CONCRETE ONTARIO
Ready Mixed Concrete Association of Ontario

CONCRETE ZERO

TECHNICAL SPECIFICATION

Classes of Exposure

Determining the minimum performance properties of concrete involves identifying several key requirements. When these requirements result in varying material properties, the designer must select the most stringent requirement as the minimum concrete performance standard. The minimum durability criteria are outlined in CSA A23.1:24 – Concrete Materials and Methods of Concrete Construction, Tables 1 through 4:

- **Applicable Exposure Conditions**

  The designer must evaluate the environmental conditions that the concrete will face throughout its service life. Additionally, input from the Owner regarding potential future uses is crucial, as these factors can greatly influence the selection of the exposure class.

- **Minimum Durability Requirements**

  Based upon the designer's assessment of the exposure conditions, the CSA A23.1 standard sets minimum concrete properties.

- **Structural Requirements**

  The designer must establish the minimum concrete properties necessary to withstand the applicable loading conditions.

- **Architectural Requirements**

  The designer must take into account the impact of different architectural finishes on the properties of the concrete material.

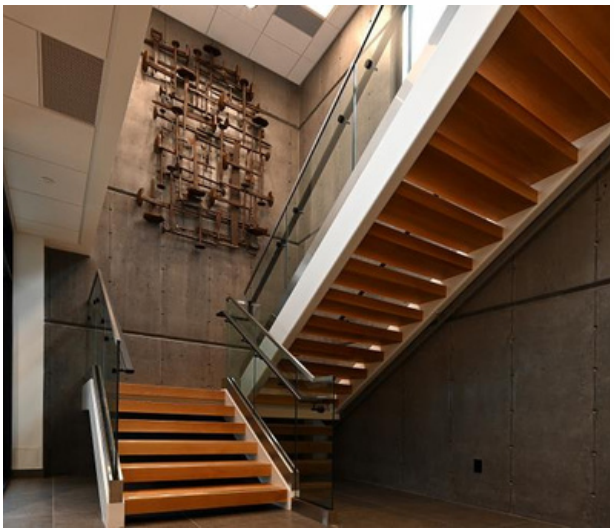

Table 1
Definitions of C, F, N, A, S and R classes of exposure

(See Clauses 3, 4.1.1.1.1, 4.1.1.8.2, 4.1.1.8.2, 4.1.2.3, 6.1.4, 6.6.7.6.1, 6.8.2.5, 7.1.2.1, 8.13.2.2, 9.2, A.1, I.4.1.2.1.3 and L3 and Tables 2, 3, and 17)

C-XL	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	Concrete exposed to chlorides with or without freezing and thawing conditions where the reinforcing steel must be protected from corrosion. For seawater exposures, the requirements for S-3 exposure shall also be met. 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, airborne chlorides, and saltwater pools.
C-2	Concrete exposed to chlorides and freezing and thawing without reinforcement or where corrosion of reinforcement will not be critical to the performance of the element. Examples: residential garage floors, porches, steps, pavements, sidewalks, curbs and gutters.
C-3	Continuously submerged concrete exposed to chlorides, but not to freezing and thawing. For seawater exposures, the requirements for S-3 exposure shall also be met. Examples: underwater portions of structures exposed to seawater.
C-4	Concrete exposed to chlorides, but not to freezing and thawing. Examples: underground parking slabs on ground.
F-1	Concrete exposed to freezing an thawing in a saturated condition, but not to chlorides. Examples: pool decks, patios, tennis courts, freshwater pools, and freshwater control structures.
N	Concrete that when in service is neither exposed to chlorides nor to freezing and thawing nor to sulphates, either in a wet of dry environment. Examples: footings, walls, and columns.
N-CF	Interior concrete floors with a trowel finish that are not exposed to chlorides, nor to sulphates either in a wet or dry environment, and are either not exposed to cycles of freezing and thawing or only exposed to very limited cycles of freezing and thawing while in an air dry condition. Examples: interior floors, surface covered applications (carpet, vinyl tile) and surface exposed applications (with or without floor hardener), ice rinks, freezer floors.
A-XL	Structural concrete exposed to manure and/or silage gases with or without freeze-thaw exposure or 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 or A-2 class.
A-1	Structural concrete exposed to the vapour above municipal sewage or industrial effluent, where hydrogen sulphide gas might be generated. Examples: reinforced beams, suspended 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	Structural concrete exposed to manure and/or silage gases and liquids, with or without freeze-thaw exposure. Examples: reinforced walls in exterior manure tanks, silos and feed bunkers, and exterior slabs.
A-3	Structural concrete exposed to 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-structural concrete exposed to manure and/or silage gases and liquids, without freeze-thaw exposure. Examples: interior slabs on ground.
S-1	Concrete subjected to very severe sulphate exposures (Tables 2 and 3).
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 (Tables 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.

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 the 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 of structural element, and not upon the conditions during construction.*

Table 2
Requirements for C, F, N, A and S classes of exposure

(See Clauses 4.1.1.1.1, 4.1.1.1.3, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.1.8.2, 4.1.1.11, 4.1.2.1, 4.3.1, 4.3.5.1, 4.3.5.2, 4.3.7.1, 4.3.7.2, 4.3.7.3, 7.1.2.1, 7.5.1.1, 7.8.1, 7.8.2.1, 8.7.4.1, 9.3, 9.4, 9.5, A.1, I.4.1.8.6.2, K.4, K.5, L.1, L.3 and O.1.2 and Tables 1,3 and 17)

			Air content category as per Table 4[d]		Curing type (see Table 19)			Resistance to chloride ion penetration	
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	HVSCM-1	HVSCM-2	Chloride ion penetrability requirements and age at test	Bulk resistivity requirement and age at test
C-XL or A-XL	0.40	50 within 56 d	1	[e]	3	3	3	< 1000 coulombs within 91 d[c]	[c]
C-1 or A-1	0.40	35 within 56 d	1	[e]	2	3	2	< 1500 coulombs within 91 d[c]	[c]
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 28d	n/a	[e]	1	2	2	–	–
A-2	0.45	32 at 28 d	1	[e]	2	2	2	–	–
A-3	0.50	30 at 28 d	1	[e]	1	2	2	–	–
A-4	0.55	25 at 28 d	n/a	[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	[k]	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	–	–

[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. Designers are cautioned against specifying w/cm lower than required (in accordance with Clause 4.3.1) to avoid potential for workability, constructability and sustainability issues that can be associated with lower w/cm mixes.*

[c] *The Chloride ion penetrability limits may be waived by the owner if alternative bulk resistivity limits using CSA A23.2-26C are established for the concrete during project qualification testing. In accordance with CSA A23.2-23C or CSA A23.2-26C, 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 for either test method; 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 take. If cores are required, the concrete cores shall be taken in accordance with CSA A23.2-14C.*

[d] *Air entrained concrete shall not receive a trowelled finish. See Note 4 to Clauses 7.7.4.3.1 and 7.7.4.3.2.*

(Continued)

Table 2 (Continued)

[e] *No air entrainment shall be added to concrete which is to receive a trowel finish. For other concrete in this air category not receiving a trowel finish, the producer may choose to add entrained air in order to modify plastic concrete properties such as bleeding, workability, cohesiveness, etc.*

[f] *Air entrainment may be waived for F-2 class exposures frozen in an air dry condition and receiving very limited cycles of freeze/thaw.*

[g] *See Clause 7.1.2 for concrete mixes for interior 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 not be 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.*

[k] *Classes N-CF and R-3 concrete shall not contain air entraining admixture.*

(Continued)

Table 3
Additional requirements for concrete subjected to sulphate attack*

(See Clauses 4.1.1.1.1, 4.1.1.5, 4.1.1.6.2, 4.1.1.6.3, and L.3 and Tables 1, 24 and 25.)

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

* *For sea water exposure, also see Clause 4.1.1.5.*

† *In accordance with CSA A23.2-3B.*

‡ *In accordance with CSA A23.2-2B.*

§ *Combinations of supplementary cementitious materials and portland, portland-limestone, or blended hydraulic cements may be used in the concrete mix design instead of the cementitious materials listed, provided they meet the performance requirements demonstrating equivalent performance against sulphate exposure, and 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).*

** *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.*

†† *When the 6-month expansion is compliant to this table, the cementitious materials combination shall be considered to have passed and does not require further testing at 1 year. The 1-year expansion limit is only required to be verified with testing if the measured expansion exceeds the 6-month expansion limit. If the 1-year expansion limit is met, the cementitious materials combination shall also be considered to have passed, regardless of the expansion at 6 months.*

Note: *Limestone filler shall not be used in concrete for 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, 4.1.1.8.2, 4.3.1, 4.3.3.1, and 4.3.3.2, and Table 2)

	Range in air content* for concretes with indicated nominal maximum sizes of coarse 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 - 6

** At the point of discharge form 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.*

Technical information prepared by: Ready Mixed Concrete Association of Ontario, 102B – 1 Prologis Blvd. Mississauga ON L5W 0G2 - info@concreteontario.org