFICATIONS

Concrete Exposure Classes

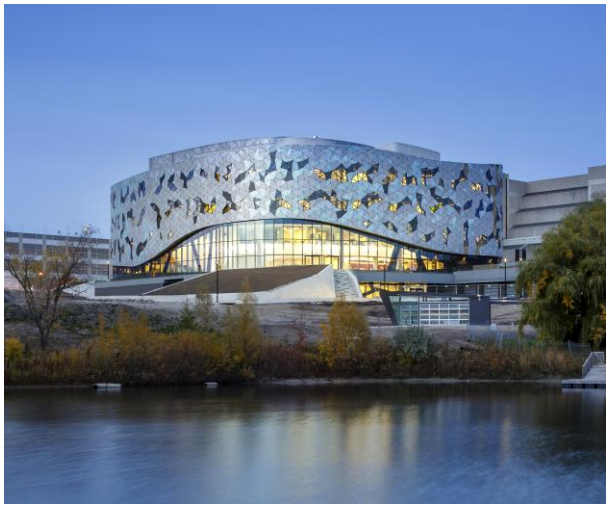
CONCRETE ONTARIO
Ready Mixed Concrete Association of Ontario

Determination of the minimum concrete performance properties is based upon identifying the following key requirements:

- **Applicable Exposure Conditions** – The designer must assess the environmental conditions that the concrete will be exposed to during its service life. Direct input is also required from the Owner regarding possible future uses since they can significantly affect the exposure class selection.
- **Structural Requirements** – The designer must determine the minimum concrete properties required to meet the applicable loading conditions.
- **Architectural Requirements** – The designer must consider the effects of selecting various architectural finishes on concrete material properties.
- **Minimum Durability Requirements** – Based upon the designer's assessment of the exposure conditions, the CSA A23.1 standard sets minimum concrete properties.

In cases where these various factors result in differing material properties, the designer must select the most stringent requirement as the minimum concrete performance requirement.

CSA A23.1:19 – Concrete materials and methods of concrete construction, Tables 1 – 4 outline the minimum durability requirements.



THE Power of Concrete

Table 1
Definitions of C, F, N, A, S and R classes of exposure

(See Clauses 3, 4.1.1.1.1, 4.1.1.1.3, 4.1.1.5, 4.1.1.8.1, 4.1.2.3, 6.1.4, 6.6.7.6.1, 7.1.2.1, 9.1, L.3, and R.1, Tables 2, 3, and 17, and Annex L.)

C-XL	Structurally reinforced concrete exposed to chlorides or other severe environments with or without freezing and thawing conditions, with higher durability performance expectations than the C-1 classes.
C-1	Structurally reinforced concrete exposed to chlorides with or without freezing and thawing conditions. Examples: bridge decks, parking decks and ramps, portions of structures exposed to seawater located within the tidal and splash zones, concrete exposed to seawater spray, and salt water pools. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.
C-2	Non-structurally reinforced (i.e., plain) concrete exposed to chlorides and freezing and thawing. Examples: garage floors, porches, steps, pavements, sidewalks, curbs, and gutters.
C-3	Continuously submerged concrete exposed to chlorides, but not to freezing and thawing. Examples: underwater portions of structures exposed to seawater. For seawater or seawater-spray exposures the requirements for S-3 exposure also have to be met.
C-4	Non-structurally reinforces concrete exposed to chlorides, but not to freezing and thawing. Examples: underground parking slabs on grade.
F-1	Concrete exposed to freezing and thawing in a saturated condition, but not to chlorides. Examples: pool decks, patios, tennis courts, freshwater pools, and freshwater control structures.
F-2	Concrete in an unsaturated condition exposed to freezing and thawing, but not to chlorides.
N	Concrete that when in service is neither exposed to chlorides nor to freezing and thawing nor to sulphates, either in a wet or dry environment. Examples: footings, walls and columns.
N-CF	Interior concrete floors with a steel-trowel finish that are not exposed to chlorides, nor to sulphates either in a wet or dry environment. Examples: interior floors, surface covered applications (carpet, vinyl tile) and surface exposed applications (with or without floor hardener), ice-hockey rinks, freezer warehouse floors.
A-XL	Structurally reinforced concrete exposed to severe manure and/or silage gases, with or without freeze-thaw exposure. Concrete exposed to the vapour above municipal sewage or industrial effluent, where hydrogen sulphide gas might be generated, with higher durability performance expectations than A-1 class.
A-1	Structurally reinforced concrete exposed to severe manure and/or silage gases, with or without freeze-thaw exposure. Concrete exposed to the vapour above municipal sewage or industrial effluent, where hydrogen sulphide gas might be generated. Examples: reinforced beams, slabs, and columns over manure pits and silos, canals, and pig slats; and access holes, enclosed chambers, and pipes that are partially filled with effluents.
A-2	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure. Examples: reinforced walls in exterior manure tanks, silos and feed bunders, and exterior slabs.
A-3	Structurally reinforced concrete exposed to moderate to severe manure and/or silage gases and liquids, with or without freeze-thaw exposure in a continuously submerged condition. Concrete continuously submerged in municipal or industrial effluents. Examples: interior gutter walls, beams, slabs, and columns; sewage pipes that are continuously full (e.g., forcemains); and submerged portions of sewage treatment structures.
A-4	Non-structurally reinforced concrete exposed to moderate manure and/or silage gases and liquids, without freeze-thaw exposure. Examples: interior slabs on grade.
S-1	Concrete subjected to very severe sulphate exposures (Table 2 and 3).

Table 1 (Concluded)

S-2	Concrete subjected to severe sulphate exposure (Tables 2 and 3).
S-3	Concrete subjected to moderate sulphate exposure and to seawater or seawater spray (Table 2 and 3).
R-1	Residential concrete for footings for walls, columns, fireplaces and chimneys.
R-2	Residential concrete for foundation walls, grade beams, piers, etc.
R-3	Residential concrete for interior slabs on ground not exposed to freezing and thawing or deicing salts.

Notes:

1) *"C" classes pertain to chloride exposure.*
2) *"F" classes pertain to freezing and thawing exposure without chlorides.*
3) *"N" class is exposed to neither chlorides nor freezing and thawing.*
4) *All classes of concrete exposed to sulphates shall comply with the minimum requirements of S class noted in Tables 2 and 3. In particular, Classes A-1 to A-4 and A-XL in municipal sewage elements could be subjected to sulphate exposure.*
5) *No hydraulic cement concrete will be entirely resistant in severe acid exposures. The resistance of hydraulic cement concrete in such exposures is largely dependent on its resistance to penetration of fluids.*
6) *Decision of exposure class should be based upon the service conditions of the structure or structural element, and not upon the conditions during construction.*

CSA A23.1 – Table 2

Requirements for C, F, N, R, S and A classes of exposure

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.2.1, 4.3.1, 7.4.1.1, 8.8.3, and 8.8.6.1, and Table 1.)

			Air Content category as per Table 4[d]		Curing type (see Table 19)			
Class of exposure[a]	Maximum water-to-cementitious materials ratio[b]	Minimum specified compressive strength (MPa) and age (d) at test[b,i]	Exposed to cycles of freeze/ thaw	Not Exposed to cycles of freeze/ thaw	Normal concrete	HVSCMN-1	HVSCM-2	Chloride ion penetrability requirements and age at test[c]
C-XL or A-XL	0.40	50 within 56 d	1	[e]	3	3	3	< 1000 coulombs within 91 d
C-1 or A-1	0.40	35 within 56 d	1	[e]	2	3	2	< 1500 coulombs within 91 d
C-2	0.45[h]	32 at 28 d	1	n/a	2	2	2	--
C-3	0.50	30 at 28 d	n/a	[e]	1	2	2	--
C-4[e]	0.55	25 at 28 d	n/a	[e]	1	2	2	--
A-2	0.50	32 at 28 d	1	[e]	2	2	2	--
A-3	0.50	30 at 28 d	2	[e]	1	2	2	--
A-4	0.45	25 at 28 d	2	[e]	1	2	2	--
F-1	0.50[j]	30 at 28 d	1	n/a	2	3	2	--
F-2 or R-1 or R-2	0.55[j]	25 at 28 d	2[f]	n/a	1	2	2	--
N	As per the mix design for the strength required	For structural design	n/a	[e]	1	2	2	--
N-CF[g] or R-3	0.55	25 at 28 d	n/a	[e]	1	2	2	--
S-1	0.40	35 within 56 d	1	[e]	2	3	2	--
S-2	0.45[j]	32 within 56 d	1	[e]	2	3	2	--
S-3	0.50[j]	30 within 56 d	1	[e]	1	2	2	--

(Continued)

Table 2 (Concluded)

[a] *See Table 1 for a description of classes of exposure.*
[b] *The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementitious materials ratio provided that freezing and thawing and de-icer scaling resistance have been demonstrated to be satisfactory. The water-to-cementitious materials ratio shall not be exceeded for a given class of exposure.*
[c] *In accordance with CSA A23.2-23C, an age different from that indicated may be specified by the owner. Accelerated moist curing in accordance with CSA A23.2-23C may be specified by the owner; in such cases, the age at test shall be 28 d. Where calcium nitrite corrosion inhibitor is to be used, the same concrete mixture, without calcium nitrite, shall be qualified to meet the requirements for the permeability index in this Table. For field testing, the owner shall specify the type of specimen and location from which it is taken. If cores are required, the concrete cores shall be taken in accordance with CSA A23.2-23C.*
[d] *Air entrained concrete shall not receive a steel trowelled finish. See Note 4) to Clauses 7.7.4.3.1 and 7.7.4.3.2.*
[e] *Class N-CF concrete shall not contain an air entraining admixture. Other classes of concrete falling in this air content category have no requirement to provide entrained air however the producer may choose to add entrained air in order to modify plastic concrete properties such as bleeding, workability, cohesiveness, etc. No air entrainment shall be added to concrete which is to receive a steel trowel finish.*
[f] *Air entrainment shall be waived for F-2 class exposures frozen in an air dry condition and receiving very limited cycles of freeze/thaw. Interior ice rink slabs brought to sub-zero levels before the introduction of water and dry freezer slabs have been found to perform satisfactorily without entrained air when steel trowelled.*
[g] *See Clause 7.1.2 for concrete mixes for concrete floors.*
[h] *The maximum water-to-cementitious material ratio for HVSCM-1 concrete in a C-2 exposure shall not exceed 0.40.*
[i] *A different age at test may be specified by the owner to meet structural or other requirements.*
[j] *For reinforced concrete surfaces exposed to air and not directly exposed to precipitation, with depths of cover less than 50 mm, the water-to-cementitious materials ratio shall be not greater than 0.40 for HVSCM-1 concrete and not greater than 0.45 for HVSCM-2 concrete. This requirement is intended to minimize the risk of corrosion of embedded steel due to carbonation of the concrete cover. The exposure conditions that present the greatest risk are the soffits of suspended slabs and balconies and exposed vertical surfaces that receive little direct precipitation. For concrete that is continuously moist, the process of carbonation will be very slow.*

Table 3

Additional requirements for concrete subjected to sulphate attack[1]

(See Clauses 4.1.1.1.1, 4.1.1.6.2, 4.1.1.6.3, and L.3 and Tables 1, 7, 24, and 25.)

Class of exposure	Degree of exposure	Water-soluble sulphate (SO_4)† in soil sample,[2] %	Sulphate (SO_4) in groundwater sample,[3] mg/L	Water soluble sulphate (SO_4) in recycled aggregate sample, %	Cementitious materials to be used[4]	Performance requirements[4, 6] Maximum expansion when tested using CSA A3004-C8, %	
						At 6 months	At 12 months[7]
S-1	Very severe	> 2.0	> 10,000	> 2.0	HS[5],HSb, HSLb, or HSe	0.05	0.10
S-2	Severe	0.20 – 2.0	1500 – 10 000	0.60 – 2.0	HS[5], HSb, HSLb, or HSe	0.05	0.10
S-3	Moderate (including seawater exposure[1])	0.10 – 0.20	150 – 1500	0.20 – 0.60	MS, MSb, MSe, MSLb, LH, LHb, HS[5], HSb, HSLb, or HSe	0.10	

[1] *For sea water exposure, also see Clause 4.1.1.5.*
[2] *In accordance with CSA A23.2-3B.*
[3] *In accordance with CSA A23.2-2B.*
[4] *Where combinations of supplementary cementitious materials and Portland, Portland-limestone, or blended hydraulic cements are to be used in the concrete mix design instead of the cementitious materials listed, and provided they meet the performance requirements demonstrating equivalent performance against sulphate exposure, they shall be designated as MS equivalent (MSe) or HS equivalent (HSe) in the relevant sulphate exposures (see Clauses 4.1.1.6.2, 4.2.1.1, and 4.2.1.3, and 4.2.1.4).*
[5] *Type HS cement shall not be used in reinforced concrete exposed to both chlorides and sulphates, including seawater. See Clause 4.1.1.6.3.*
[6] *For demonstrating equivalent performance, use the testing frequency in Table 1 of CSA A3004-A1 and see the applicable notes to Table A3 in CSA A3001 with regard to re-establishing compliance if the composition of the cementitious materials used to establish compliance changes.*
[7] *If the expansion is greater than 0.05% at 6 months but less than 0.10% at 1 year, the cementitious materials combination under test shall be considered to have passed.*

Note: *Limestone fillers shall not be used in concrete for any S class exposure listed in Tables 1 to 3. Portland-limestone cement shall not be used as the sole cementitious material in concrete for any S class exposure listed in Tables 1 to 3. However, blended hydraulic cements, or combinations of Portland-limestone cement and the minimum levels of supplementary cementitious materials listed in Table 9 of CSA A3001 and also meeting the test requirements of Table 5 in CSA A3001, may be used in any S class exposure listed in Tables 1 to 3.*

Table 4
Requirements for air content categories

(See Clauses 4.1.1.1.1, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.3.1, and 4.3.3.2, and Table 2.)

	Range in air content* for concretes with indicated nominal maximum sizes of course aggregate, %		
Air content category	**10 mm**	**14-20 mm**	**28-40 mm**
1†	6-9	5-8	4-7
2	5-8	4-7	3-7

** At the point of discharge from the delivery equipment, unless otherwise specified.*

† For hardened concrete, see Clause 4.3.3.2.

Notes:

1) *The above difference in air contents has been established based upon the difference in mortar fraction volume required for specific coarse aggregate sizes.*
2) *Air contents measured after pumping or slip forming can be significantly lower than those measured at the end of the chute.*

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